Quelques résultats récents dans le domaine de l'accélération plasma

Nicolas Delerue (LAL), Sophie Kazamias (LPGP) et Rui Prazeres (LCP)

Université Paris-Sud

Plan du séminaire

- Introduction sur l'accélération accélération.
- Résultats récents des différents techniques
- ESCULAP au LAL
- Les applications

La plupart des transparents présentés ici sont tirés de matériel présenté lors de la conférence EAAC 2017.

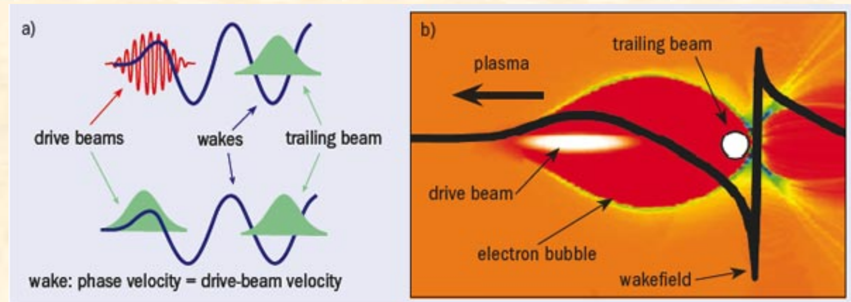
https://agenda.infn.it/internalPage.py?pageId=1&confId=12611

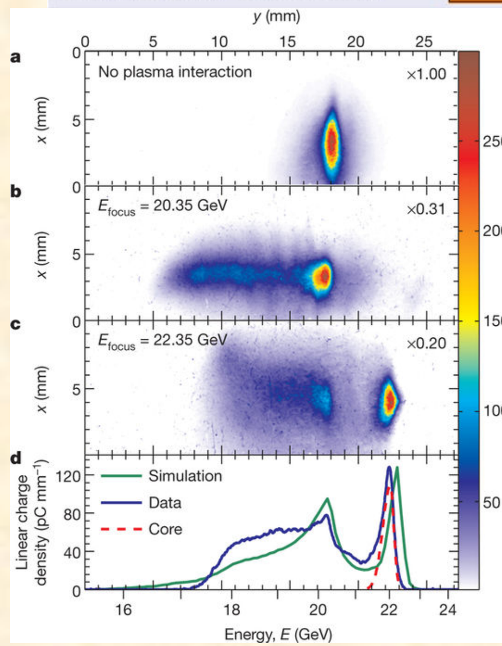
Qu'est-ce que l'accélération dans un plasma?

- Différentes techniques:
  - Accélération par un faisceau de particules
  - Accélération par laser avec auto-injection
  - Accélération par laser avec injection externe
  - Production d'électrons et d'ions de haute énergie par impact laser sur une cible (non couvert ici).
- Il existe d'autres « nouvelles techniques d'accélération » (diélectriques, THz, Accelerator on a chip…) qui ne sont pas couvertes ici.

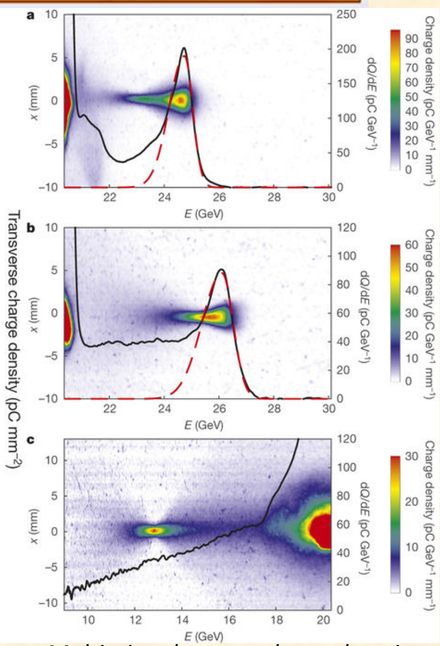
Principe de l'accélération par un faisceau de particules

- Un paquet de particules (électrons ou protons) ionise un gaz et y crée une onde de sillage.
- Un second paquet de particules (électrons ou positrons) est capturé et accéléré dans cette onde de sillage.





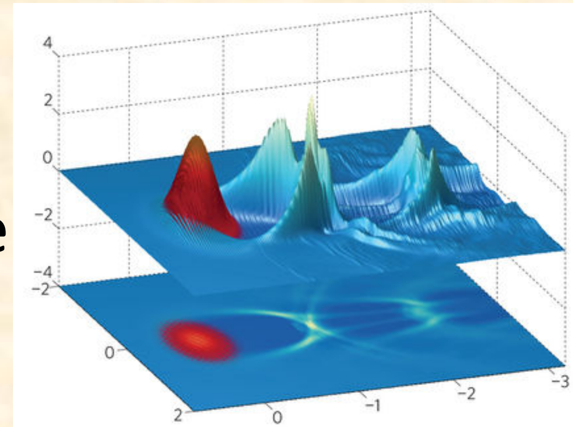
High-efficiency acceleration of an electron beam in a plasma wakefield accelerator Nature volume 515, pages 92–95



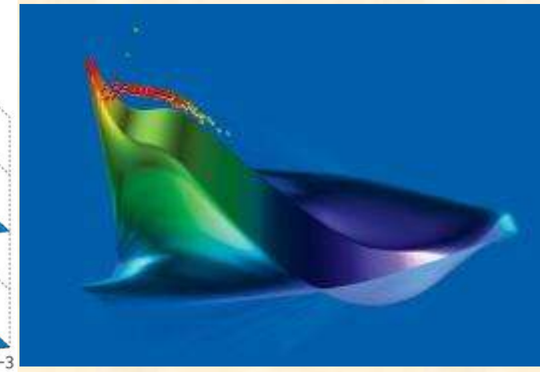
Multi-gigaelectronvolt acceleration of positrons in a self-loaded plasma wakefield Nature volume 524, pages 442–445 (27 August 2015)

Principe de l'accélération par un laser avec auto-injection externe

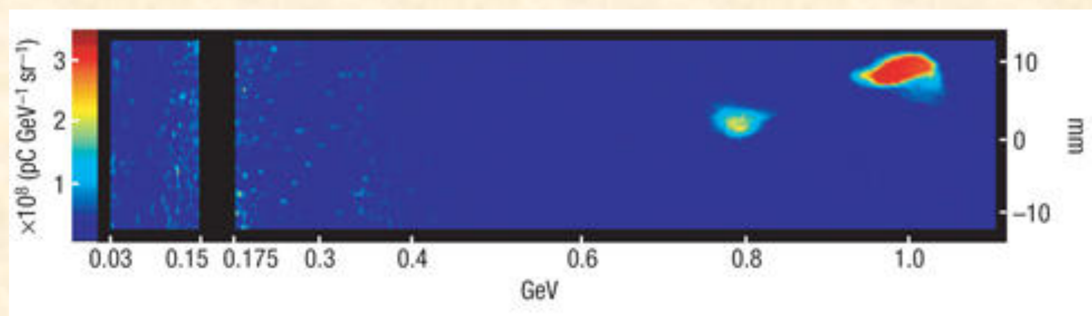
- Une impulsion laser de haute puissance ionise un gaz et y crée une onde de sillage.
- Des électrons de ce plasma sont capturés par l'onde de sillage et accélérés.
- Accélération d'électrons jusqu'à 1 GeV démontrée en 2006.



Nature Photonics **volume 7**, pages 775–782 (2013)



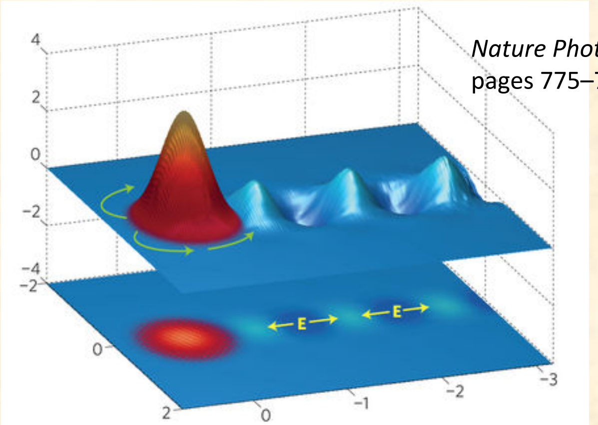
https://phys.org/news/2009-11-size-barrier.html



Leemans et al, doi:10.1038/nphys418

Principe de l'accélération par un laser avec injection externe

- Une impulsion laser de haute puissance ionise un gaz et y crée une onde de sillage.
- Un paquet d'électrons est injecté dans cette onde de sillage et capturé.
- Il est ensuite accéléré.
- Expériences plus anciennes mais regain d'intérêt récent.



Nature Photonics **volume 7**, pages 775–782 (2013)

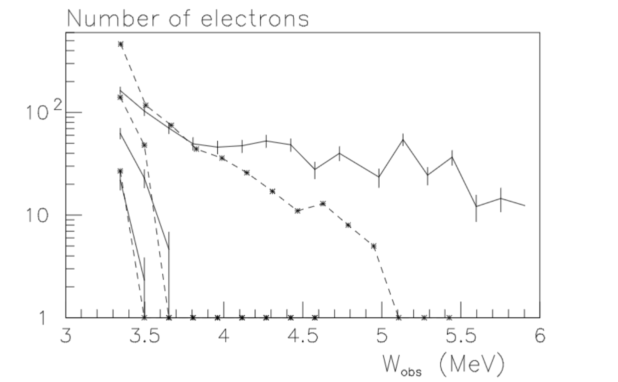
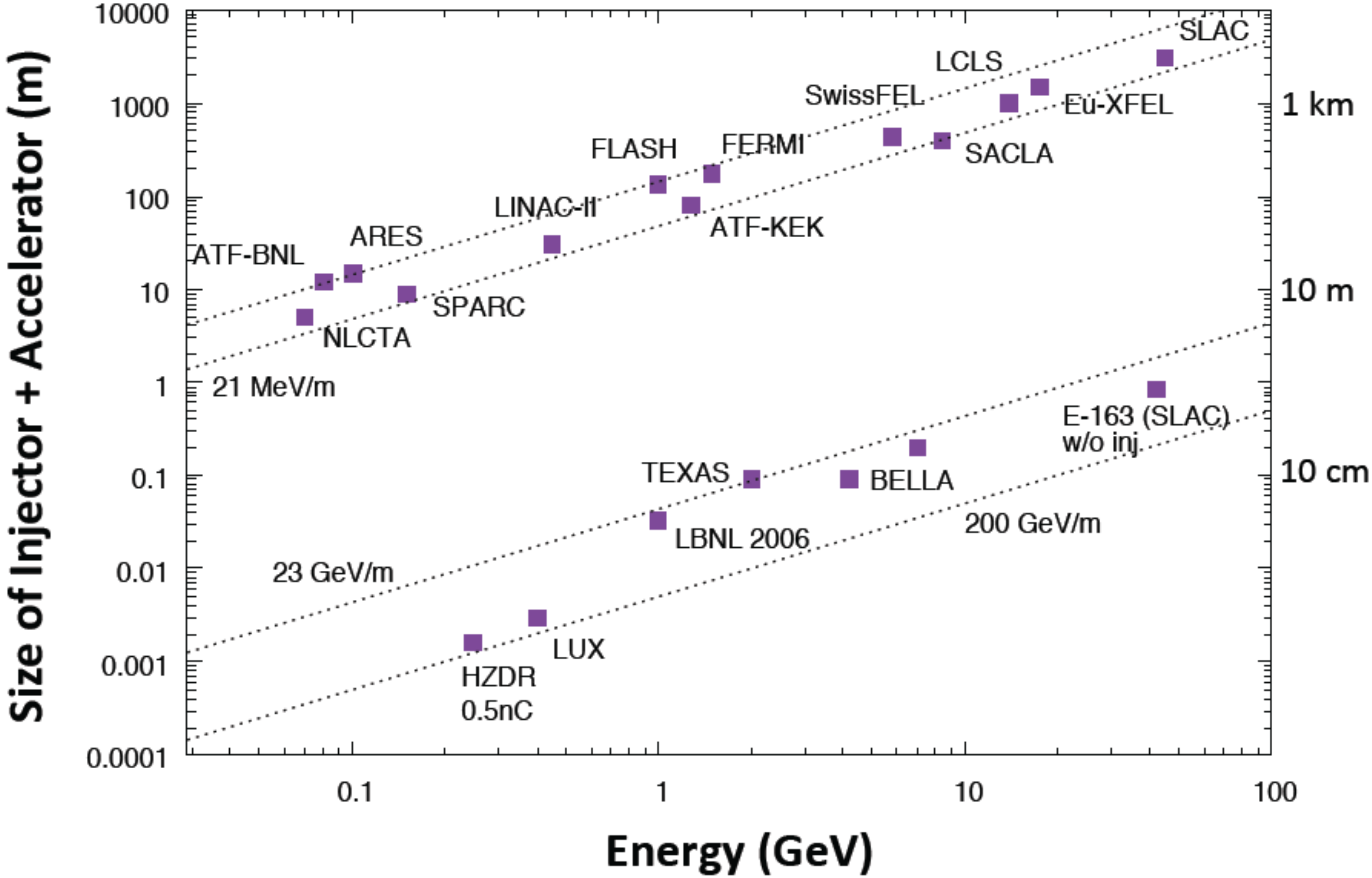


FIG. 4. Electron spectra with $E = 0.25, 0.49, 2.1$ J (continuous lines) compared to simulated spectra (2000 incident electrons, dashed lines). At 2.1 J, the high energy tail is due to EPW BG noise.

Observation of Laser Wakefield Acceleration of Electrons (1998)
https://doi-org.proxy.scd.u-psud.fr/10.1103/PhysRevLett.81.995

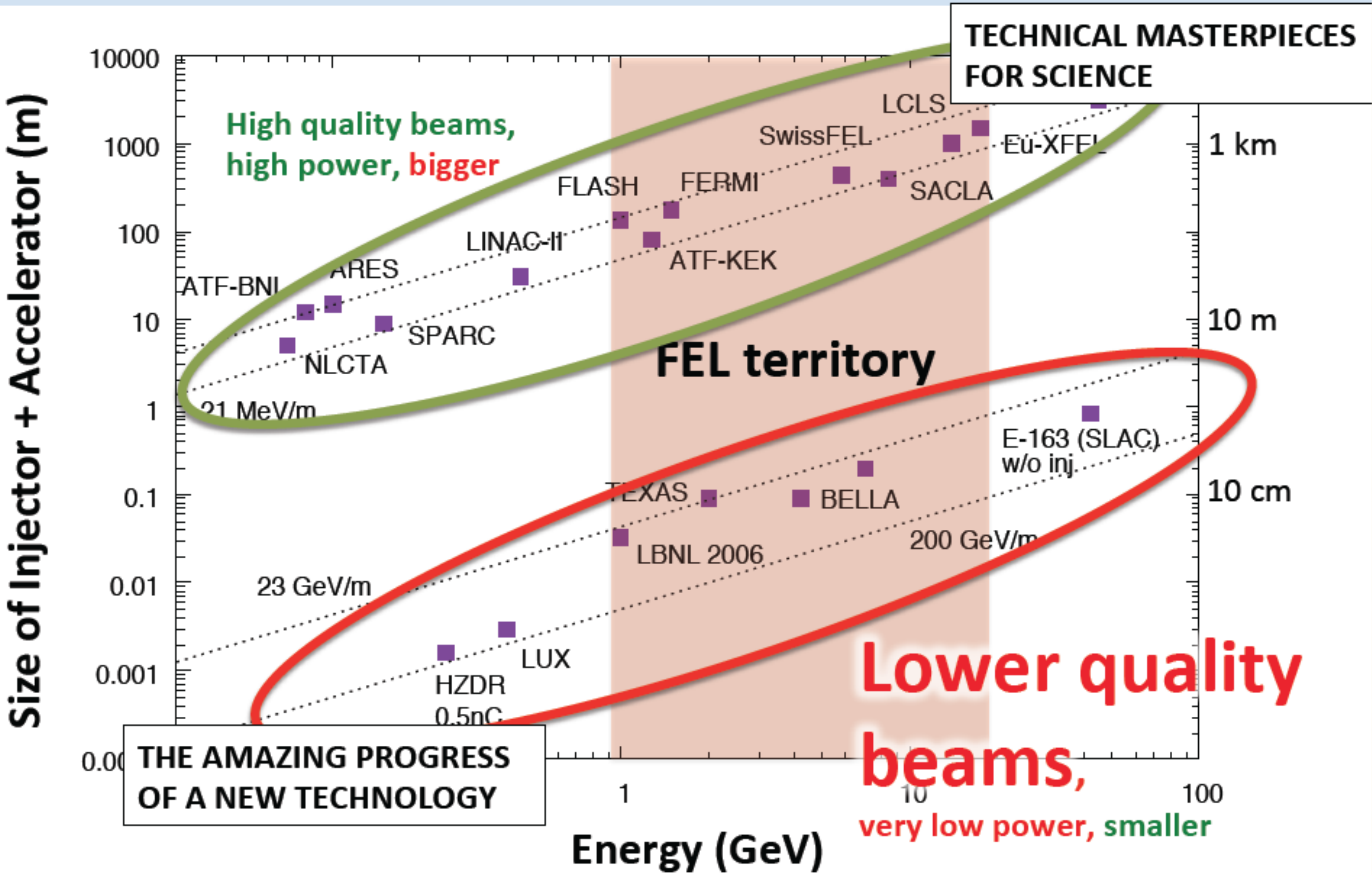
Size versus Energy

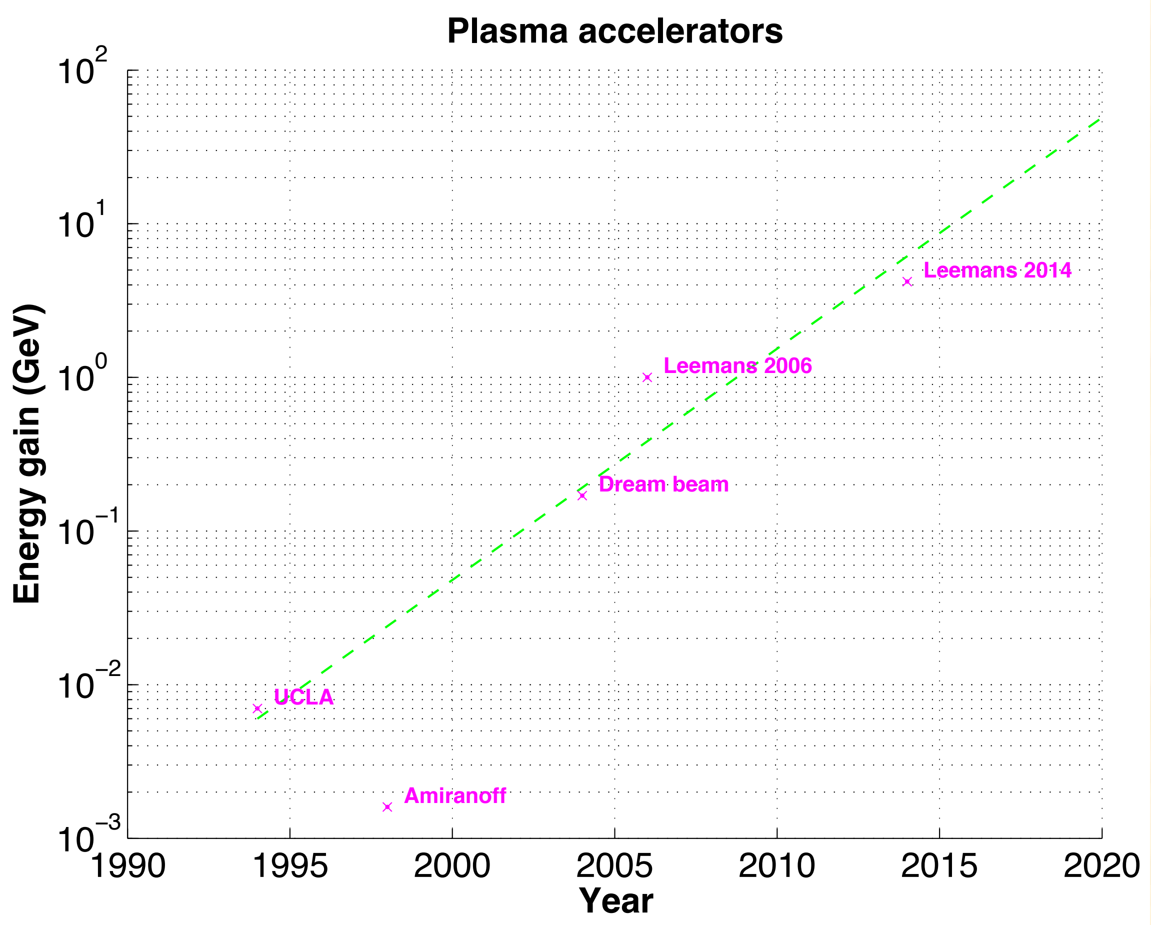
electron linear accelerators



Size versus Energy

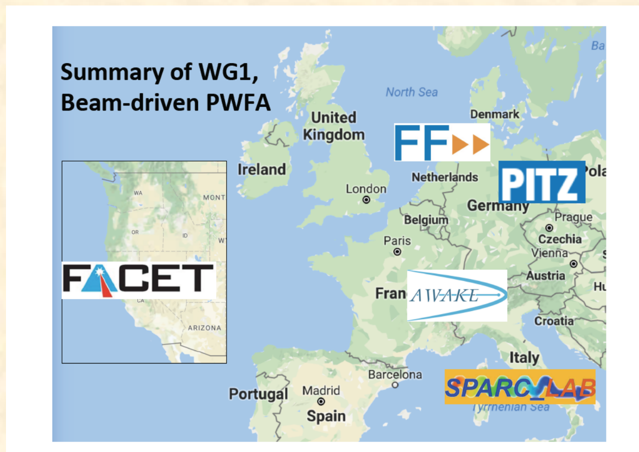
electron linear accelerators



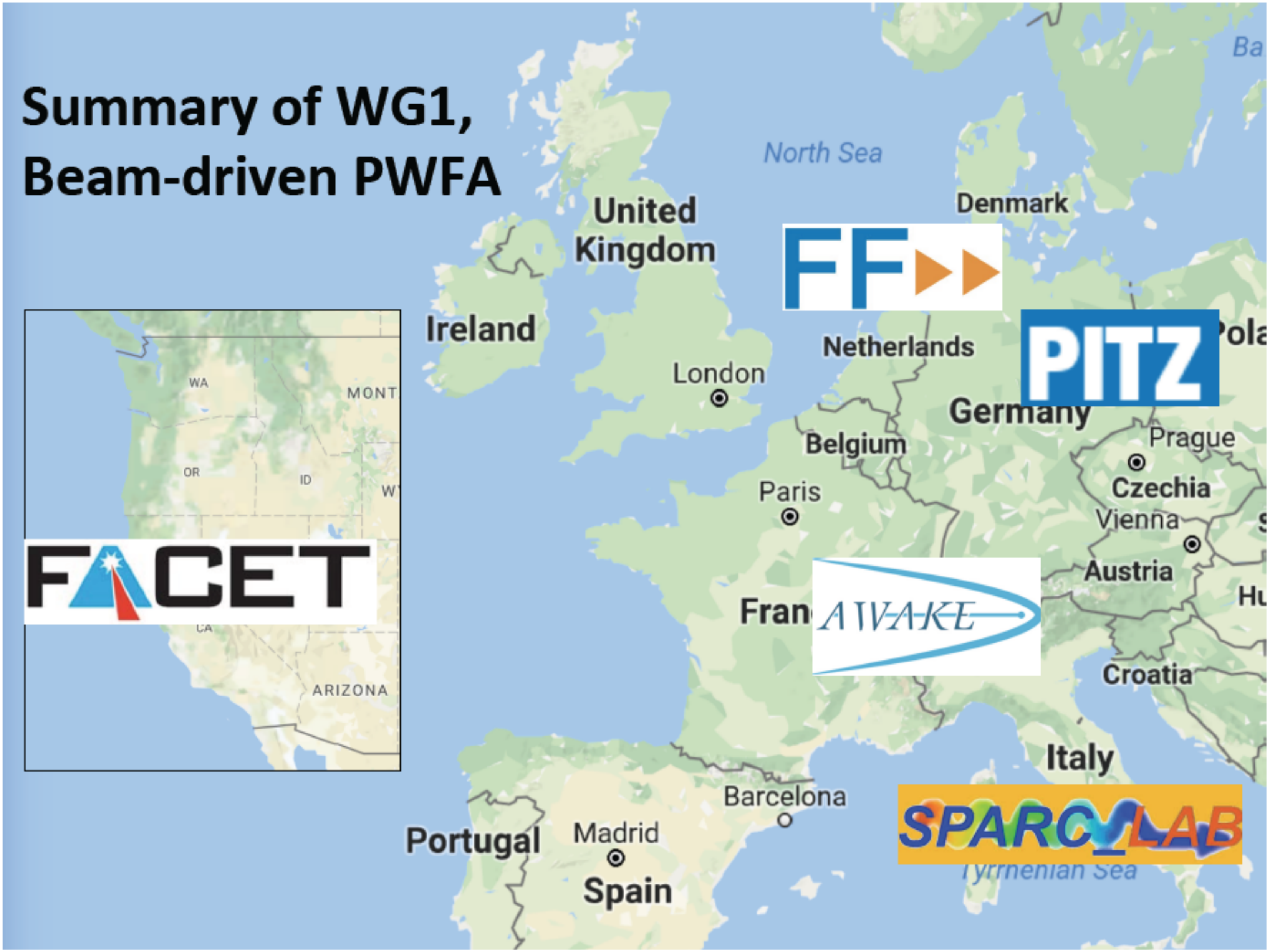


Non-exhaustive chart showing the electron energy reached in laser-driven plasma acceleration experiments versus the experiment year. The green line corresponds to an energy doubling every two years. It is important to stress that the data from this figure show the maximum energy reached, not the energy at which a stable beam was produced.

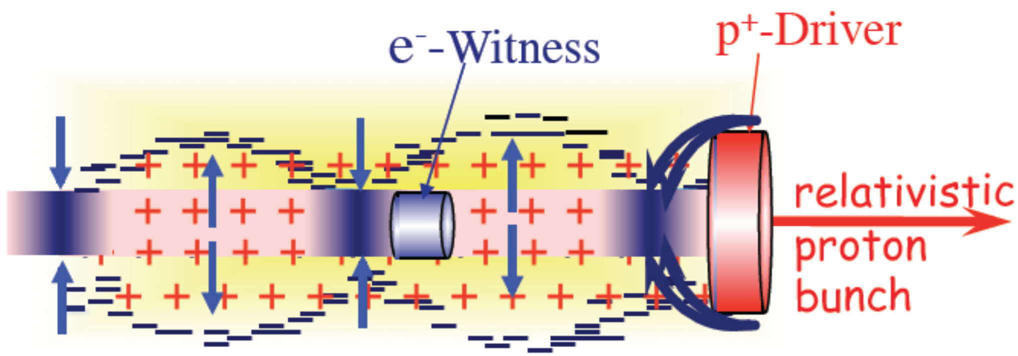
Accélération par un faisceau de particules

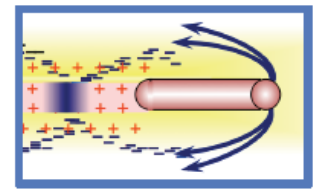


Summary of WG1, Beam-driven PWFA



p⁺-DRiVEN PWFA

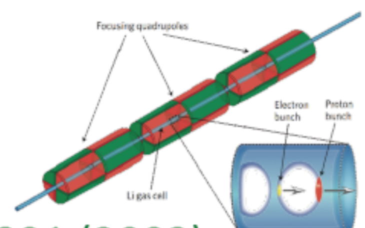




- ILC-CLIC, 0.5TeV bunch with $2\times10^{10}e^-$ ~1.6kJ
- CERN-SPS, 400GeV bunch with $10^{11}p^+$ ~6.4kJ
  CERN-LHC, 7TeV bunch with $10^{11}p^+$ ~112kJ
- A single LHC bunch could produce an ILC bunch in a single PWFA stage!

Caldwell, Nat. Phys. 5, 363, (2009)

- No staging …
- Large average gradient! (≥1GeV/m, 100's m)

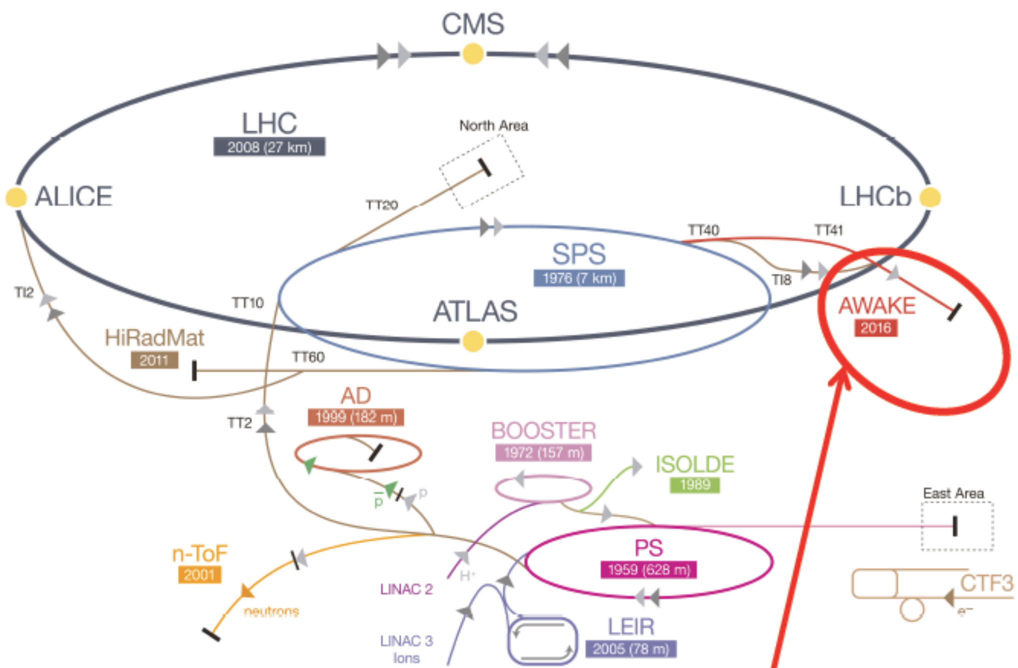


- Wakefields driven by e^+ bunch: Blue, PRL 90, 214801 (2003)

PROTON BEAMS @ CERN

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

CERN's Accelerator Complex



AWAKE experimental area

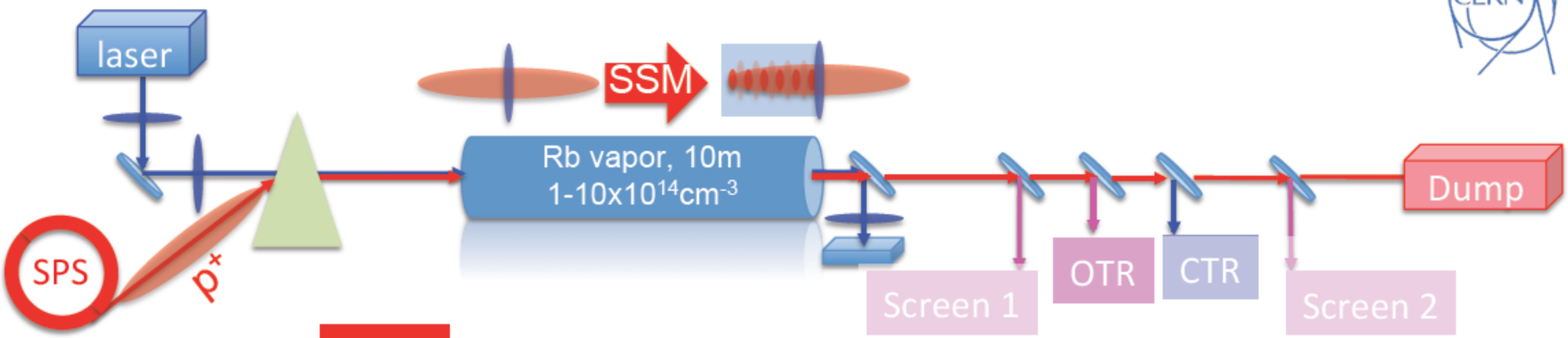
Parameter	PS	SPS	SPS Opt
E_0 (GeV)	24	400	400
N_p (10^{10})	13	10.5	30
$\Delta E/E_0$ (%)	0.05	0.03	0.03
σ_z (cm)	20	12	12
ε_N (mm-mrad)	2.4	3.6	3.6
σ_r^* (µm)	400	200	200
β^* (m)	1.6	5	5

σ_z=12cm!!

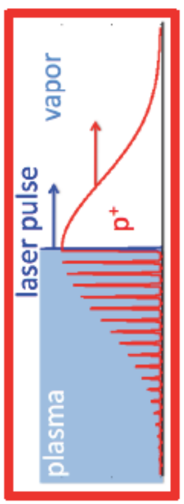
- SPS beam: high energy, small σ_r^*, long β^*

MAX-PLANCK-GESELLSCHAFT

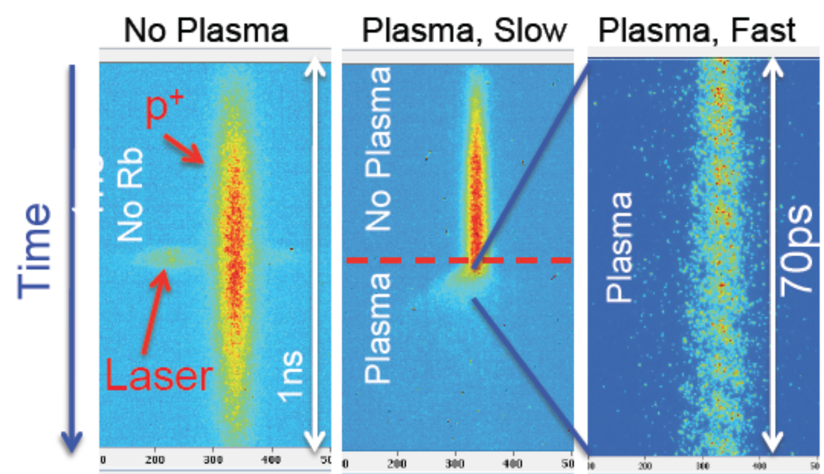
SEEDED SM



OTR



Streak camera Images



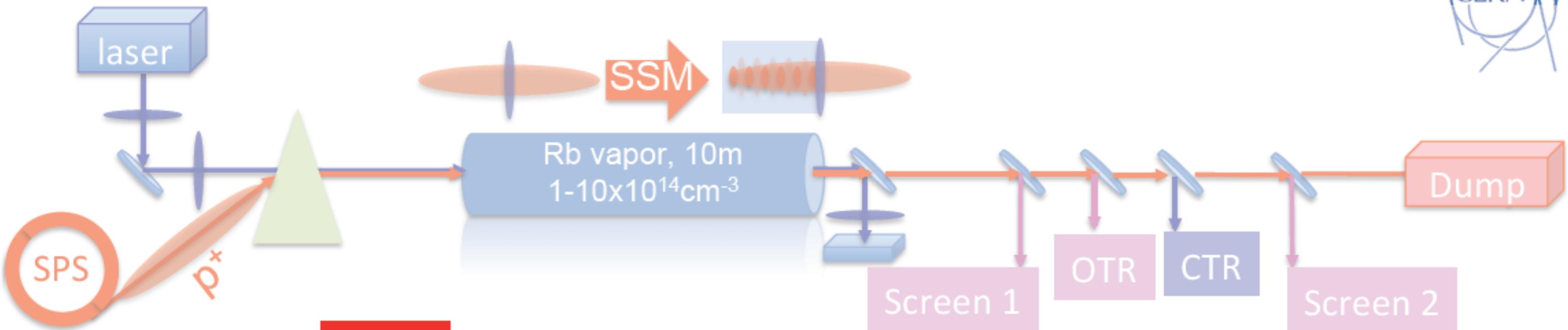
n_{Rb}=3.7x10^{14}cm^{-3}
N=3x10^{11}p$^+$
Long
f_{mod}~164GHz

Preliminary!!!

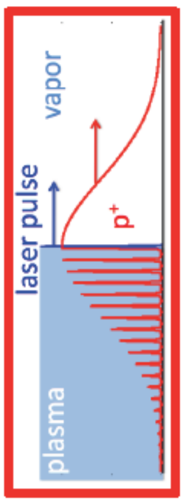
K. Rieger, MPP

- ✧Timing at the ps scale
- ✧Effect starts at laser timing → SM seeding
- ✧Density modulation at the ps-scale visible

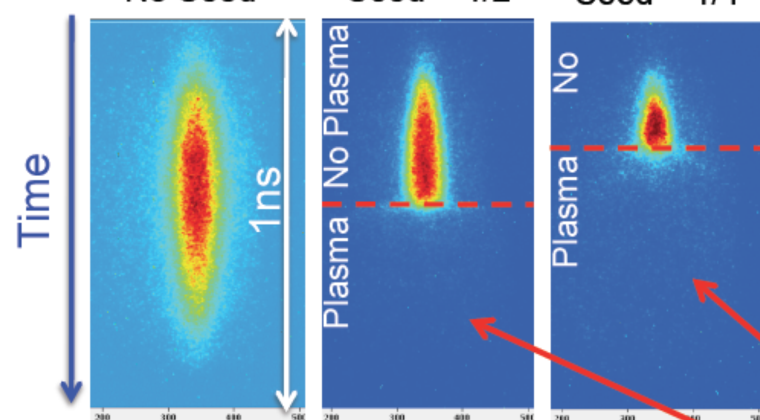
SEEDED SM



OTR



Streak camera images



n_{Rb}=2.2x10^{14}cm^{-3}
N=3x10^{11}p$^+$
Short

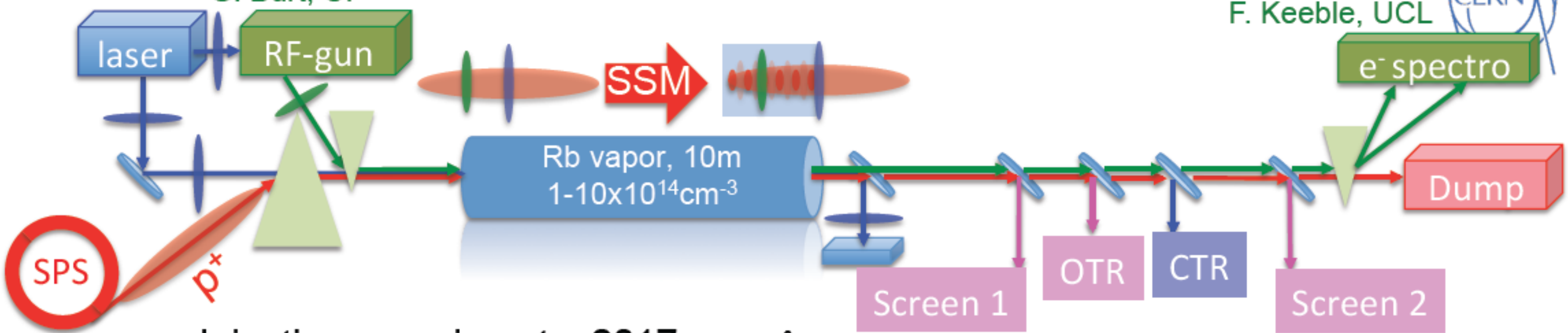
Preliminary!!!

p$^+$ defocused by SSM

- ✧Various seeding position/times
- ✧Effect starts at laser timing → SM seeding
- ✧Stronger effects with seed at ¼ than ½

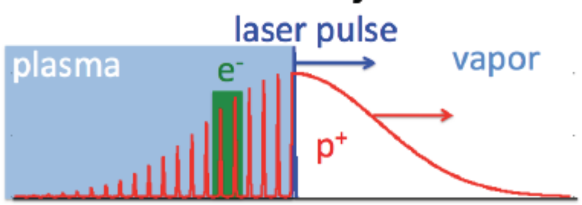
WAKEFIELDS SAMPLING / ACCELERATION

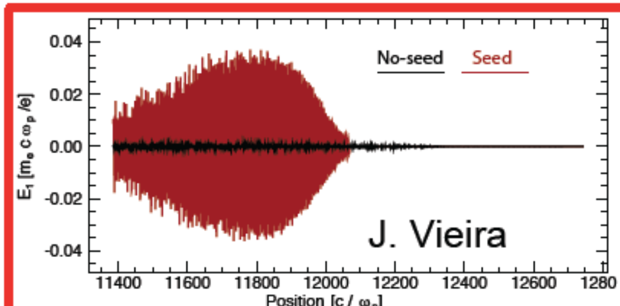
Max-Planck-Institut für Physik (Werner-Heisenberg-Institut)
S. Doebert, , K. Pepitone, CERN
G. Burt, CI
F. Keeble, UCL

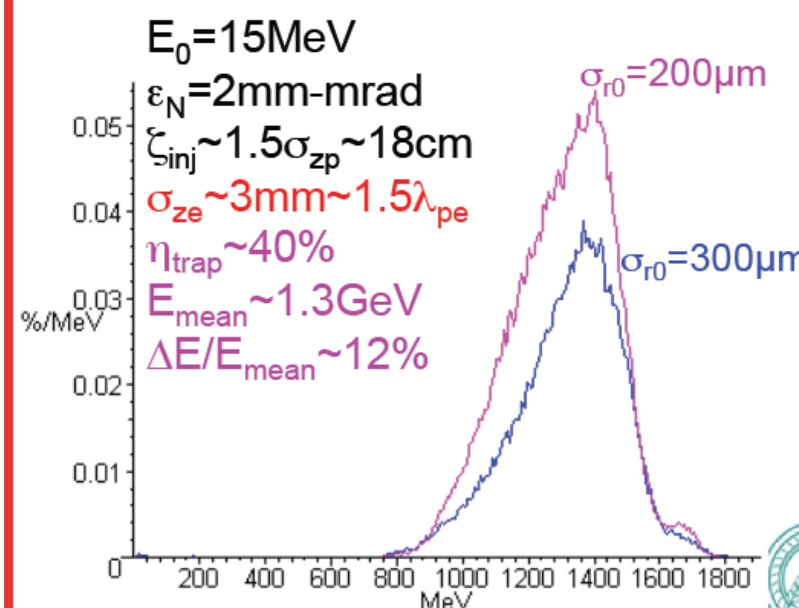


Injection experiments: 2017: $\sigma_{ze-} > \lambda_{pe}$

external e^- injection







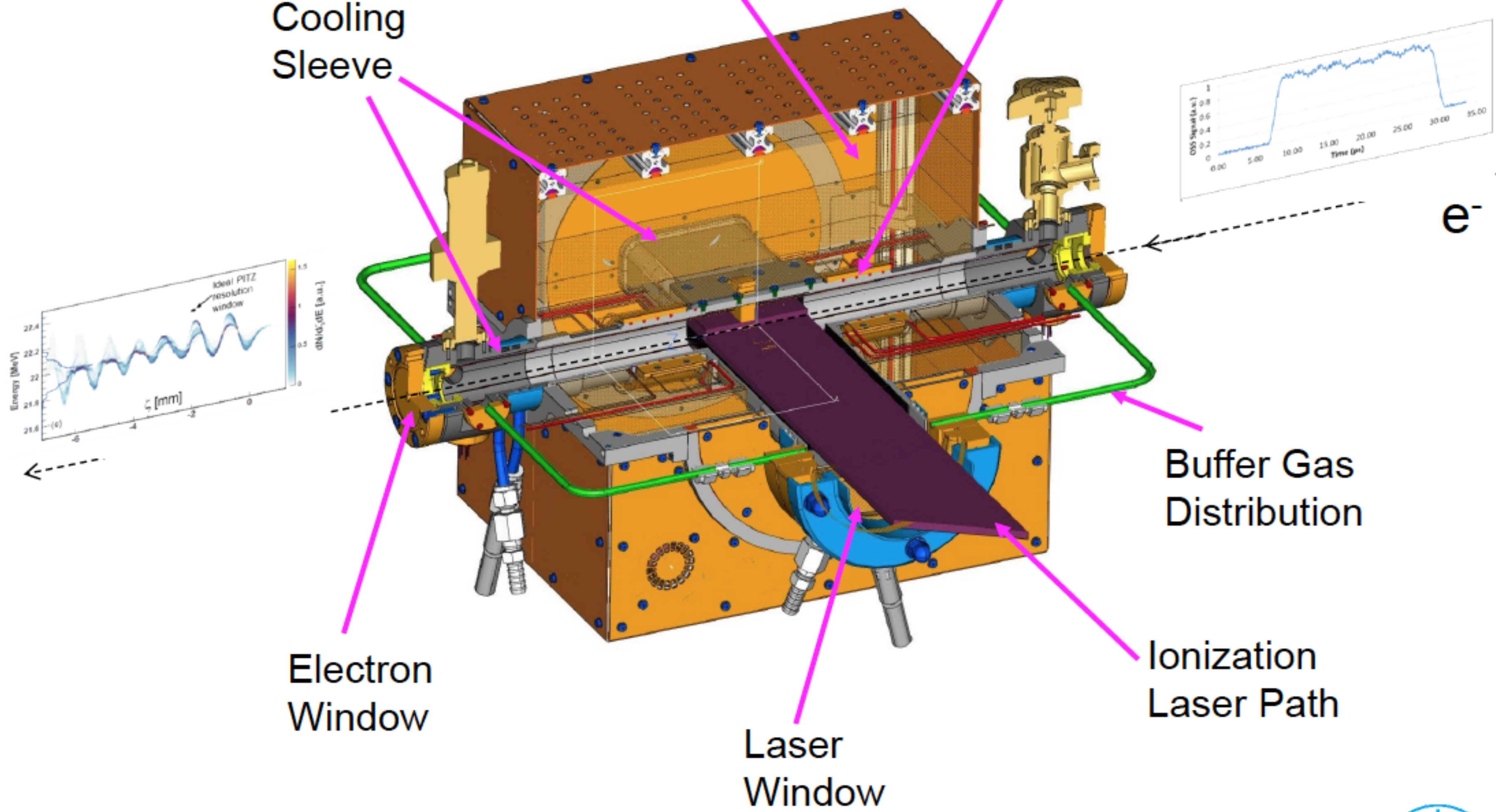
Lotov/Petrenko

✧ Accelerate e^- to GeV energy with ~GeV/m gradient and finite $\Delta E/E$

Lithium Plasma Cell Design: Novel Cross Shape

Design:
Gerald Koss

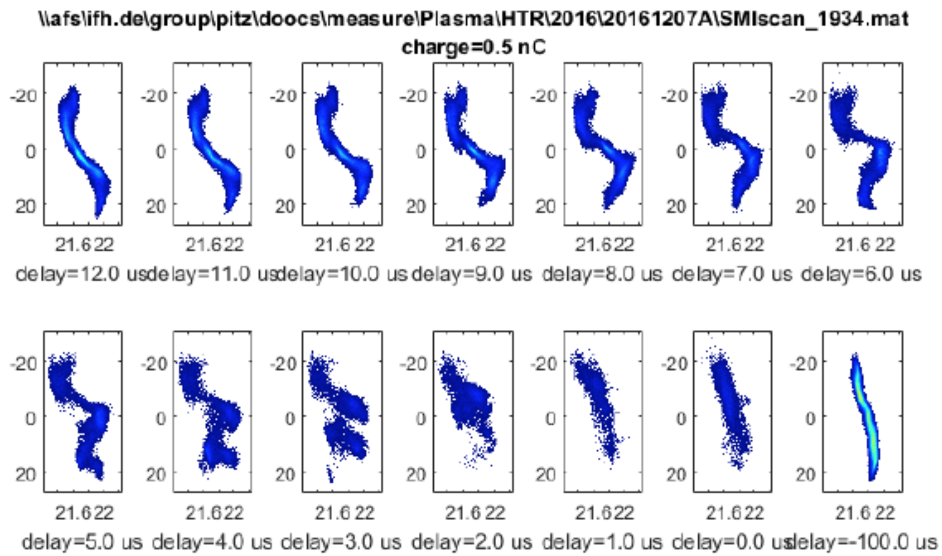
2nd generation

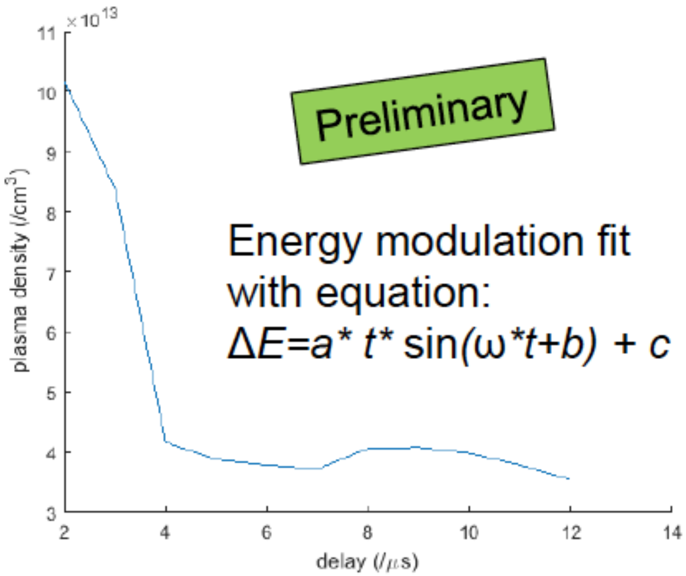


SMI Experimental results with Discharge Plasma Cell

<u>Self-modulated bunch vs. discharge to electron beam delay</u>

- Vertical axis: time (streaked with TDS)
- Horizontal axis: momentum





Energy modulation fit with equation:
$\Delta E = a * t * \sin(\omega * t + b) + c$

> Self-modulation also seen with this plasma cell

> Is utilized to measure plasma density (novel method)

Carl A. Lindstrøm, University of Oslo and FACET, SLAC

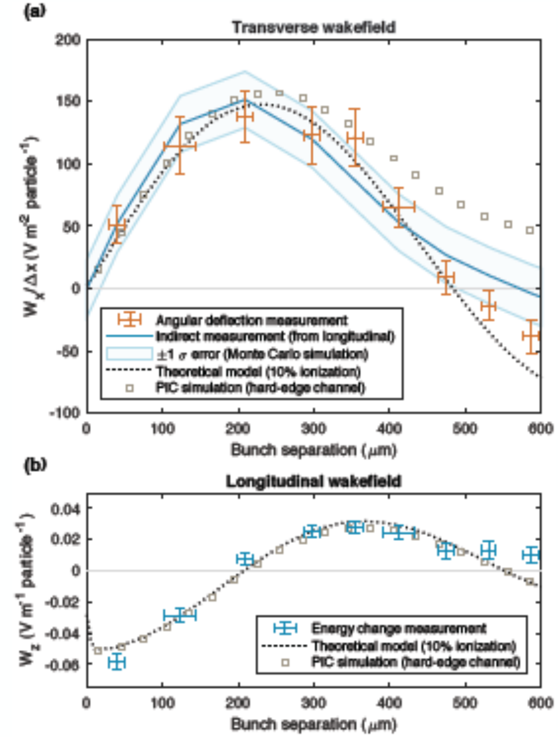
Measurement of transverse wakefields in a positron-driven hollow channel

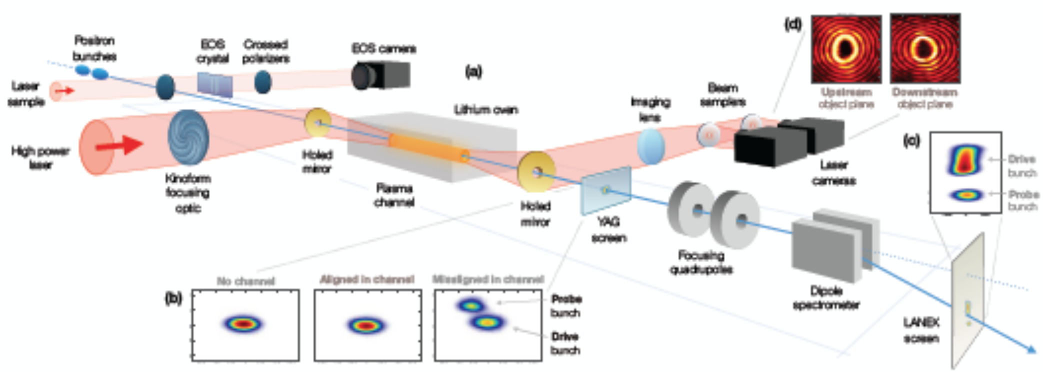
- **Hollow plasma channels**: a proposed method to accelerate low emittance positrons with high gradient (key to a complete plasma linear collider concept). Challenge: **Strong deflecting transverse wakefields** for misaligned beams.

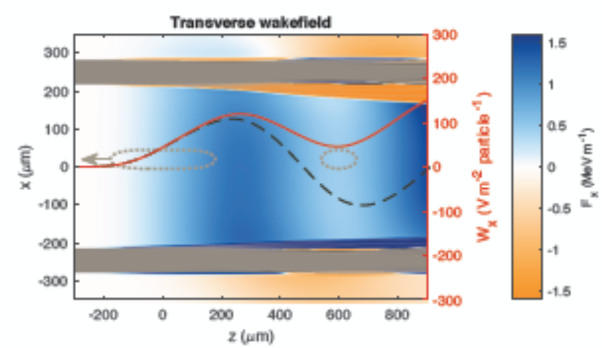
- **E225** Hollow Channel experiment at **FACET at SLAC**:
  – Two-bunch 20 GeV positron beam (0.5 nC drive bunch + 0.1 nC probe bunch)
  – 25 cm long, 500 μm diameter hollow channel using a high-order Bessel kinoform

- **Transverse offset of channel was scanned for many probe positions behind the drive bunch.**
  – Transverse wakefield measured directly via the kick of the probe bunch.
  – Extra independent measurement: Indirect estimate of transverse wakefield from the measured longitudinal wakefield via the Panofsky-Wenzel theorem.

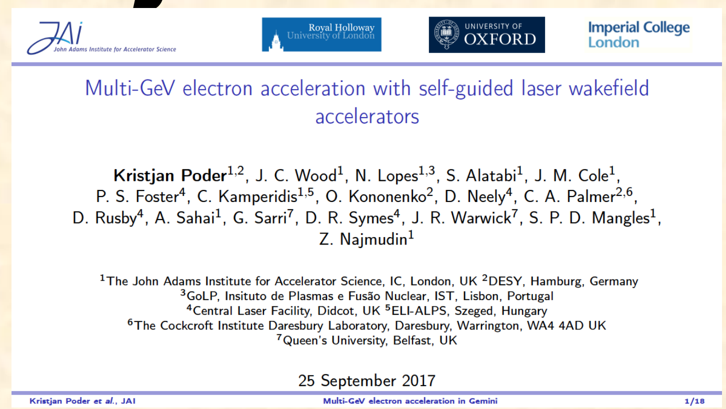
- **Good agreement between theory and experimental measurements!**
  Some discrepancy further behind the drive bunch, likely due to imperfect knowledge of radial plasma profile.

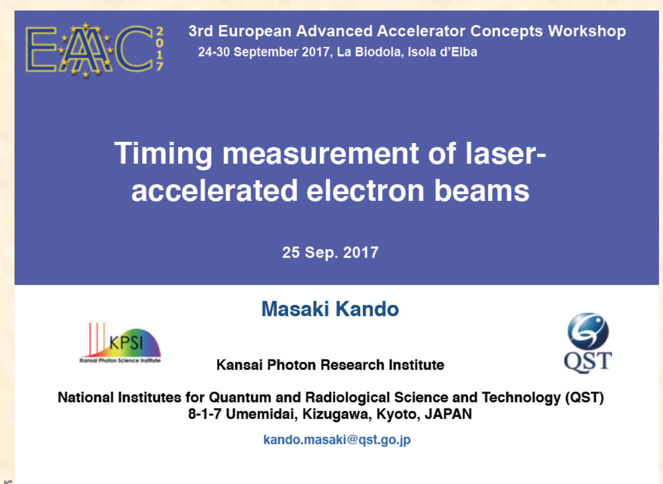




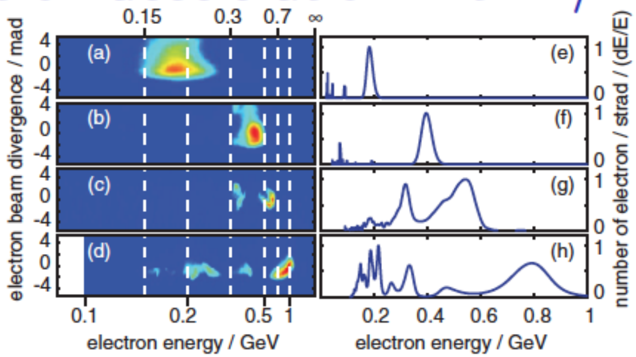


Accélération par laser avec auto-injection

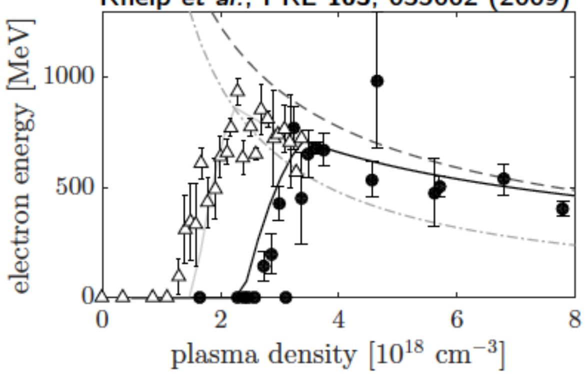




Electron acceleration with F/20



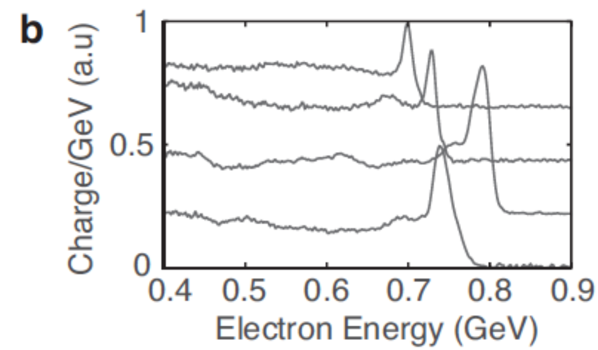
Kneip *et al.*, PRL **103**, 035002 (2009)



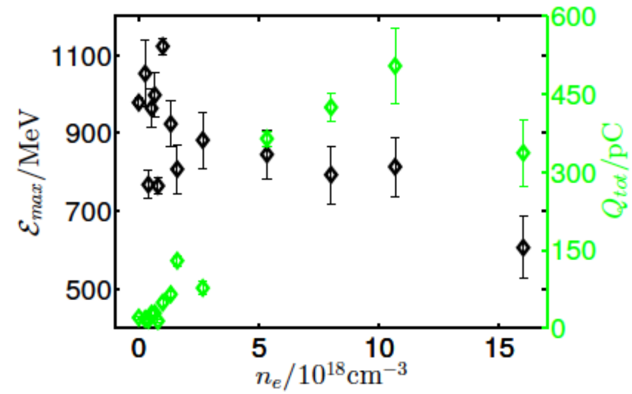
M. Bloom, PhD thesis, in preparation

Gas jet

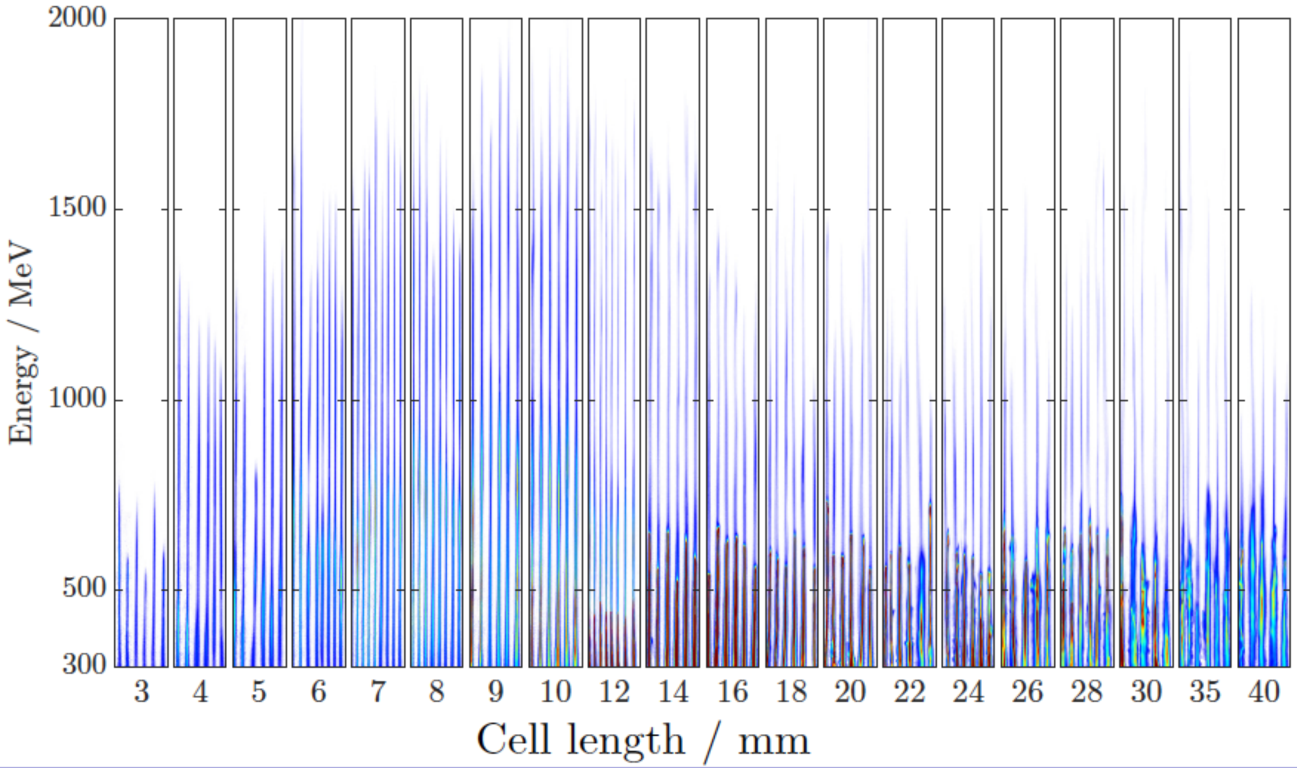
Gas cell



J. M. Cole *et al.*, Sci. Rep. 5, 13244 (2015)

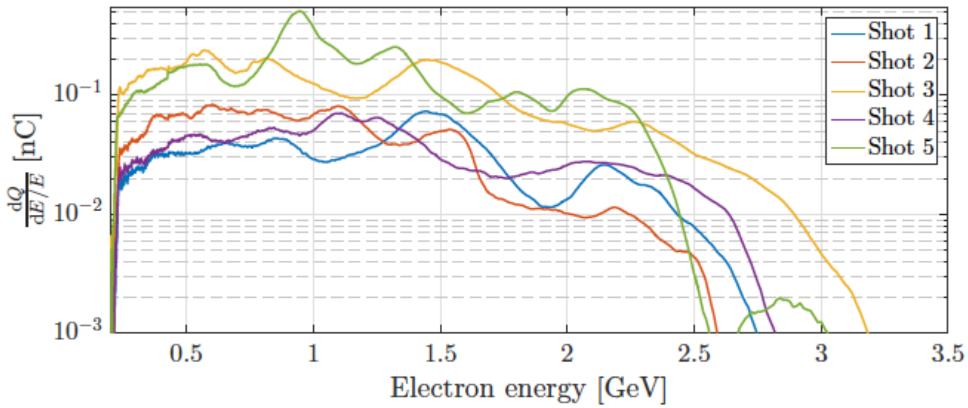


Length scans probe injection and acceleration



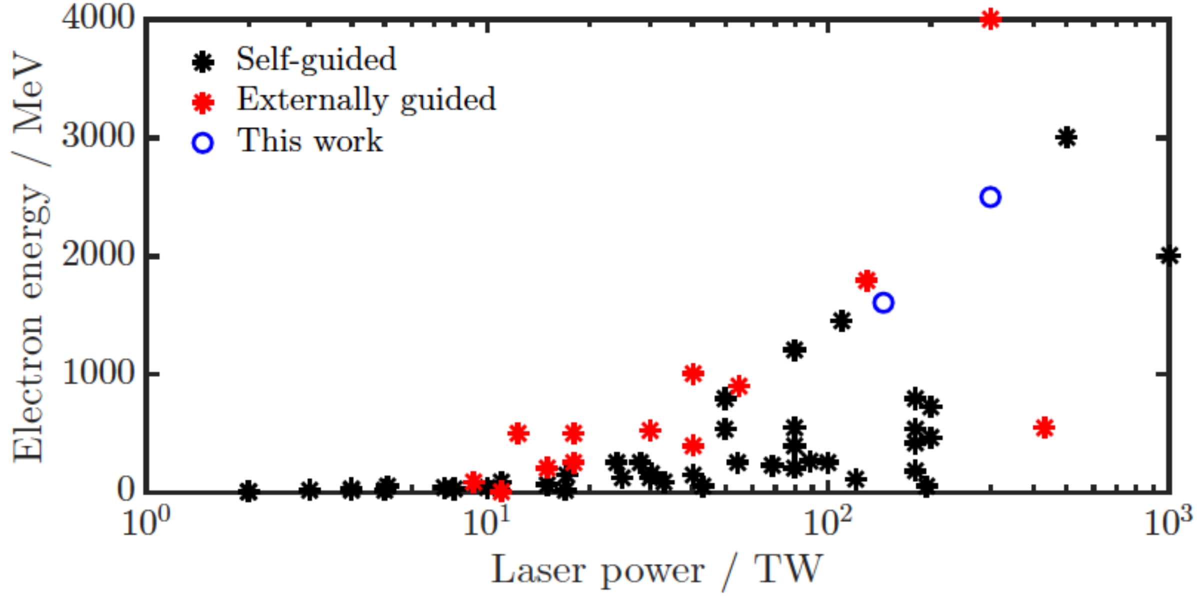
Energy on target
5.0 ± 0.7 J
Plasma density
$2.3 \cdot 10^{18}\ \mathrm{cm}^{-3}$

Multi-GeV electron energies from 250TW laser



Shot	$\mathcal{E}_L$ J	Beam charge pC			Beam energy mJ		
		> 2 GeV	> 1 GeV	> 0.25 GeV	> 2 GeV	> 1 GeV	> 0.25 GeV
1	11.29	4.4	31.0	77.5	9.9	47.5	73.6
2	11.31	2.0	31.5	122.2	4.5	42.8	93.4
3	11.42	14.9	98.9	343.4	34.8	154.2	286.3
4	11.31	6.4	35.7	92.1	14.6	53.6	85.7
5	11.31	15.2	127.8	373.9	33.0	182.1	335.1

Enhanced energies and empirical scalings



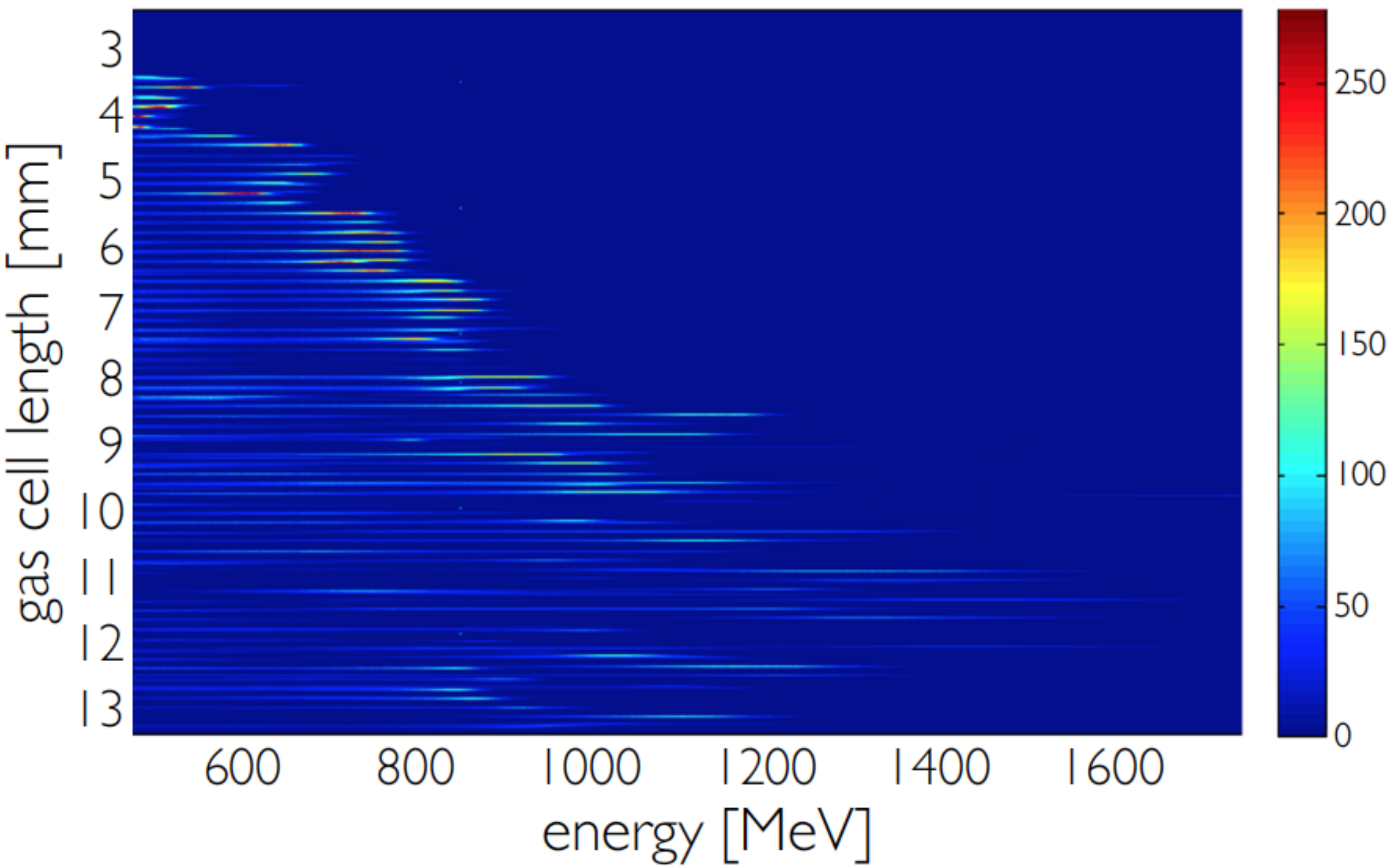
Compilation of data[9] from ~ 70 results published between 2004-2015

[9] S. Mangles, CERN Yellow Reports, **1**, 289.

Electron acceleration: Wavebreaking injection:

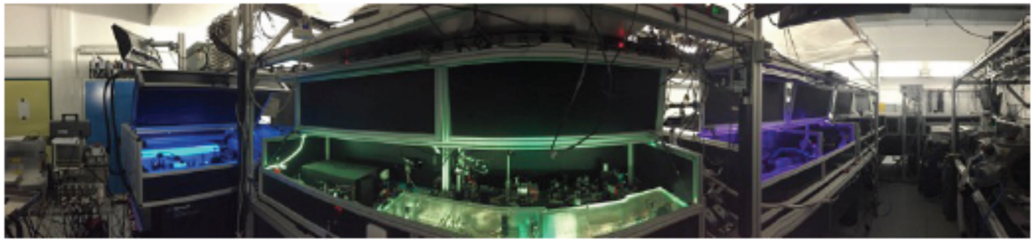
Length-variable gas cell: up to >1 GeV beams with multi-100 pC charge

- Peaked spectra up to 800 MeV
- Unstable, fluctuating spectra beyond 1 GeV – possible LWFA/PWFA transition

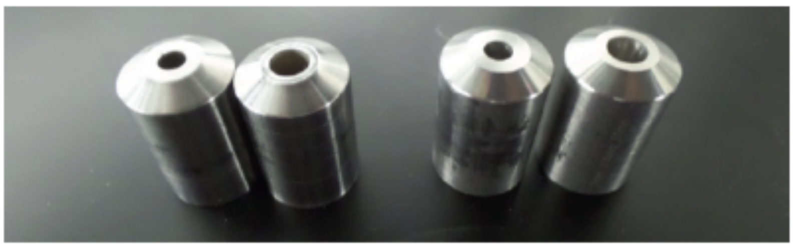


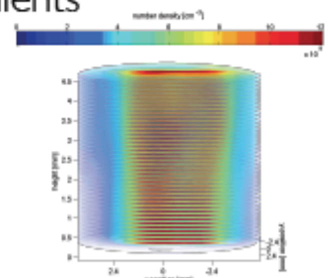
Electron acceleration: Shock-front injection

- Upgraded laser (now 2-3 J on target)

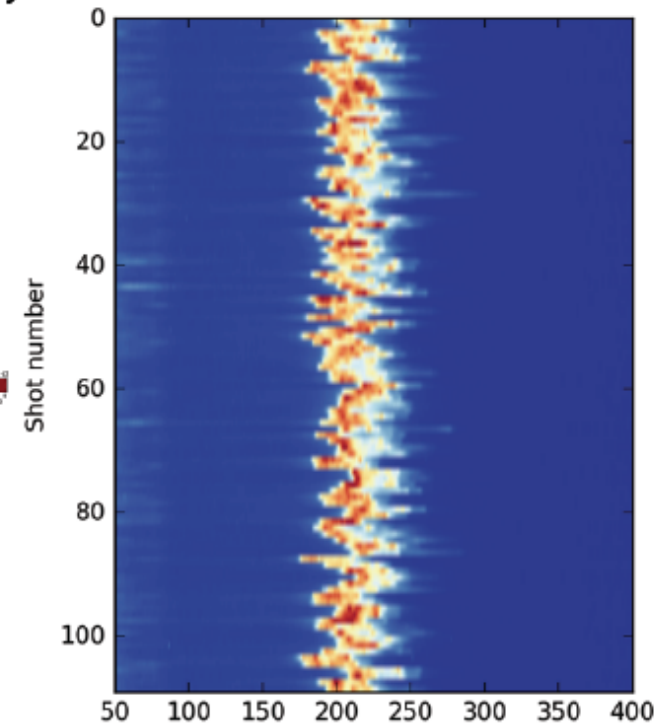


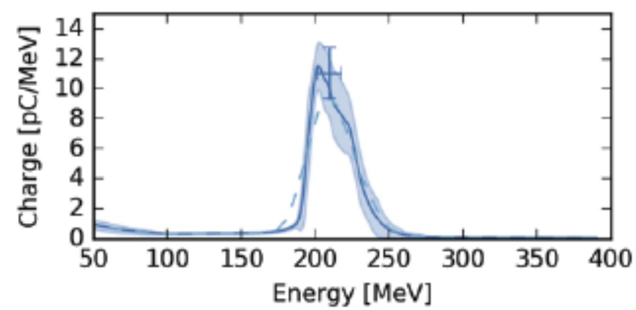
- Made new nozzles (Mach 6+) for sharper gradients





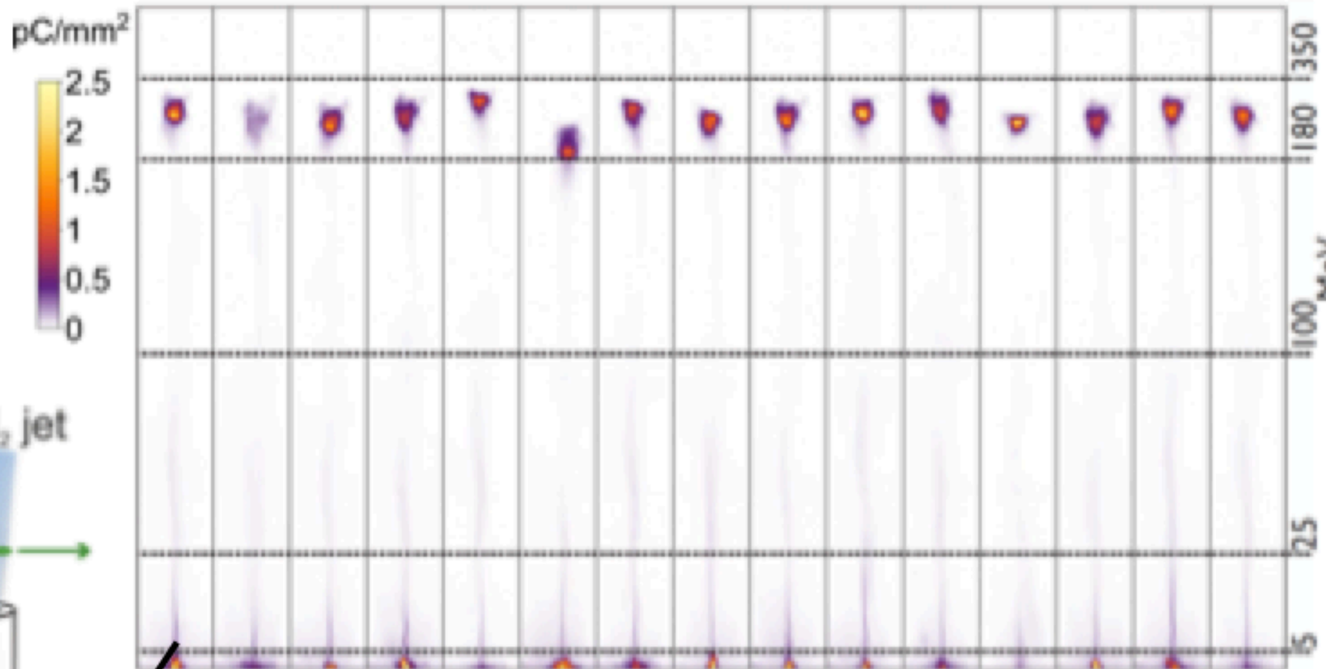
- **Stable, monoenergetic, high charge electron beams**
  - Charge: **256 ± 36 pC (14 %)**
  - Peak energy: **210 ± 8 MeV (4 %)**
  - Energy spread (rms): **13.4 ± 1.6 MeV (6.5 %)**
- What is the scaling of this?

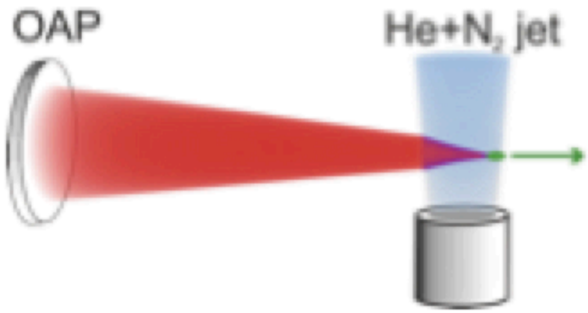


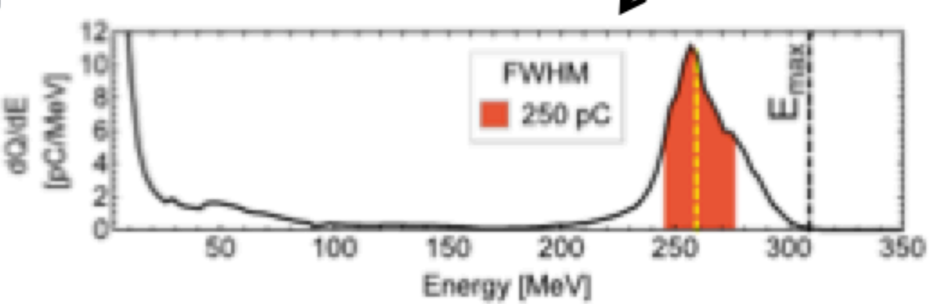


Stable operation with high charge

consecutive shots





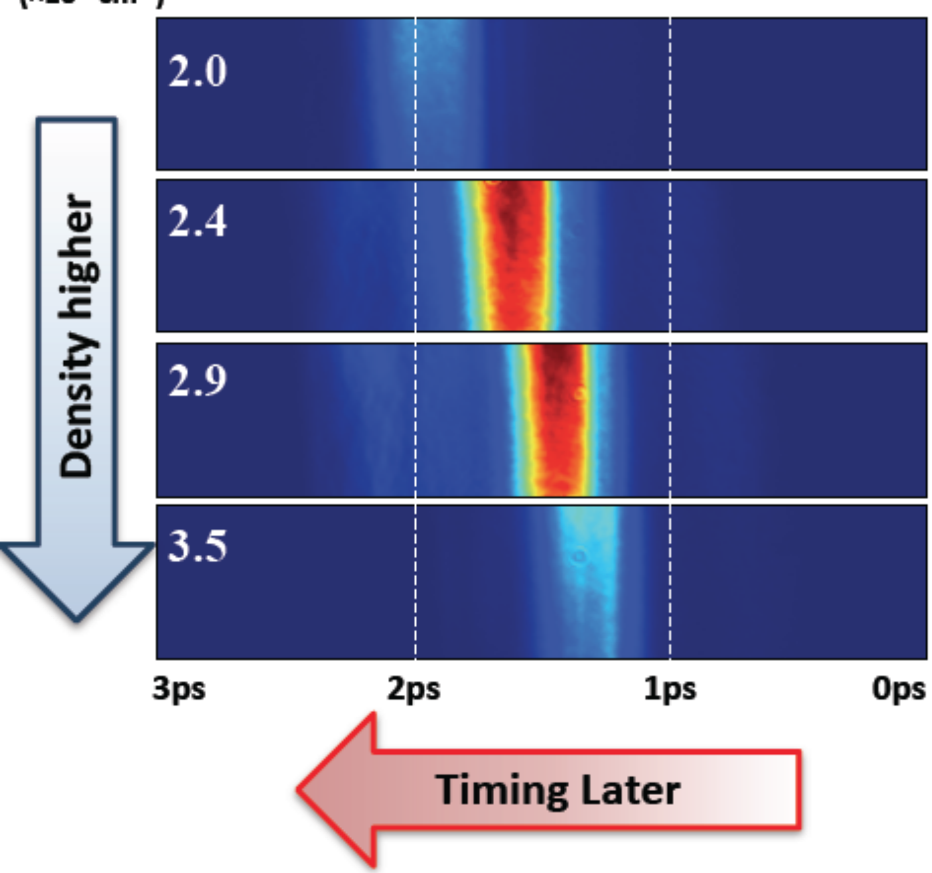


Parameters	Mean ± Shot-to-shot jitter
Mean peak energy	250 MeV ± 22.5 MeV
Charge in fwhm	220 pC ± 40 pC
Abs. energy width	36 MeV ± 11 MeV
Divergence	7 mrad ± 1 mrad

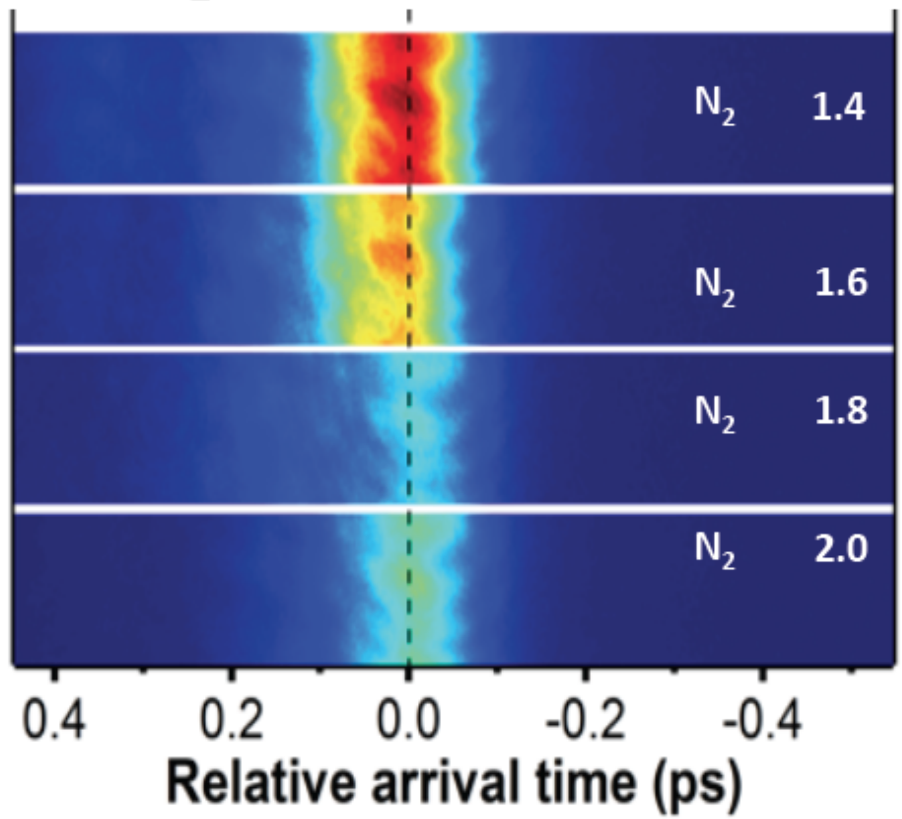
- 2.5 J, 30 fs, plasma density 3.1×10^{18} cm^{-3} , mixed He + 1% N_2 , 3 mm gas jet

Timing of electron beams delays in self-injection case

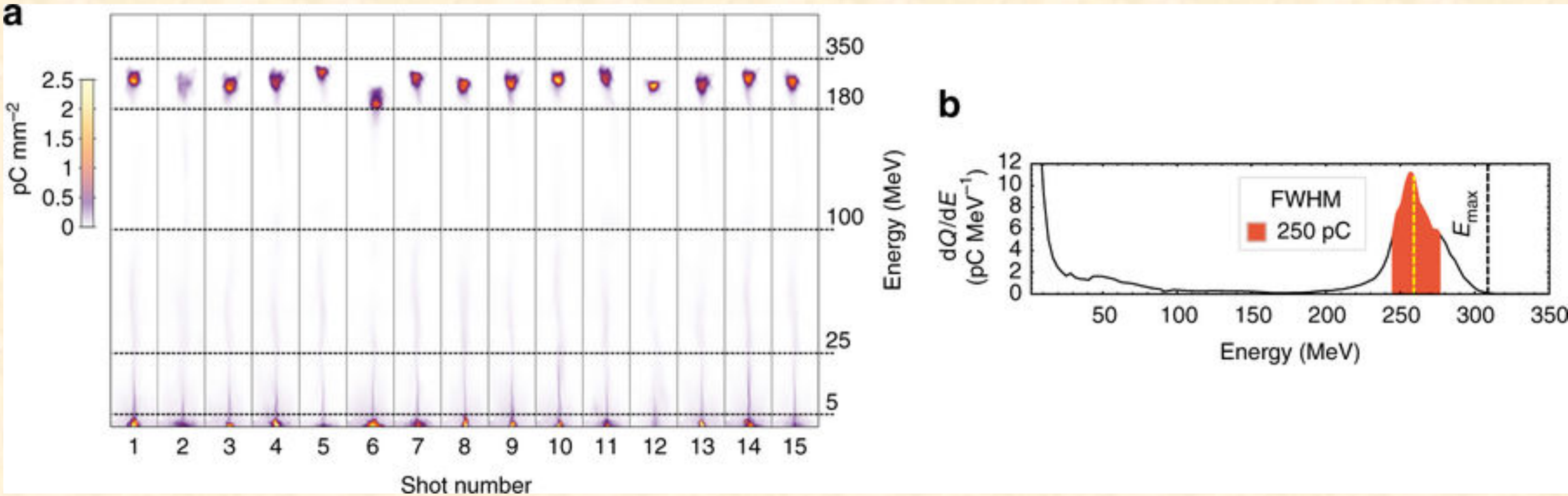
He (Self-Injection scheme)



N_2 (Ionization scheme)

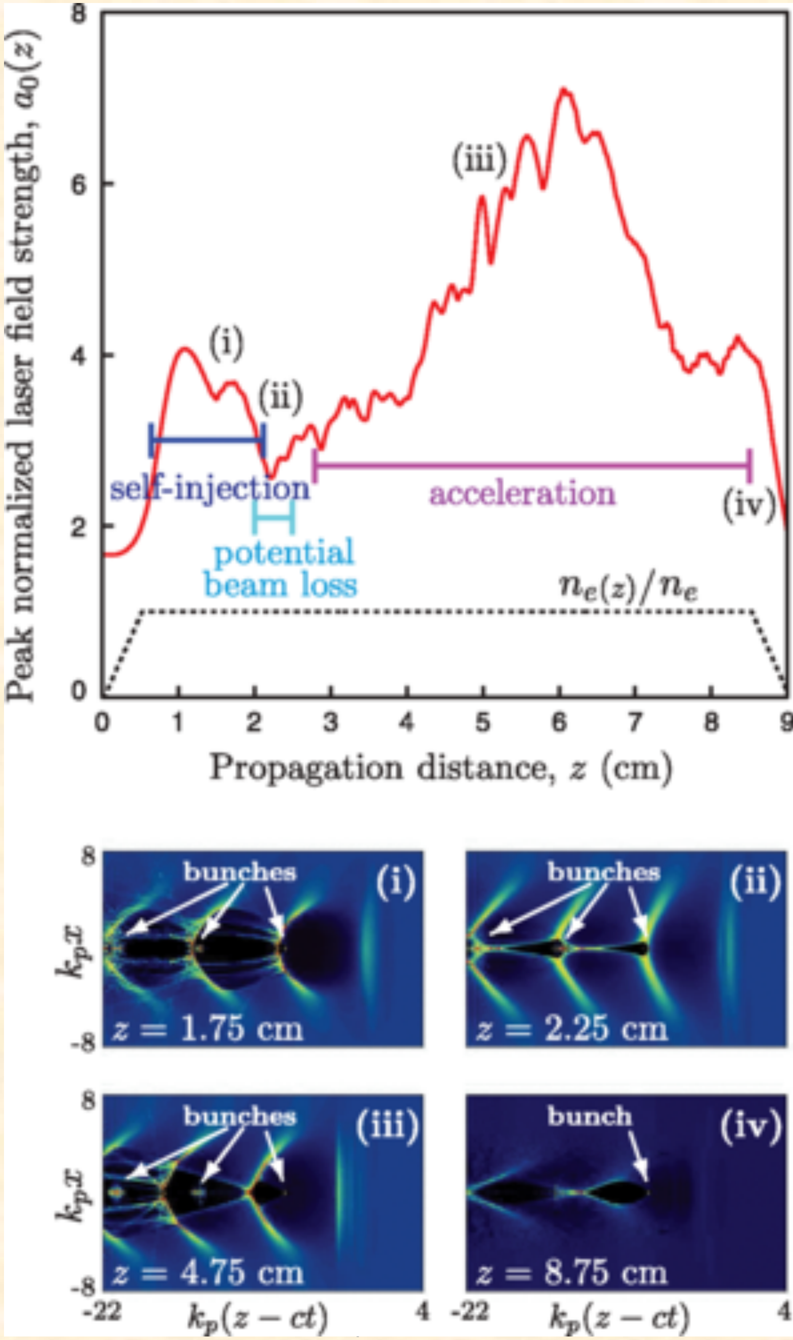


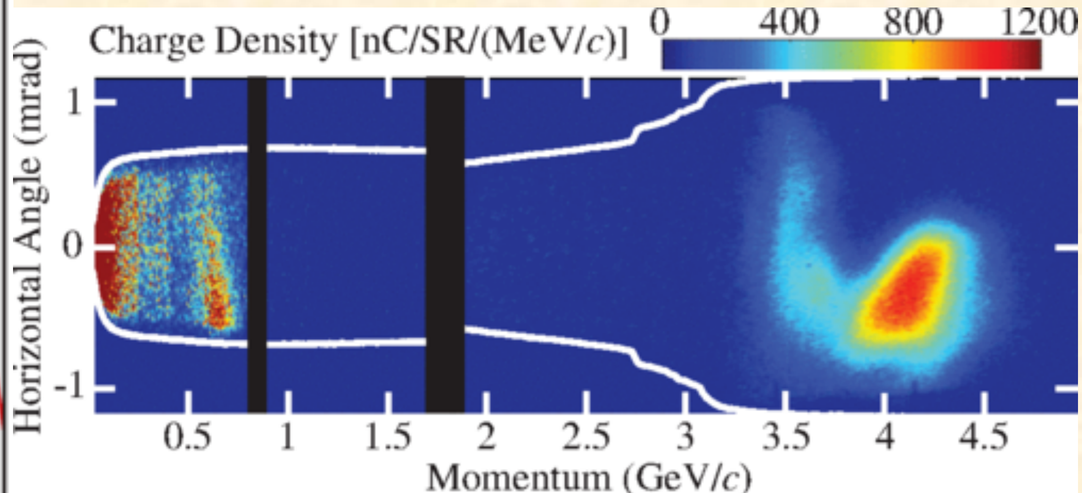
Propagation time difference between **50 MeV** and **10 MeV** after 2mm propagation is merely **8 fs** → **Different injection position**



Energy spectra of 15 consecutive shots. **a** Raw energy electron spectra. The color map represents the charge density (pC mm^{-2}) on the detector. **b** Energy spectrum of the first shot from **a**. The *filled area* represents the charge within the FWHM, the *yellow dashed line* represents the mean peak energy and the *black dashed line* represents the maximum attained energy (E_{max}) at 0.1 pC MeV^{-1}. Obtained with a supersonic gas jet with a 1.6 mm-long plasma density plateau of 3.1×10^{18} cm^{-3}, 1% nitrogen doping and 2.5 J laser energy in 30 fs FWHM duration. Line graphs of all shots shown in (**a**) can be found in Supplementary Fig. 2

Source: http://www.nature.com.proxy.scd.u-psud.fr/articles/s41467-017-00592-7/

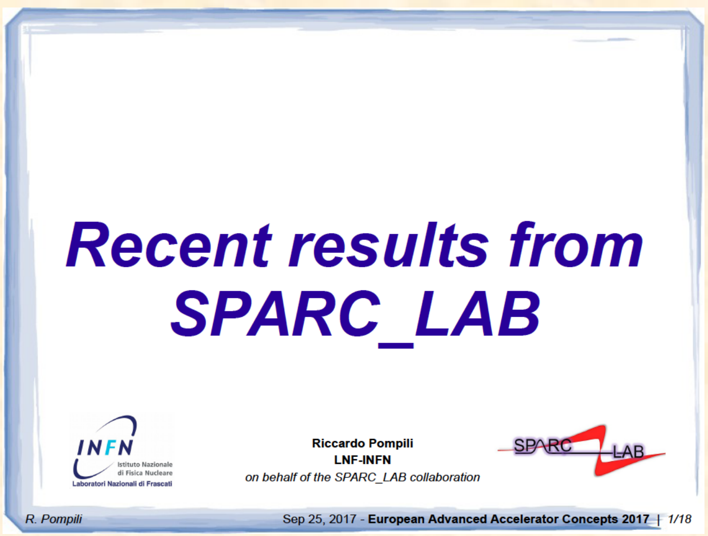




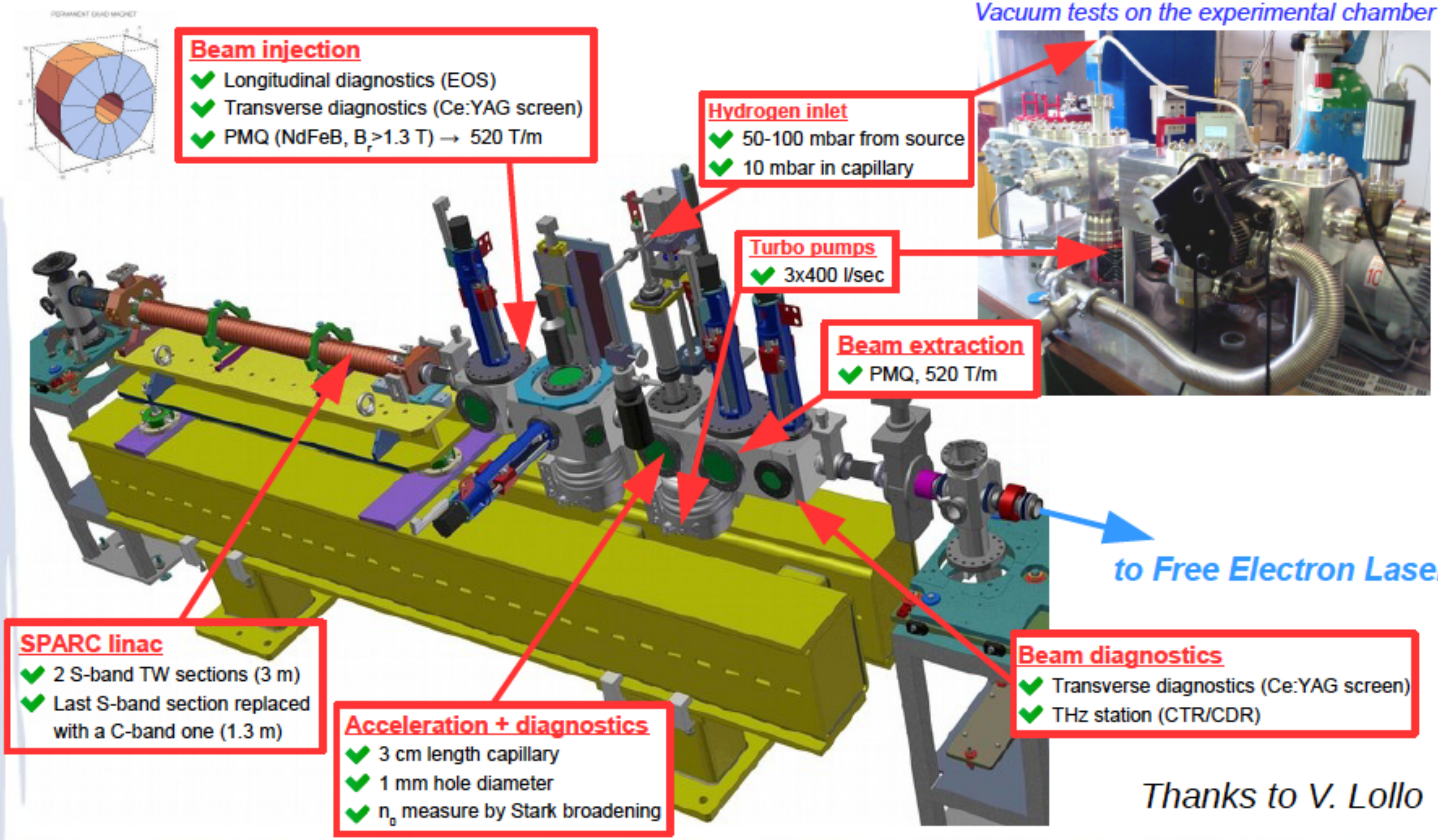
https://journals-aps-org.proxy.scd.u-psud.fr/prl/abstract/10.1103/PhysRevLett.113.245002 (2014)

LUX results: 24h run!

Accélération par laser avec injection externe

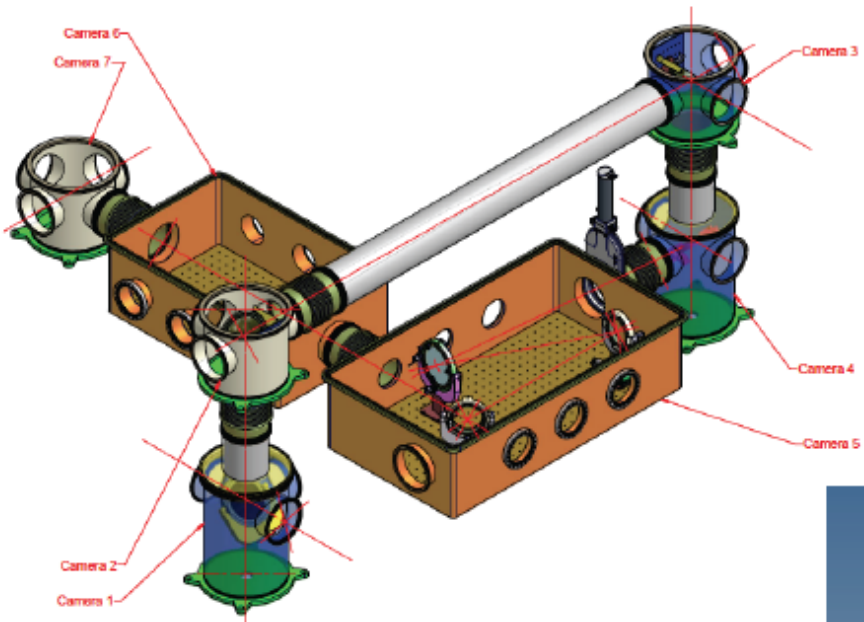


Plasma interaction chamber



Thanks to V. Lollo

External injection



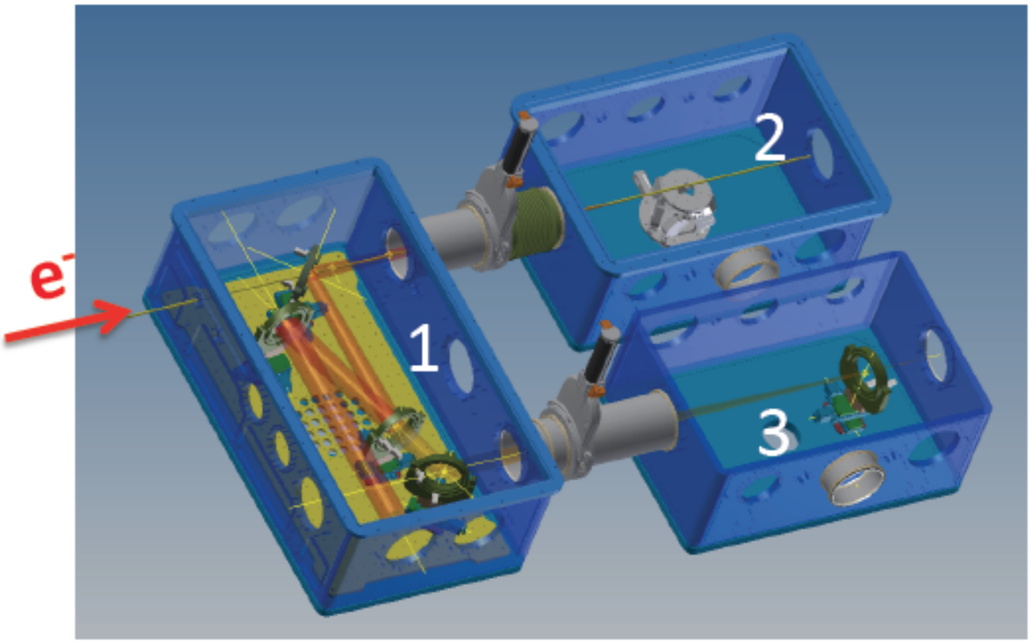
Design of the vacuum chamber for the laser transport.

1st chamber is for mirrors and 3 m focal length off-axis parabola,

2nd chamber is for interaction and 3rd chamber is for diagnostics.

Movements of the capillary (filled with H2) will be made with hexapod.

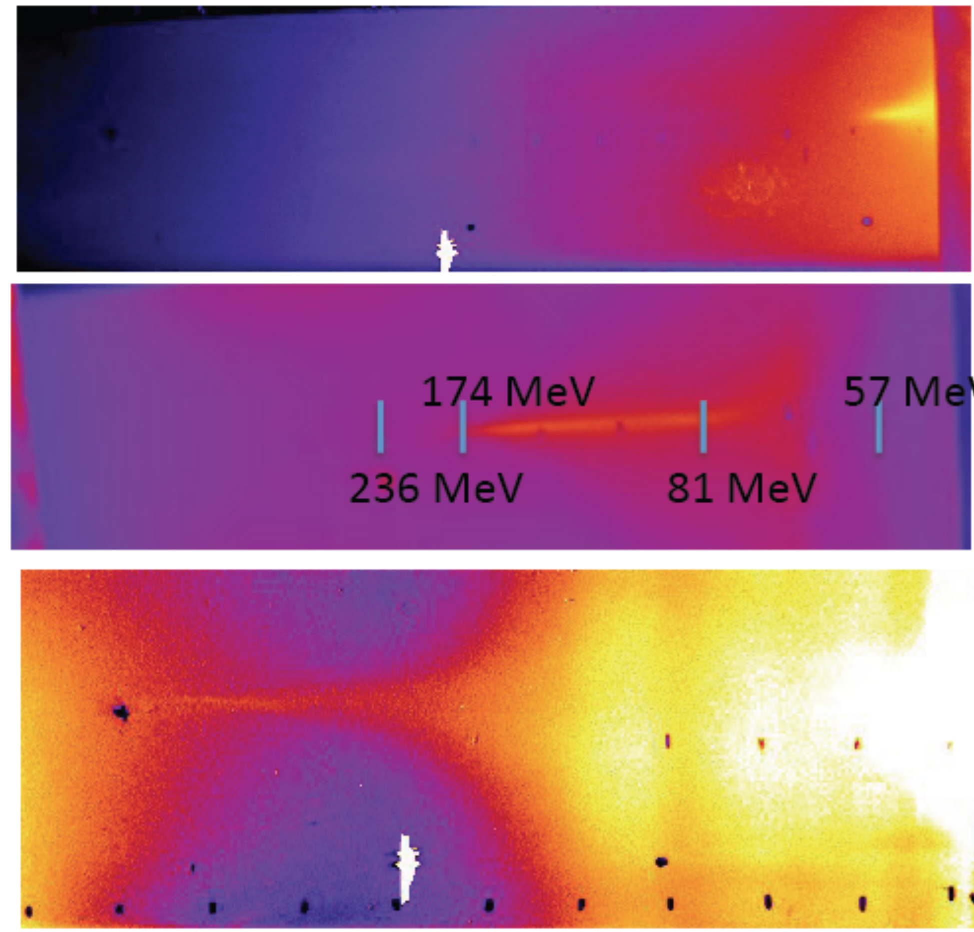
Synchronization: needs to be at the fs level.



LWFA experimental results

Source optimization and parametric study of the laser and plasma parameters is undergoing.

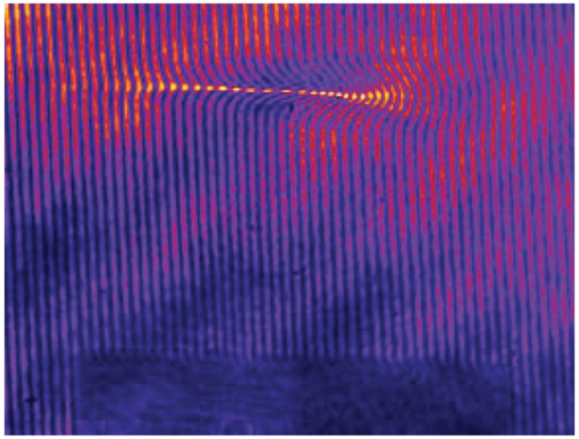
So for example by scanning the plasma density, electron energy has been varied from 50 MeV, to 175 MeV and up to 300 MeV.



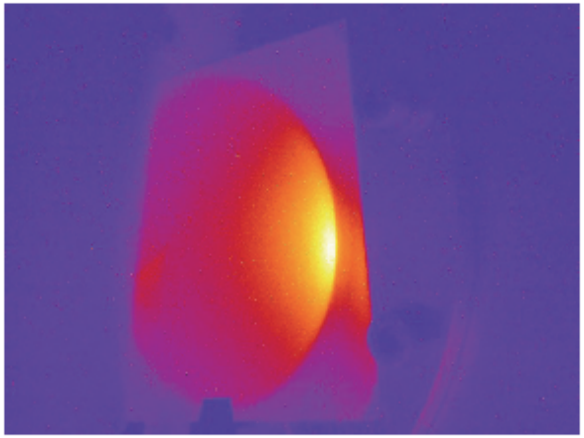
Also by tuning plasma density, energy spread has been reduced from 100% to 20%.

LWFA experimental results

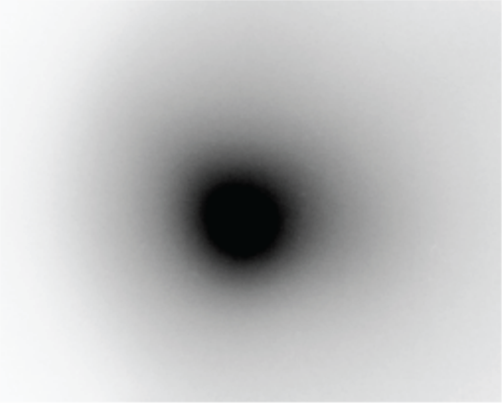
- Diagnostics



Plasma density (varied from ≈$5*10^{18}$ to ≈$2*10^{19}$).

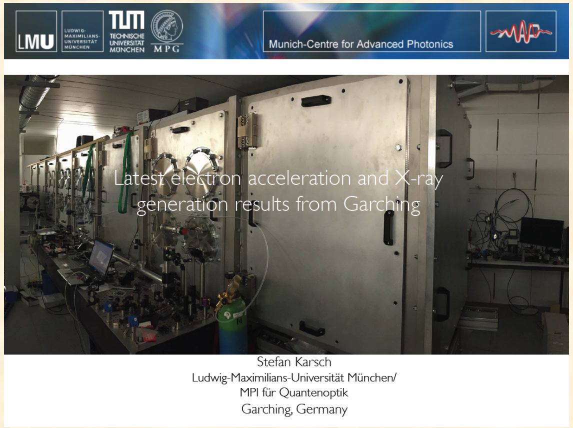


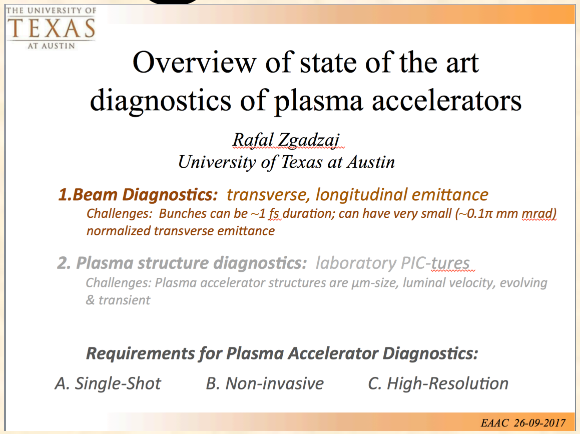
Betatron radiation (up to 20 KeV).

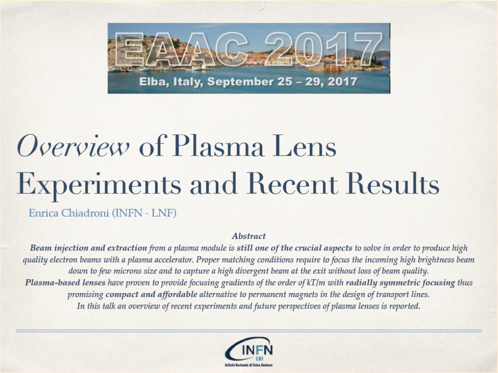


Charge (up to 10 pC in the core).

Instrumentation: plasma sources and Diagnostics

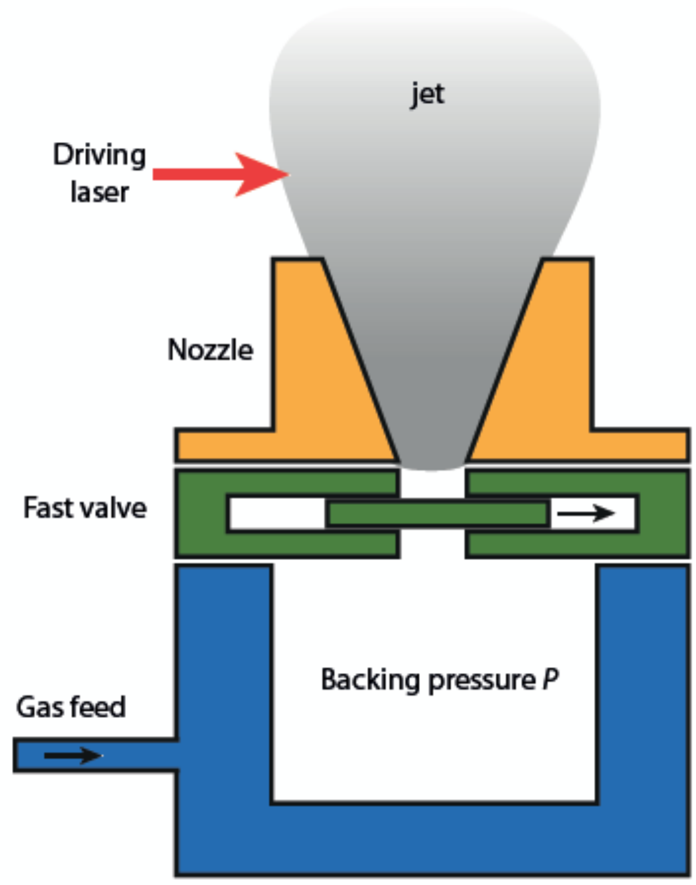






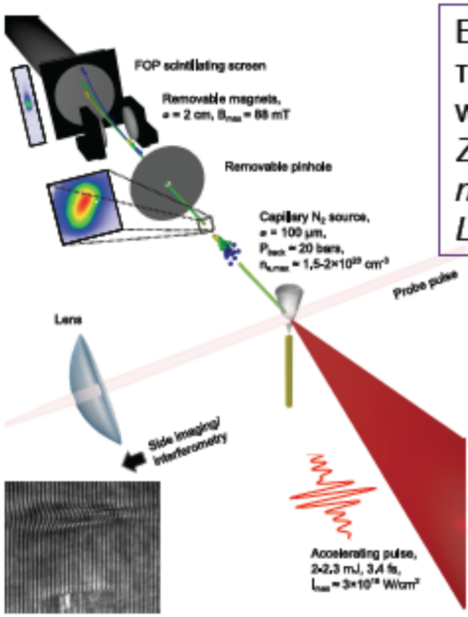
Gas jets

- Plasma density controlled by varying backing pressure behind jet -
  - 10 - 100 bar depending on nozzle diameter and desired density
- n_e typically 10^{17} - 10^{20} cm^{-3}
- Length typically few mm
- Supersonic nozzles provide near-flat-top density profile & sharper boundaries



Gas jet: kHz laser-driven accelerator

John Adams Institute for Accelerator Science

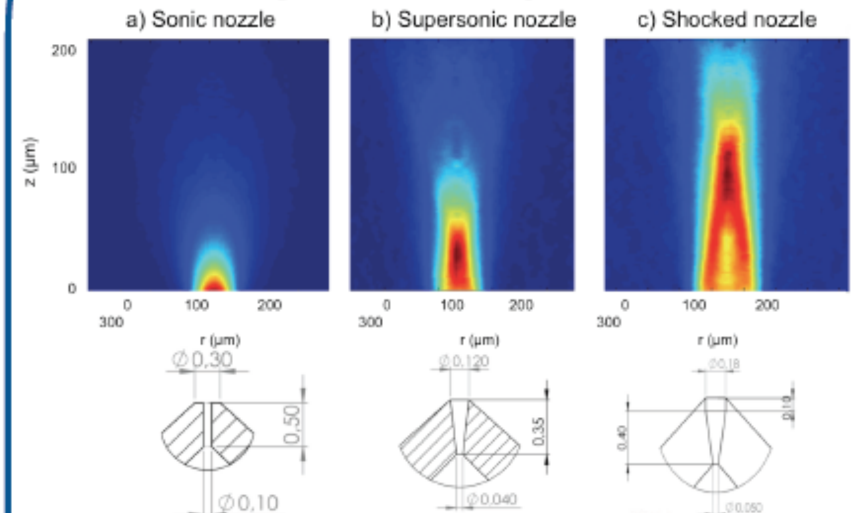


E: 3 mJ
τ: 4 fs
w0: 2-3 μm
Z_R: ≈ 20-30 μm
n_e: ≈ 1-2 × 10^{20} cm-3
L_d: ≈ 10 - 30 μm

- Low pulse energy ⇒ tight focus, short length
- High rep-rate ⇒ small mass flow required
- Gas jet:
  - nozzle dia. < 100 μm
  - Sharp boundaries to avoid refraction

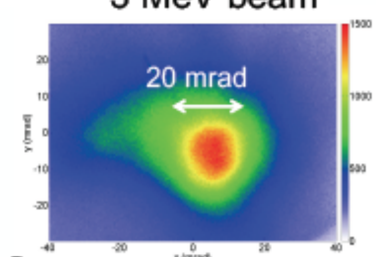
Thanks to: J. Faure (LOA, Ecole Polytechnique)

Gas jet nozzle optimization



- Sharper gradients
- Higher n_e above 100 μm (less nozzle damage)
- Supersonic nozzle: 100 × charge & increased stability

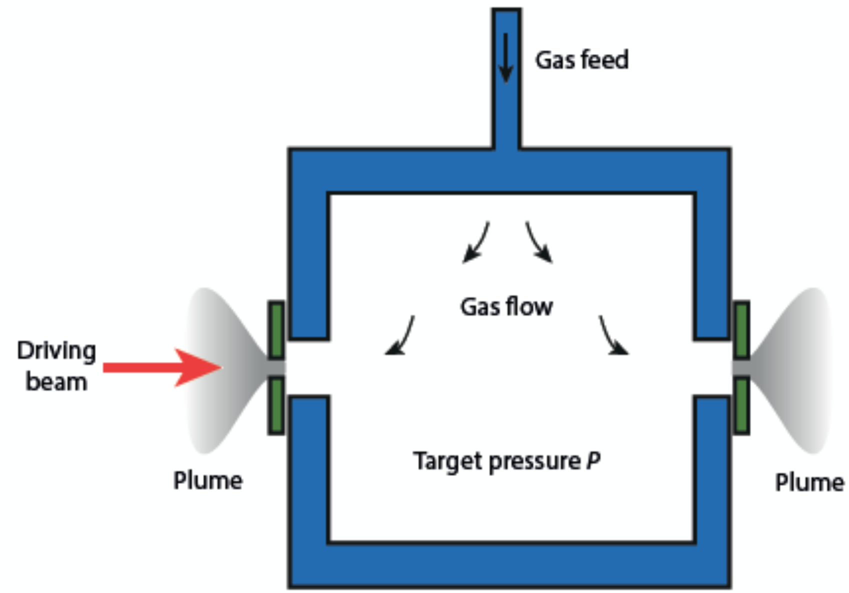
3 MeV beam



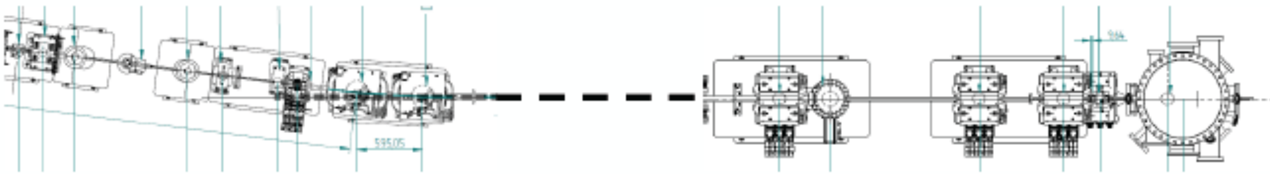
UNIVERSITY OF OXFORD

Gas cells

- Region of uniform neutral gas contained by differential pumping through coaxial pinholes
- Density fairly uniform between pinholes…
  - but plume of gas from front and back of cell
- Density easily adjusted by controlling gas flow
  - but erosion of pinholes will change density
- Several groups have designed variable length gas cells



A gas cell for a beam-driven accelerator

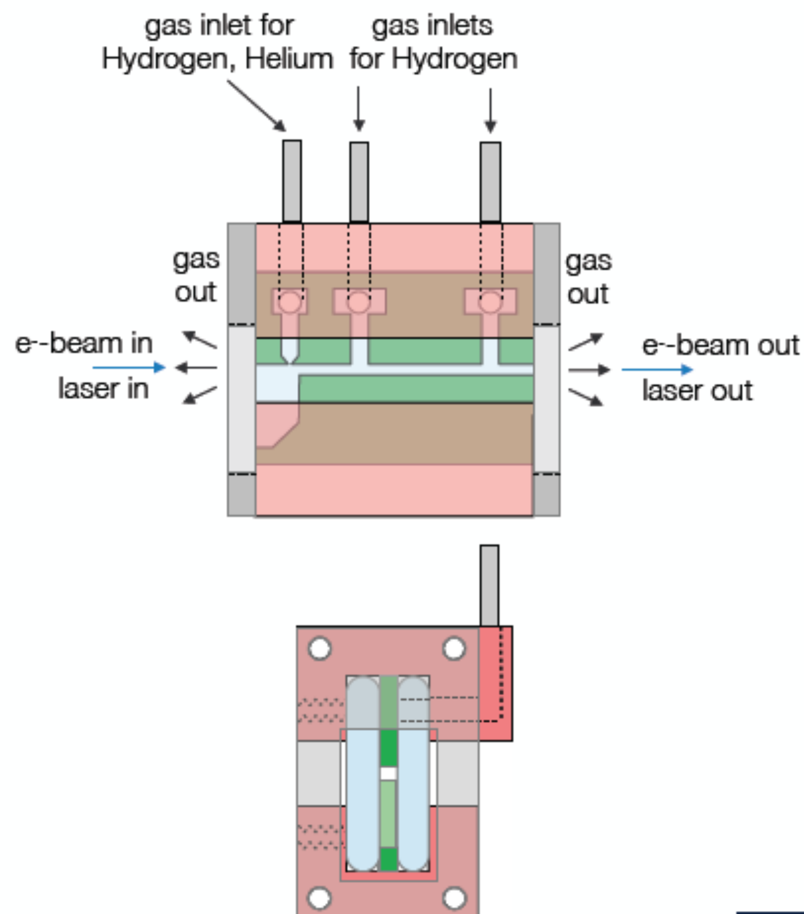


Thanks to: J. Osterhoff & L. Schaper, DESY

FLASHForward▸▸ experiment

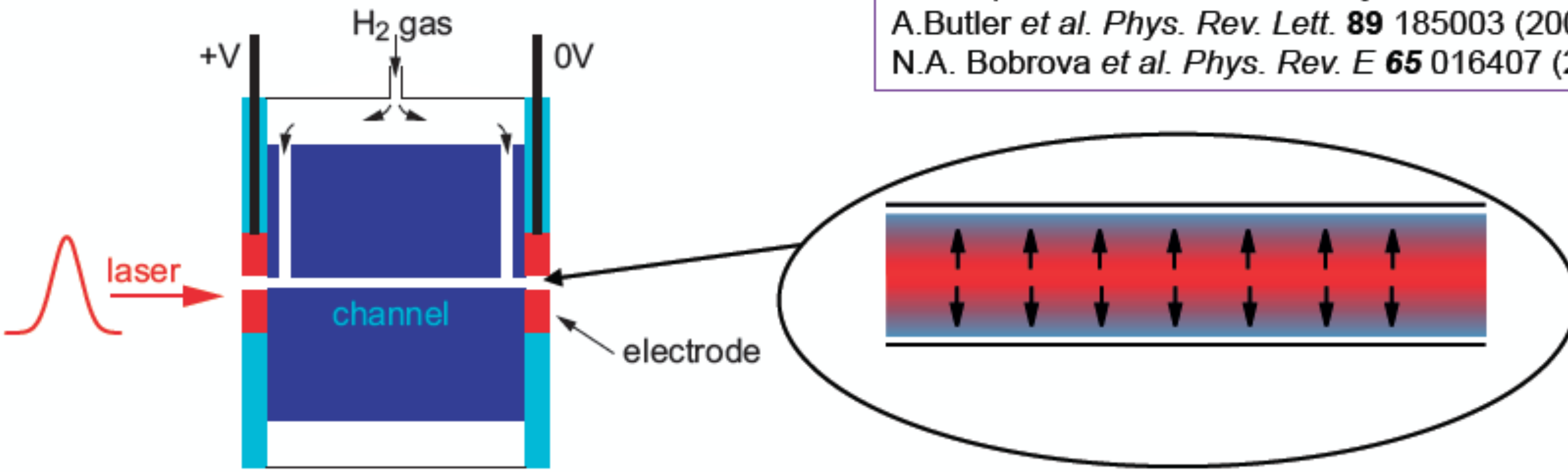
Target concept:

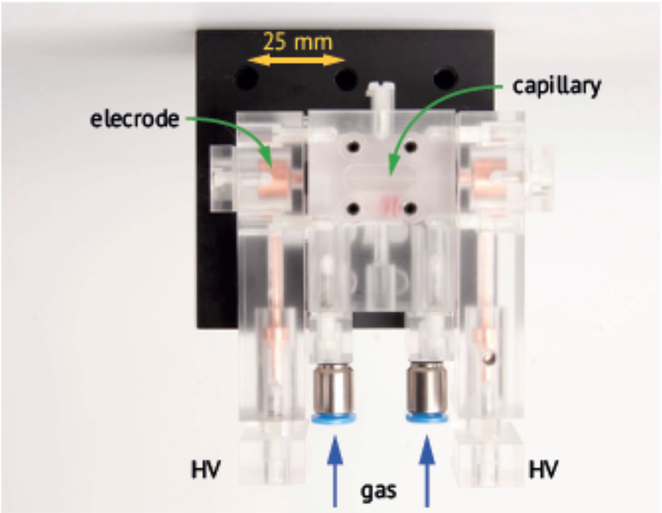
- Laser ionized
- Gas filling
  - Separate pressure control
  - Multiple species operation
  - Localised density peak and downramp possible
- Continuous gas flow design
  - No windows required
  - Compatible with FLASH vacuum standards
- Transverse access

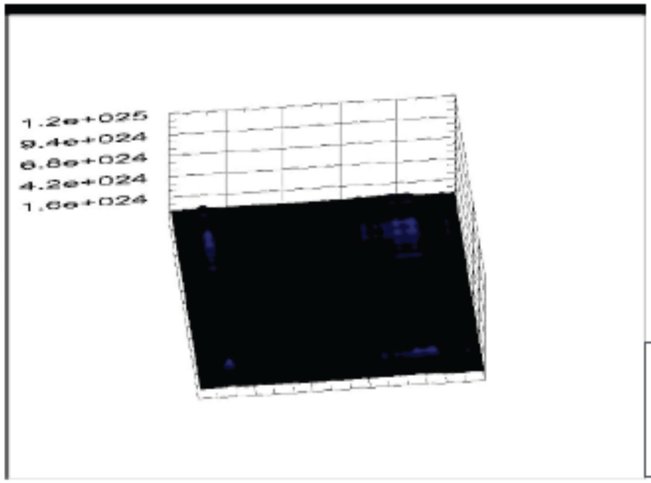


Gas-filled capillary discharge waveguides

D. J. Spence & S.M. Hooker *Phys. Rev. E* **63** 015401 (2000)
A.Butler *et al. Phys. Rev. Lett.* **89** 185003 (2002)
N.A. Bobrova *et al. Phys. Rev. E* ***65*** 016407 (2002)







Evolution of plasma channel during discharge pulse

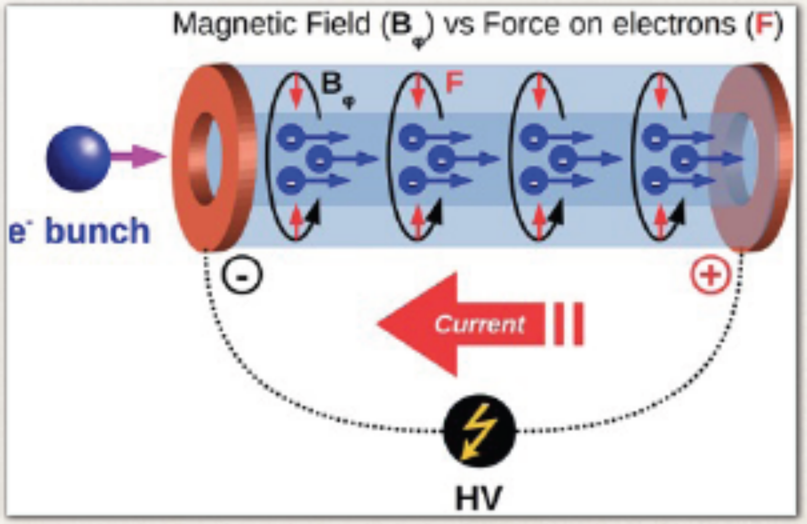
Active Plasma Lens

- Discharge current in gas-filled capillary
  - the bunch is focused by the azimuthal magnetic field generated by the discharge current density, according to Ampère's law

$$B_\phi(r) = \frac{\mu_0}{r}\int_0^r J(r')r'dr'$$

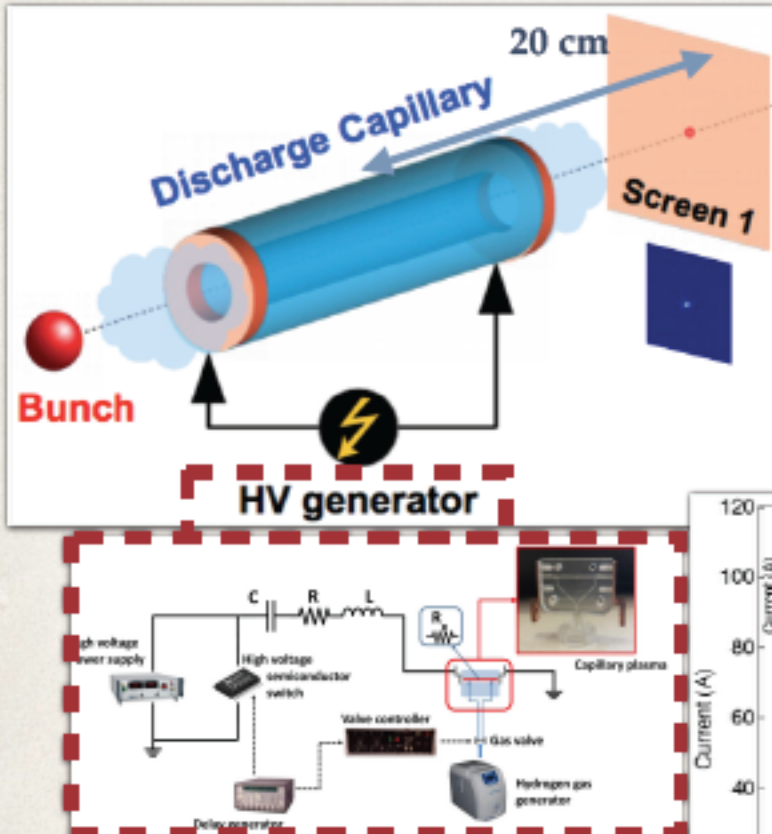
Advantages

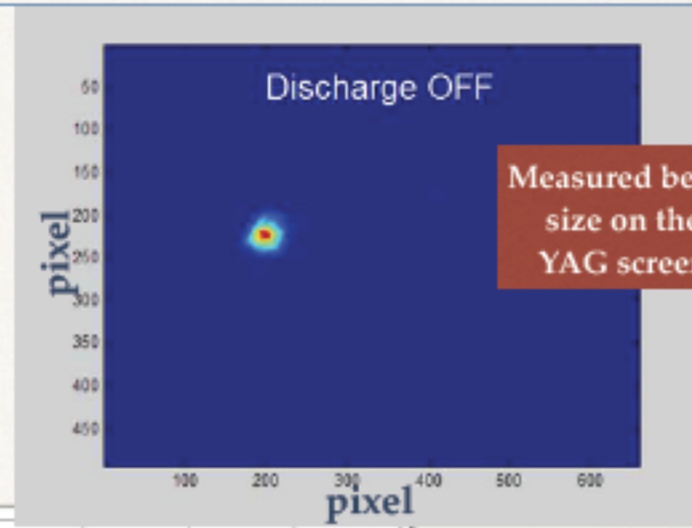
- Cylindrical symmetry
  - purely radial focusing effect
- Tunability
- Focusing strength $k \propto \frac{1}{\gamma}$
- High focusing gradient ~ kT/m
  - short focal length
    - weak chromaticity



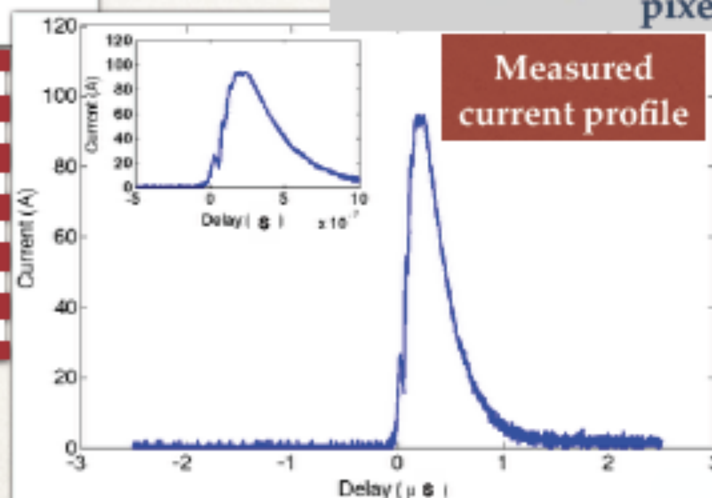
enrica.chiadroni@lnf.infn.it

Experimental setup





Measured beam size on the YAG screen



Measured current profile

A. Biagioni, Wake fields effects in dielectric capillary, WG3: Poster session I

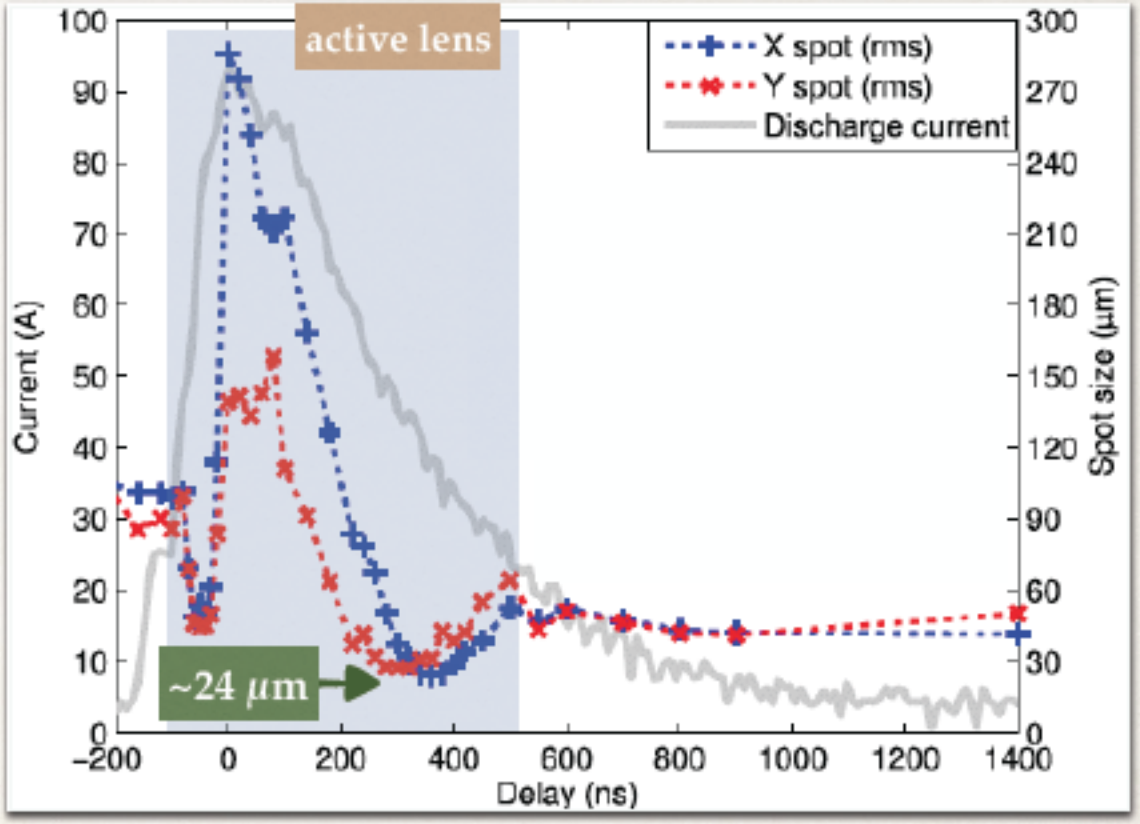
Envelope scan

Beam parameters

$Q = 50$ pC
$E = 120$ MeV
$\Delta E/E = 0.1\%$
$\varepsilon_n = 1$ mm mrad
$\sigma_t = 1$ ps
$\sigma_x = 110\ \mu$m

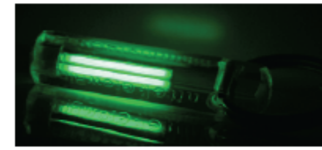
Plasma discharge parameters

$n_e = 9\ 10^{16}$ cm^{-3}
$V = 20$ kV
$I = 100$ A
$R_0 = 500\ \mu$m
$L = 3$ cm
Sapphire capillary



R. Pompili et al., Appl. Phys. Lett. 110, 104101 (2017)

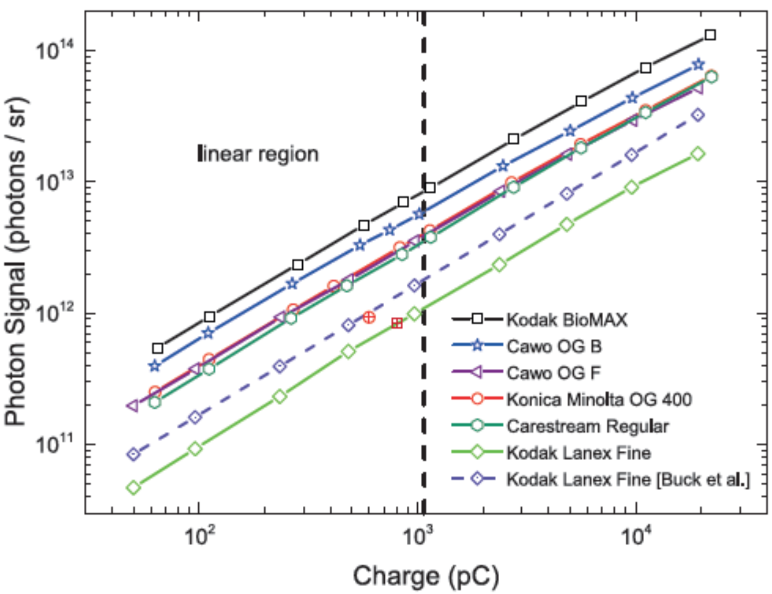
Electron diagnostic: new scintillation screen charge calibration at ELBE linac (HZDR)

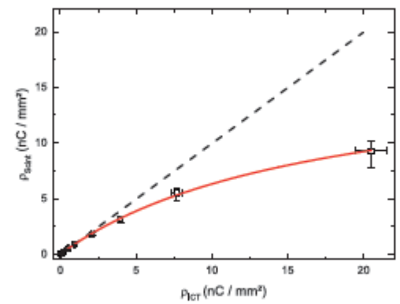


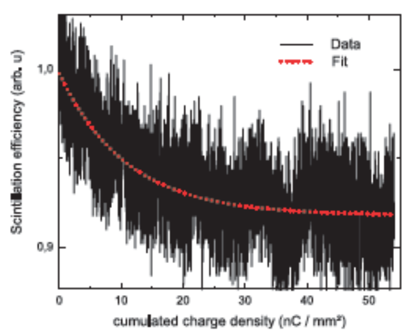
Gaseous tritium light source (GTLS) was used for absolute calibration of screen brightness. Poor knowledge of GTLS's decay curve leads to large sytematic errors.

$\Longrightarrow$ Replaced master GTLS with stabilized LED source and calibrated camera for off-line calibration of daughter GTLSs or LEDs.

$\Longrightarrow$ Extended screen brightness vs. charge density calibration towards high fluence, saturation and damage effects.







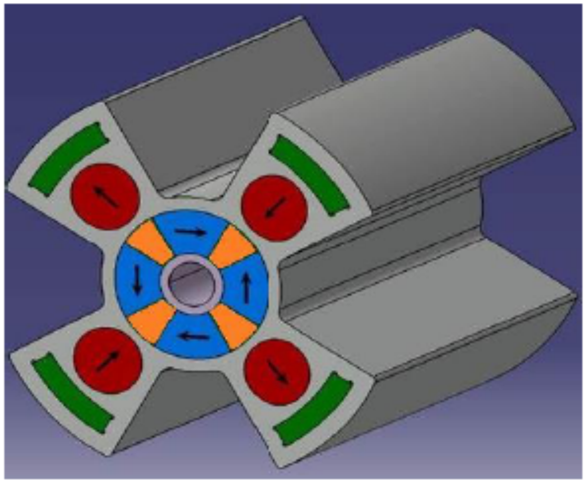
DESY

HZDR HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

In collaboration with:
U. Schramm, T. Kurz et al. (HZDR)
J.Osterhoff, R. d'Arcy et al. (DESY)

Tunable High Gradient Quadrupoles , A. Ghaith

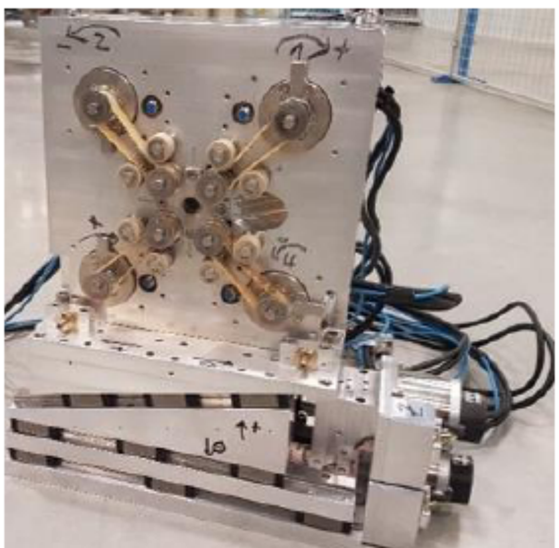
Concept was patented (QUAPEVA program-Triangle de la Physique, SOLEIL/Sigmaphi collaboration)

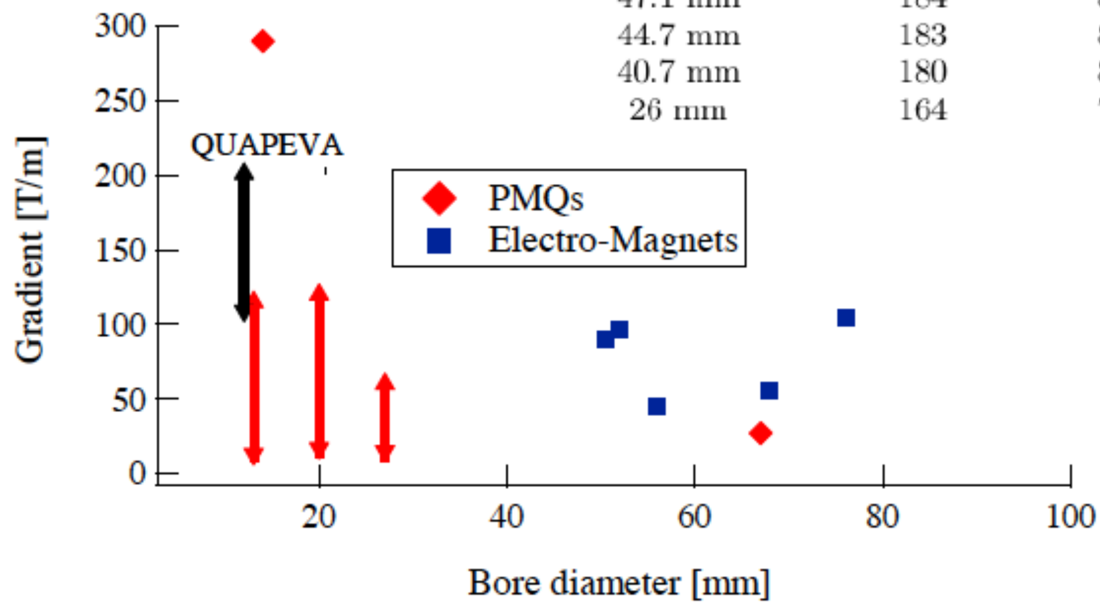


7 systems :

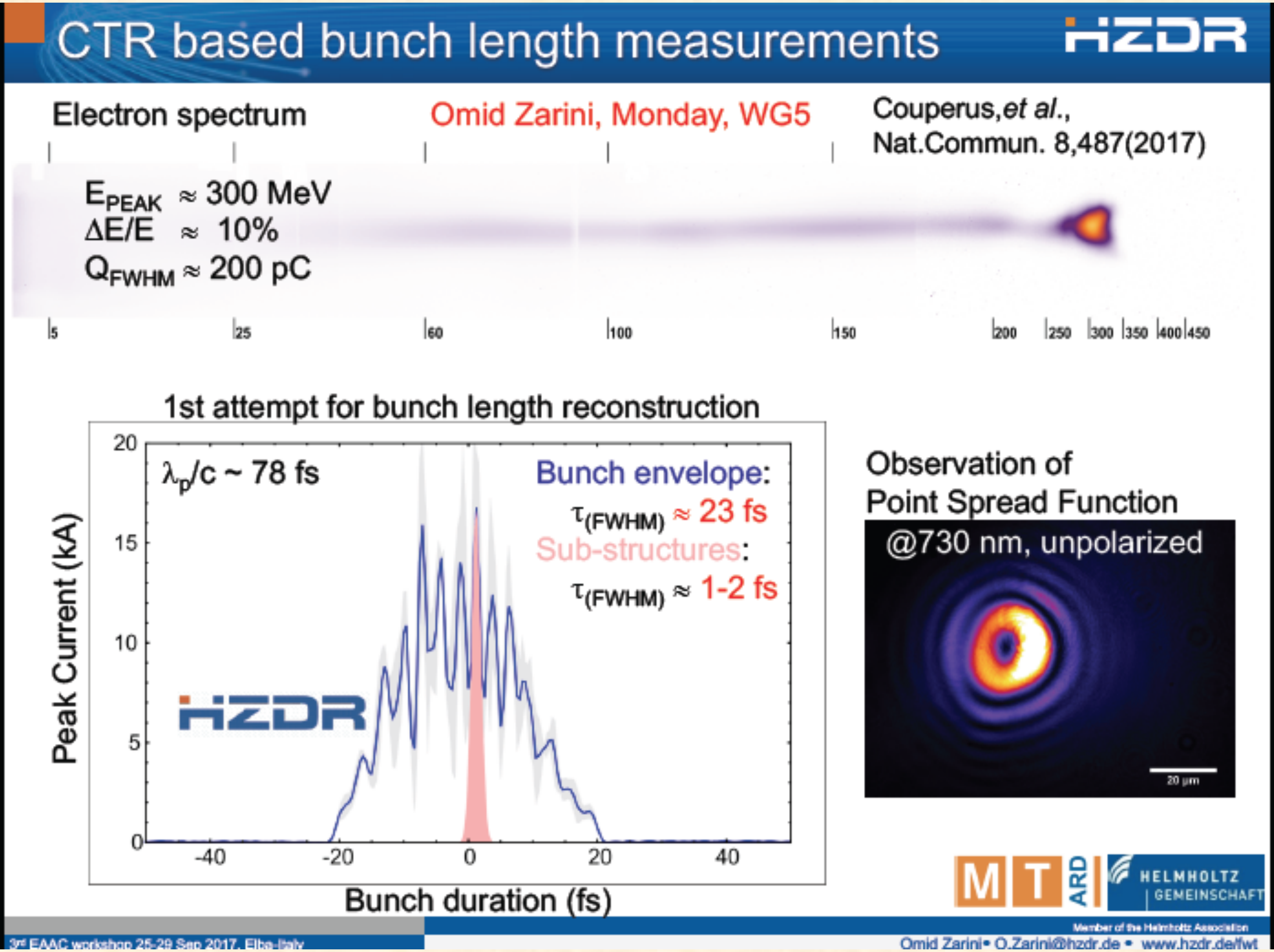
- First triplet to focus a 180 MeV beam
- Second triplet to focus a 400 MeV beam
- A prototype

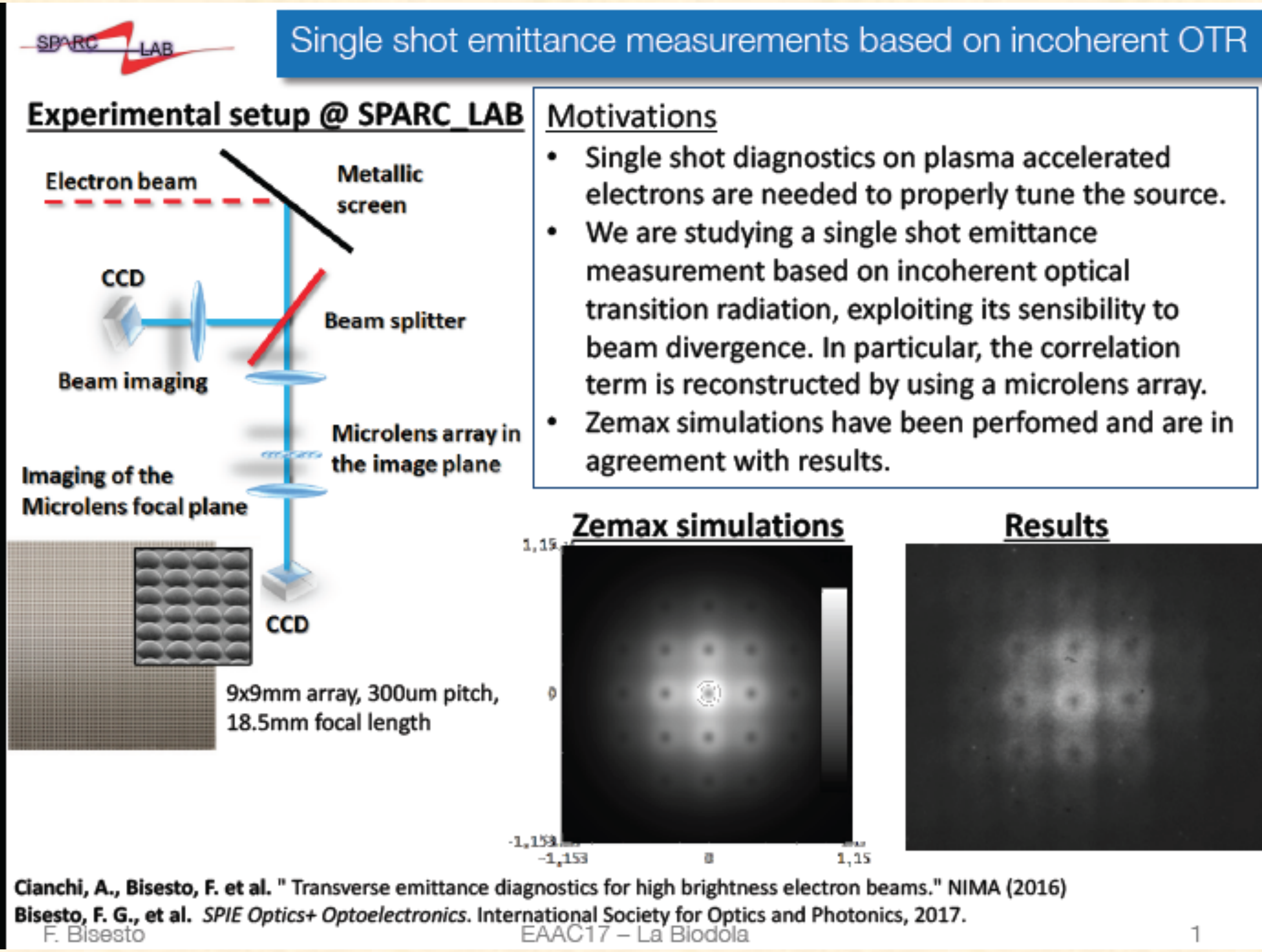
Magnetic length	G_{max} [T/m]	ΔG [T/m]
100 mm	201	92
81.1 mm	195	89
61 mm	190	88
47.1 mm	184	86
44.7 mm	183	86
40.7 mm	180	85
26 mm	164	78





Magnetic center excursion in both planes (x, z) is about ± 10 µm


CTR based bunch length measurements
Electron spectrum
Omid Zarini, Monday, WG5
Couperus, et al., Nat.Commun. 8,487(2017)
E_PEAK ≈ 300 MeV
ΔE/E ≈ 10%
Q_FWHM ≈ 200 pC
5 25 60 100 150 200 250 300 350 400 450
1st attempt for bunch length reconstruction
λp/c ~ 78 fs
Bunch envelope:
τ(FWHM) ≈ 23 fs
Sub-structures:
τ(FWHM) ≈ 1-2 fs
Peak Current (kA)
Bunch duration (fs)
Observation of Point Spread Function
@730 nm, unpolarized
20 µm
HELMHOLTZ GEMEINSCHAFT
Member of the Helmholtz Association
3rd EAAC workshop 25-29 Sep 2017, Elba-Italy
Omid Zarini• O.Zarini@hzdr.de • www.hzdr.de/fwt

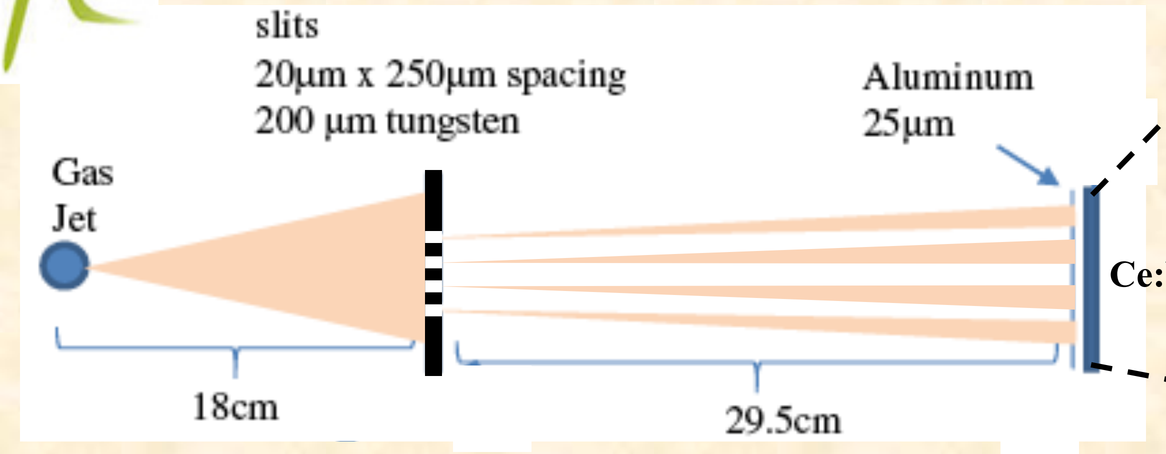


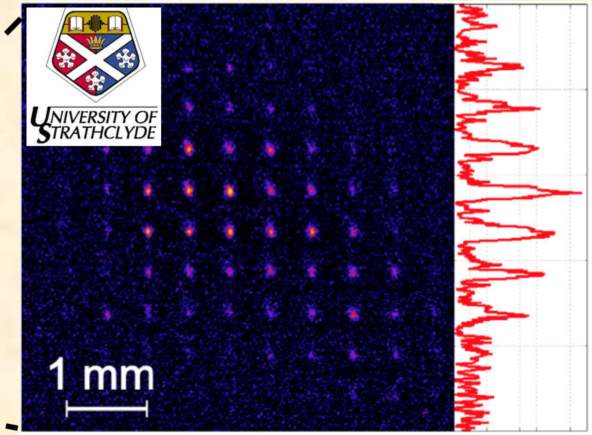
SPARC LAB
Single shot emittance measurements based on incoherent OTR
Experimental setup @ SPARC_LAB
Electron beam
Metallic screen
CCD
Beam splitter
Beam imaging
Microlens array in the image plane
Imaging of the Microlens focal plane
CCD
9x9mm array, 300um pitch, 18.5mm focal length
Motivations
• Single shot diagnostics on plasma accelerated electrons are needed to properly tune the source.
• We are studying a single shot emittance measurement based on incoherent optical transition radiation, exploiting its sensibility to beam divergence. In particular, the correlation term is reconstructed by using a microlens array.
• Zemax simulations have been perfomed and are in agreement with results.
Zemax simulations
Results
Cianchi, A., Bisesto, F. et al. " Transverse emittance diagnostics for high brightness electron beams." NIMA (2016)
Bisesto, F. G., et al. SPIE Optics+ Optoelectronics. International Society for Optics and Photonics, 2017.
F. Bisesto
EAAC17 – La Biodola
1

Conventional measurements of normalized transverse emittance ε_N of PA* electrons used the "pepper-pot" method

Fritzler, *PRL* **92**, 165006 (2004); Sears, *PR ST-AB* **13**, 092803 (2010); Brunetti, *PRL* **105**, 215007 (2010)

**plasma-accelerated*





Results showed 1 < ε_N < 3π mm-mrad, comparable with e-beams from conventional electron accelerators.

PROs

- single shot
- compact

CONs

- Invasive
- More difficult at higher energies – demonstrated up to 3GeV *.
  (LPA measurements only up 125 MeV)
- resolution limit $\varepsilon_N \sim 1\pi$ mm-mrad
- Small source size, large energy spread, large divergence make sufficient sampling of phase space difficult*.

* Thomas C., et. al., Nuclear Instruments and Methods in Physics Research A 729, 554–556 (2013)

* Cianchi, A., et. al., Nucl. Instrum. Meth. Phys. Res. A 720, 153 (2013).

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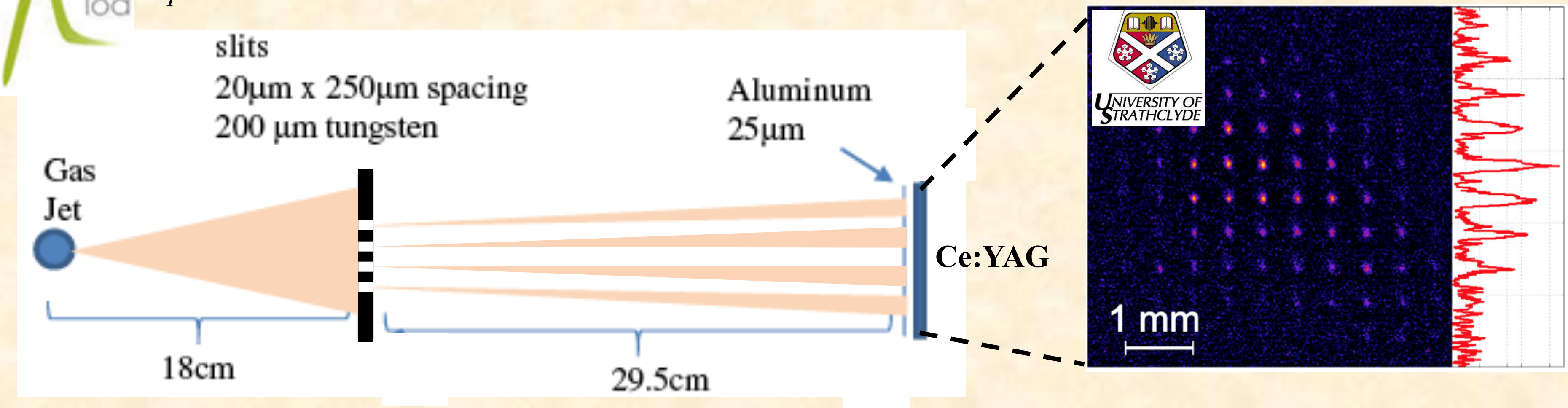

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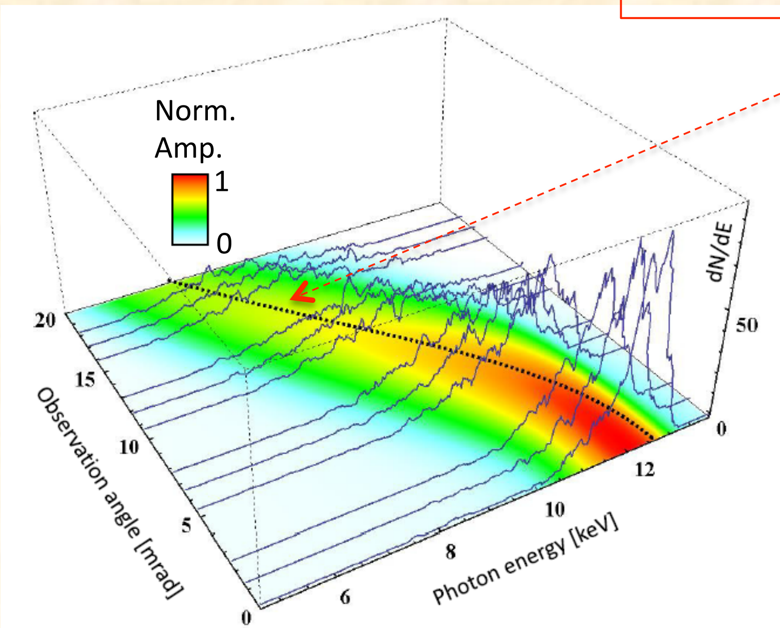
* Cianchi, A., et. al., Nucl. Instrum. Meth. Phys. Res. A 720, 153 (2013).

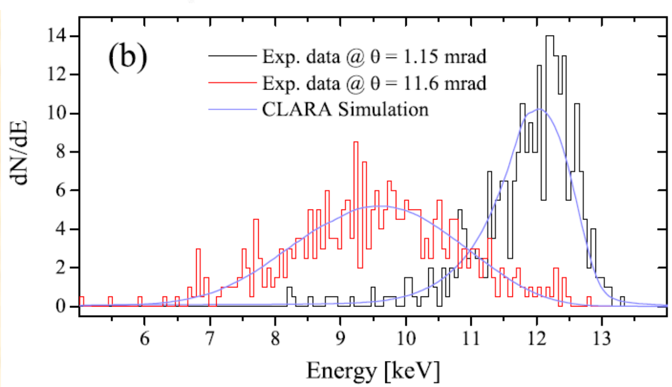
Normalized transverse emittance at exit of accelerator based on angularly resolved Thomson back scattered radiation spectrum

Leemans, W. *et al.* , **PRL 77,** 4182–4185 (1996).

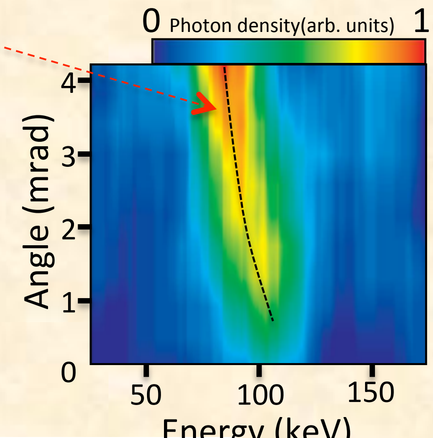
Chouffani, K., **PRSTAB 9,** 050701 (2006).

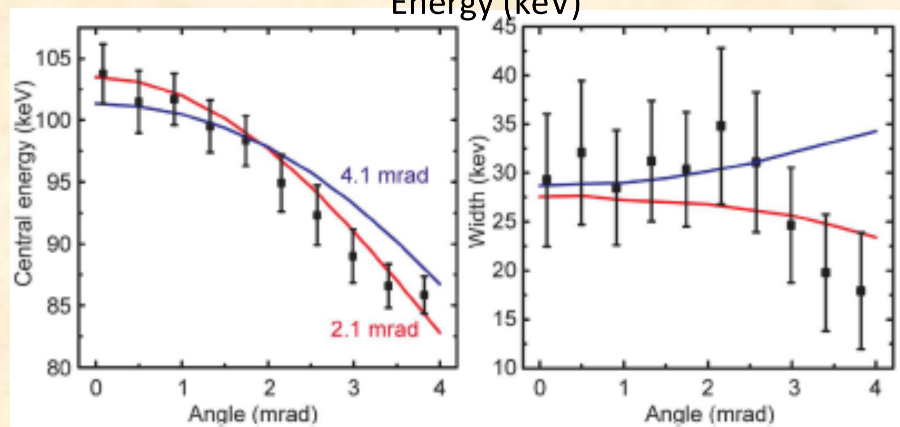
$$\omega_{sc} = \frac{2\gamma^2(1-\cos\varphi)}{1+(a_0^2/2)+\gamma^2\theta^2}\, n\,\omega_0$$





Jochmann, A., et.al., **PRL** 111 (11), 114803 (2013).



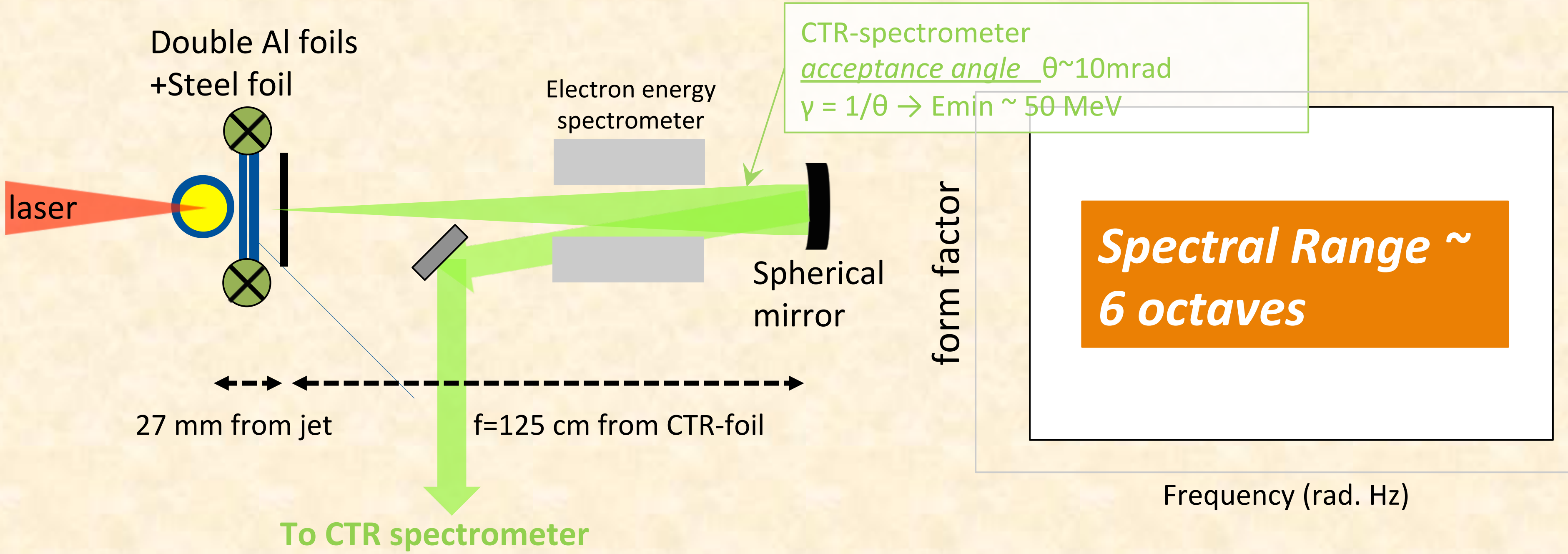


ε_n = 0.15 (±0.06) π mm mrad

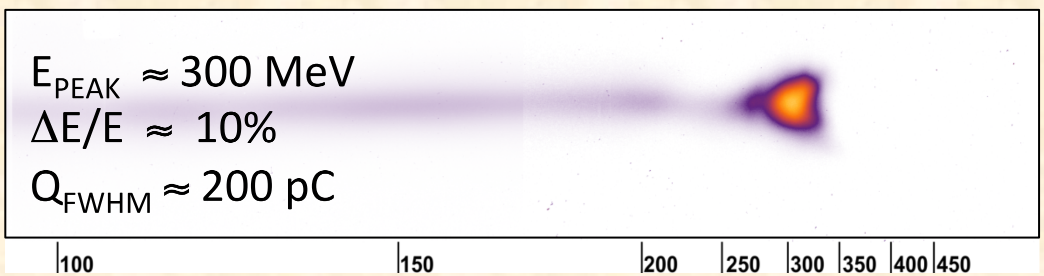
Golovin, G., et.al., **Sci. Rpts**. 6 (1), 24622 (2016).

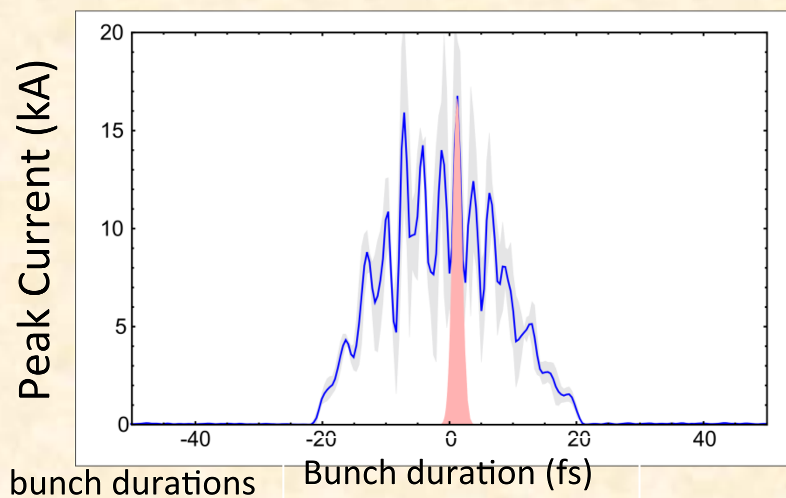
Transition radiation spectroscopy – reconstruction of bunch temporal profile

1st attempt of bunch length reconstruction



- Bunch envelope: $\tau_{(FWHM)} \approx$ 23 fs
- Sub-structures: $\tau_{(FWHM)} \approx$ 1-2 fs



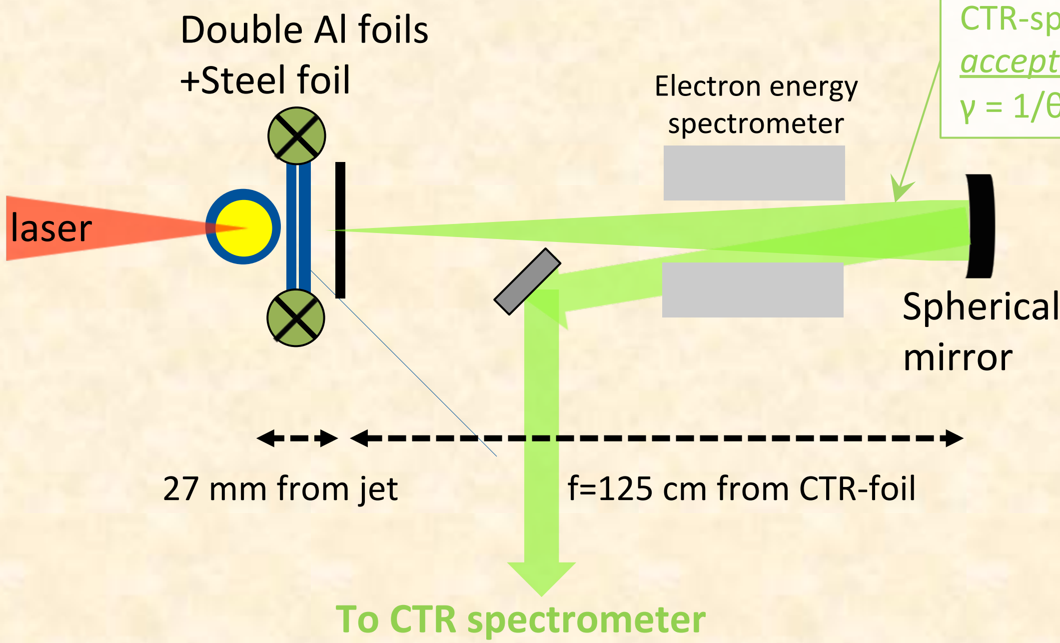


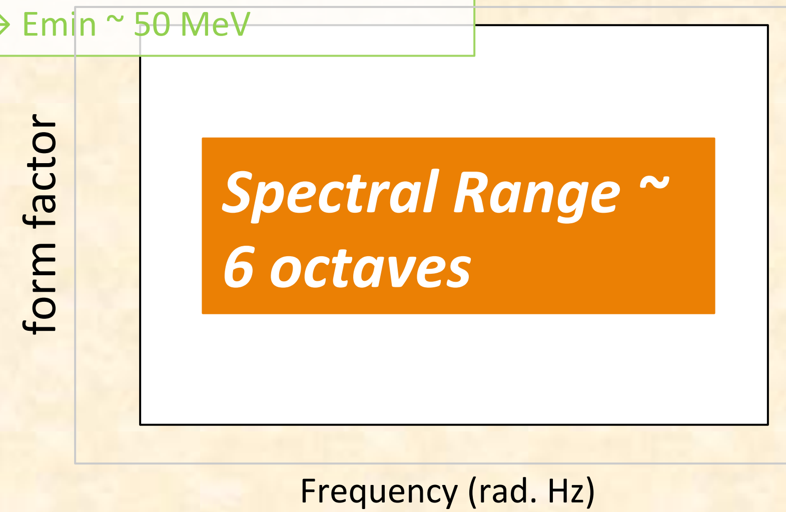
Omid Zarini: WG5 Monday 16:00;" Measuring of ultra-short electron bunch durations from LWFA by using of a broadband, single-shot spectrometer for Coherent Transition Radiation"

Transition radiation spectroscopy – reconstruction of bunch temporal profile

1st attempt of bunch length reconstruction

CTR-spectrometer
acceptance angle θ~10mrad
γ = 1/θ → Emin ~ 50 MeV





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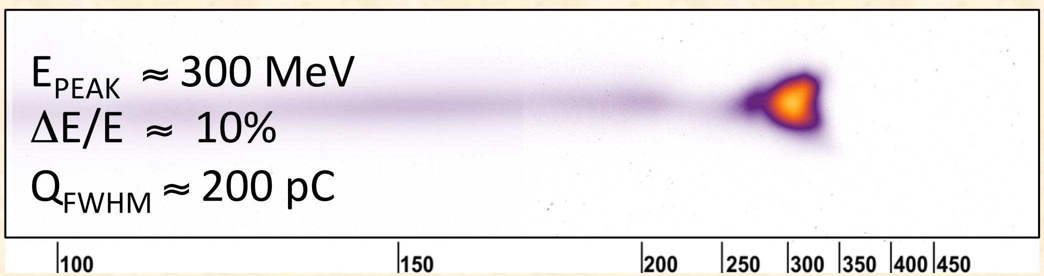
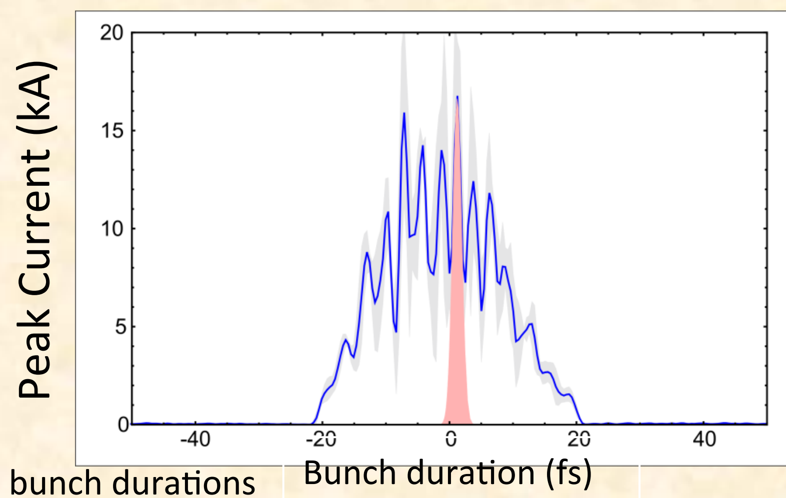
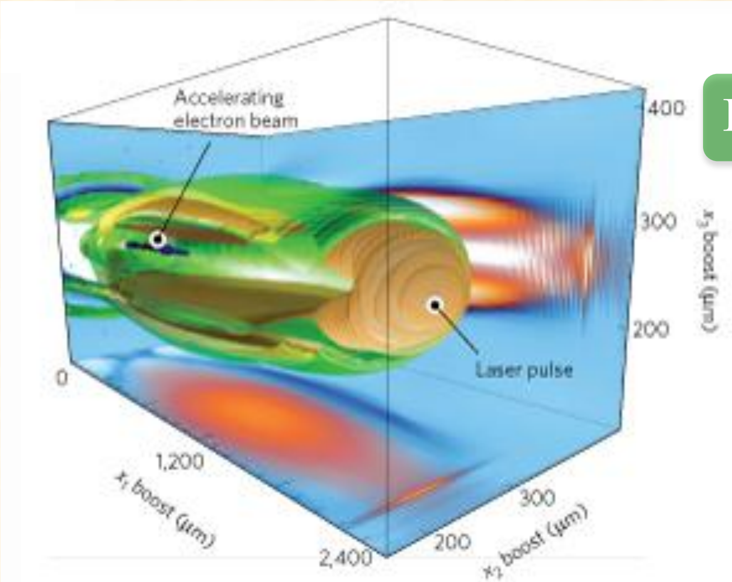




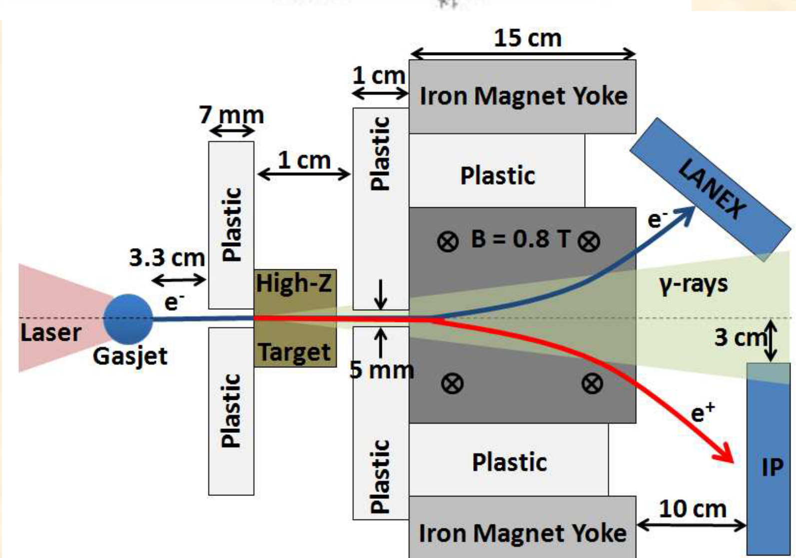
Omid Zarini: WG5 Monday 16:00;" Measuring of ultra-short electron bunch durations from LWFA by using of a broadband, single-shot spectrometer for Coherent Transition Radiation"

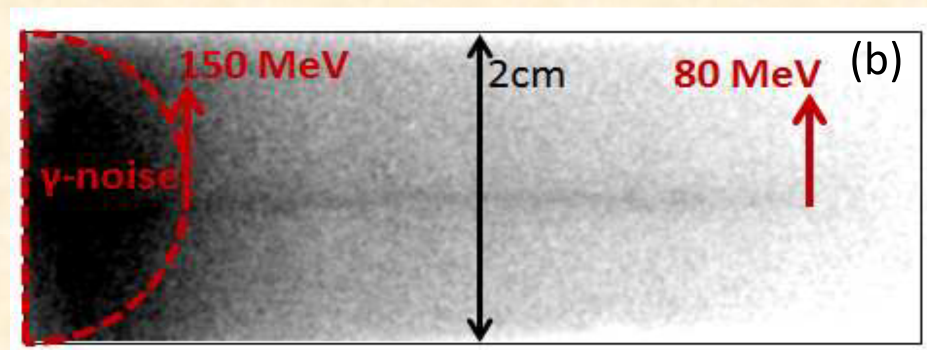
Wakefield based positron generator



Laser-wakefield electrons to trigger the cascade in a solid

- ✓ Divergence: 1-5 mrad (from solid: ~ 20 degrees)
- ✓ Duration: ~ 10 fs (from solid: 1 – 10 ps)
- ✓ Energy: 100s of MeV (from solid: 10s of MeV)
- ✓ Laser energy: ~1-10J (from solid: ~kJ)
- ✓ Possibility of generating neutral e^-/e^+ beams in situ!





G. Sarri *et al.*, Phys. Rev. Lett. 110, 255002 (2013)

New Solutions

External injection into a laser-driven plasma accelerator with sub-femtosecond timing jitter

A Ferran Pousa[1,2], R Assmann[1], R Brinkmann[1] and A Martinez de la Ossa[1,2]

[1] DESY, 22607 Hamburg, Germany
[2] Universität Hamburg, 22761 Hamburg, Germany

E-mail: angel.ferran.pousa@desy.de

External injection: timing

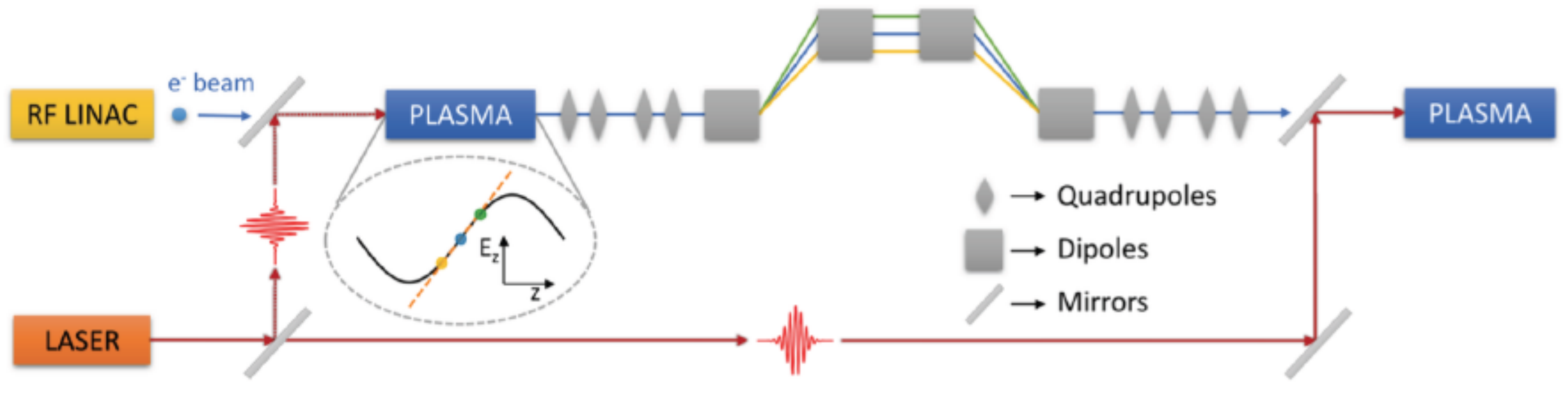


Figure 1. Schematic view of the synchronizing stage.

ESCULAP au LAL

- 3 papiers soumis et acceptés.
- Après la phase d'évaluation les 3 papiers ont été acceptés par NIM A (et 2 sont déjà publiés).

Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment

Available online 6 February 2018

In Press, Corrected Proof

Modeling of laser-plasma acceleration of relativistic electrons in the frame of ESCULAP project

E. Baynard [b], C. Bruni [a], K. Cassou [a], V. Chaumat [a], N. Delerue [a], J. Demailly [c], D. Douillet [a], N. El Kamchi [a], D. Garzella [d], O. Guilbaud [b], S. Jenzer [a], S. Kazamias [c], V. Kubytskyi [a], P. Lepercq [a], B. Lucas [c], G. Maynard [c], O. Neveu [c], M. Pittman [b] … K. Wang [a]

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Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment

Available online 9 December 2017

In Press, Corrected Proof

Longitudinal compression and transverse matching of electron bunch for external injection LPWA at ESCULAP

K. Wang [a, f], E. Baynard [b], C. Bruni [a], K. Cassou [a], V. Chaumat [a], N. Delerue [a], J. Demailly [c], D. Douillet [a], N. El.Kamchi [a], D. Garzella [e], O. Guilbaud [c], S. Jenzer [a], S. Kazamias [c], V. Kubytskyi [a], P. Lepercq [a], B. Lucas [c], G. Maynard [c], O. Neveu [c] … D. Ros [c]

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https://doi.org/10.1016/j.nima.2017.12.014

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arXiv.org > physics > arXiv:1802.09613

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Physics > Accelerator Physics

Status report of the ESCULAP project at Orsay: External injection of low energy electrons in a Plasma

Elsa Baynard, Christelle Bruni, Kevin Cassou, Vincent Chaumat, Nicolas Delerue, Julien Demailly, Denis Douillet, Noureddine El Kamchi, David Garzella, Olivier Guilbaud, Stephane Jenzer, Sophie Kazamias, Viacheslav Kubytskyi, Pierre Lepercq, Bruno Lucas, Gilles Maynard, Olivier Neveu, Moana Pittman, Rui Prazeres, Harsh Purwar, David Ros, Cynthia Vallerand, Ke Wang

(Submitted on 26 Feb 2018 (v1), last revised 5 Mar 2018 (this version, v2))

The ESCULAP project aims at studying external injection of low energy (\SI{10}{MeV}) electrons in a plasma in the quasilinear regime. This facility will use the photo injector PHIL and the high power laser LASERIX. We will give a status report of the preliminary work on the facility and the status of the two machines. We will also present the results of simulations showing the expected performances of the facility.

Comments: EAAC'17
Subjects: Accelerator Physics (physics.acc-ph)
Cite as: arXiv:1802.09613 [physics.acc-ph]
(or arXiv:1802.09613v2 [physics.acc-ph] for this version)

Principe d’ESCULAP

- Accélération d’électrons par injection externe.
- Basé sur PHIL+Laserix

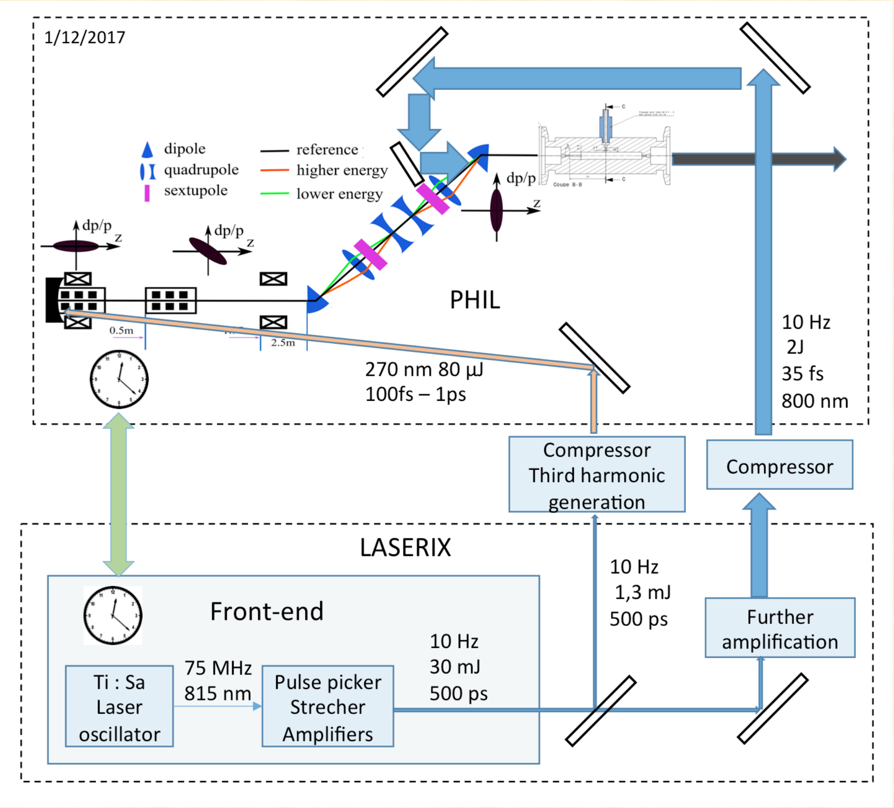
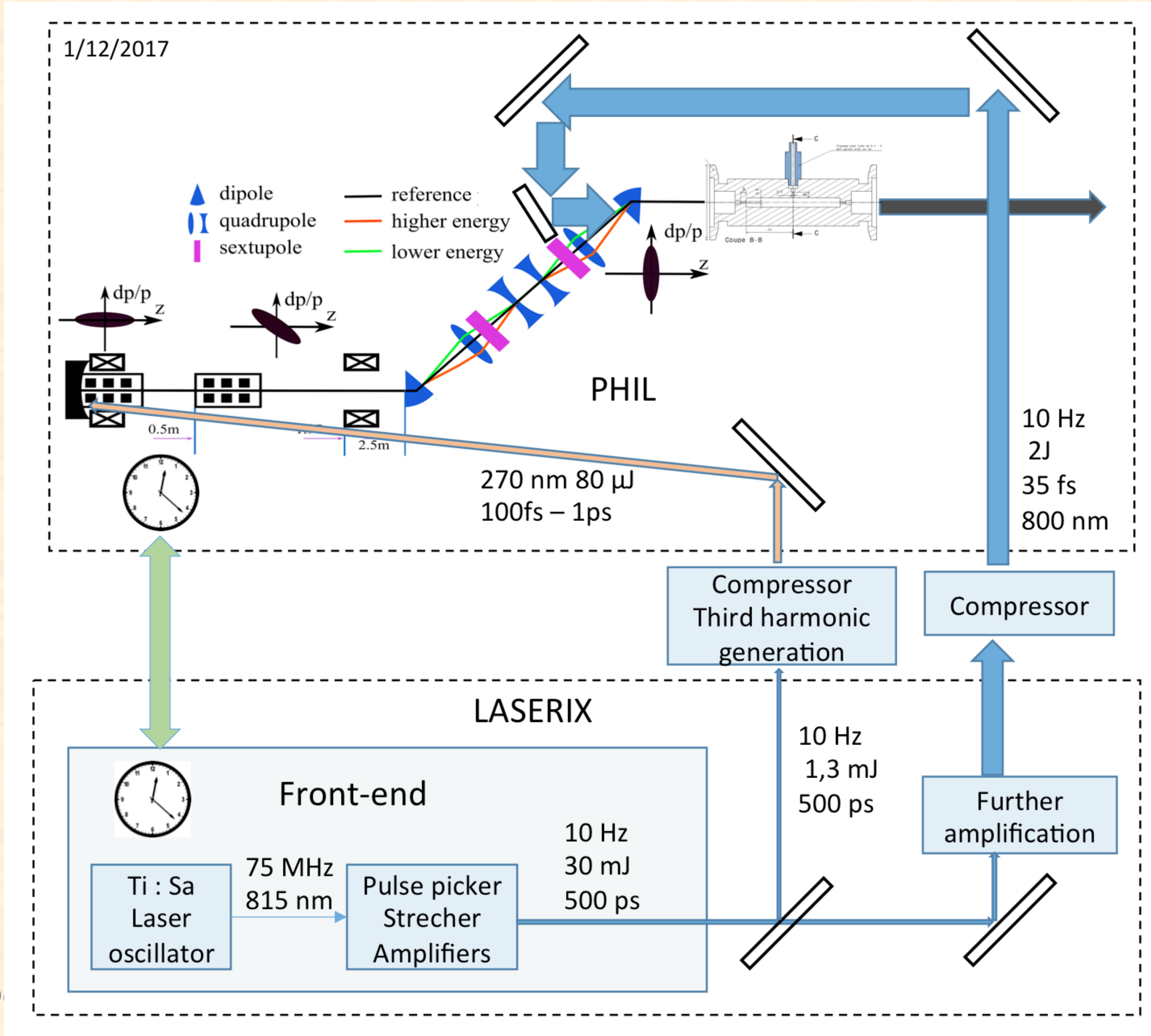
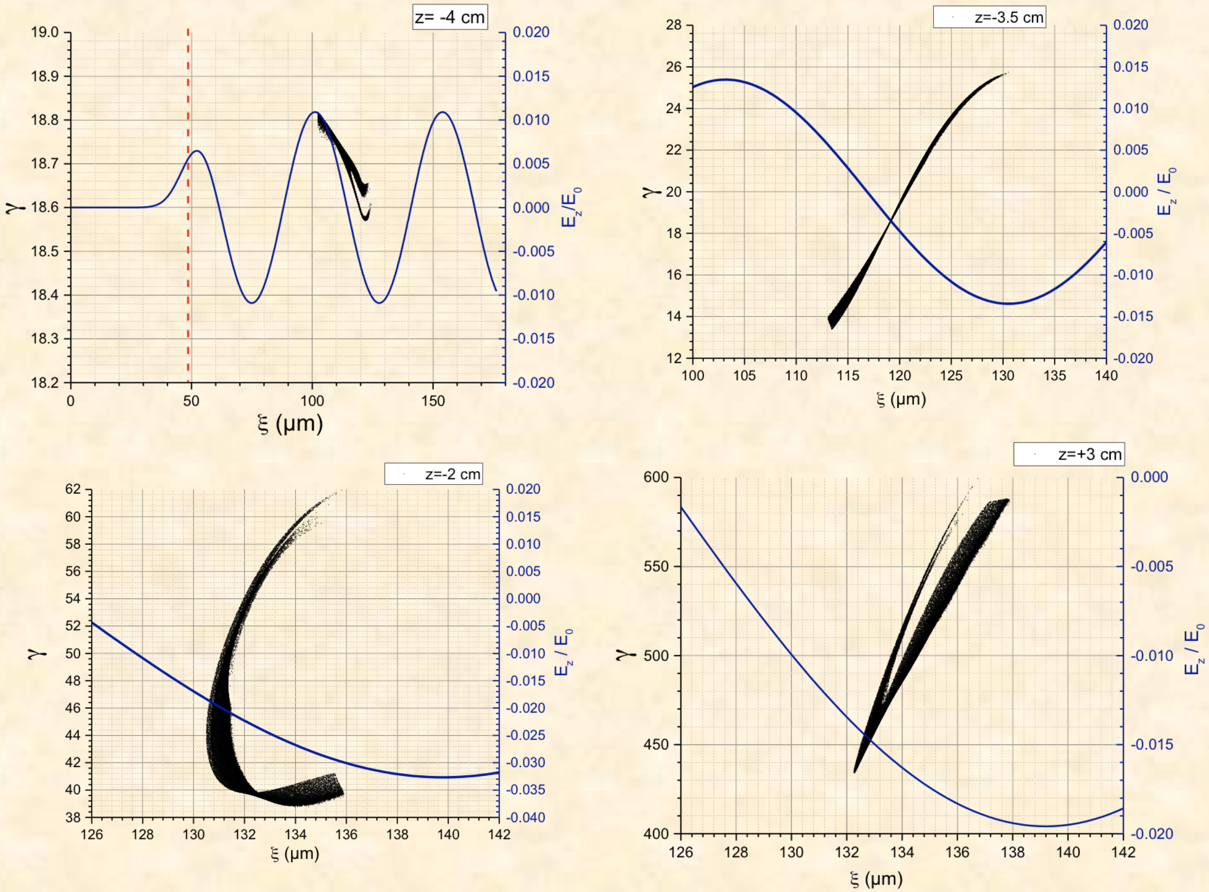


Schéma de l'expérience



Simulations



- Compression puis accelerations des électrons.
- IPAC'16: WEPMY003

Modelling of laser-plasma acceleration of relativistic electrons in the frame of ESCULAP project

E.Baynard[b], C. Bruni[a], K. Cassou[a], V. Chaumat[a], N. Delerue[a], J.Demailly[c], D.Douillet[a], N. El Kamchi[a], D. Garzella[d], O. Guilbaud[b], S. Jenzer[a], S. Kazamias[c], V. Kubytskyi[a,*], P. Lepercq[a], B. Lucas[c], G. Maynard[c], O. Neveu[c], M. Pittman[b], R. Prazeres[e], H. Purwar[a], D. Ros[b], K. Wang[a]

[a]*Laboratoire de l'Accélérateur Linéaire (LAL), Univ. Paris-Sud, CNRS/IN2P3, Université Paris-Saclay, Orsay, France*
[b]*Centre Laser de l'Université Paris-Sud (CLUPS), Univ. Paris-Sud, Université Paris-Saclay, Orsay, France*
[c]*Laboratoire de Physique des Gaz et des Plasmas (LPGP), CNRS, Univ. Paris-Sud, Université Paris-Saclay, Orsay, France*
[d]*Laboratoire Interactions, Dynamiques et Lasers (LIDYL), CEA/DRF, Université Paris-Saclay, Saclay, France*
[e]*Centre Laser Infrarouge d'Orsay, Laboratoire de Chimie Physique (CLIO/LCP), Univ. Paris-Sud, CNRS, Université Paris-Saclay, Orsay, France*

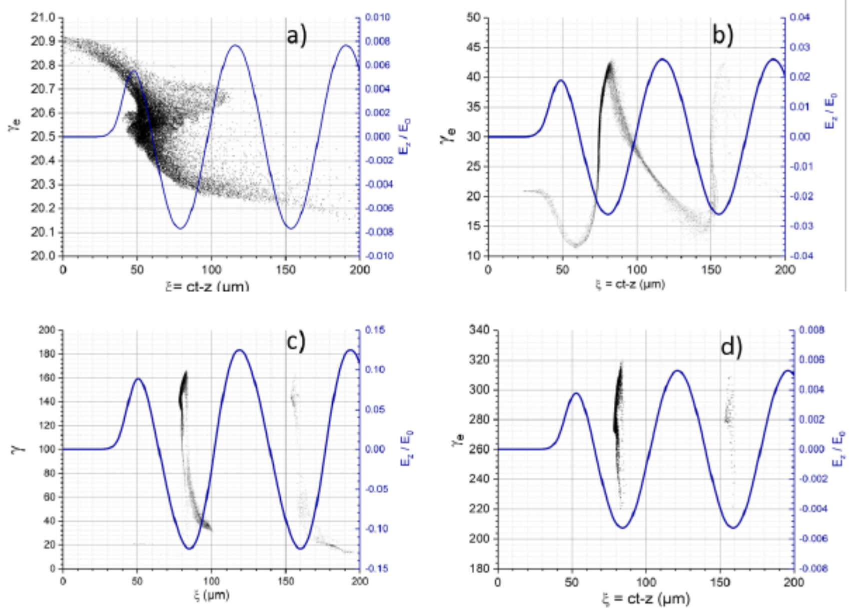
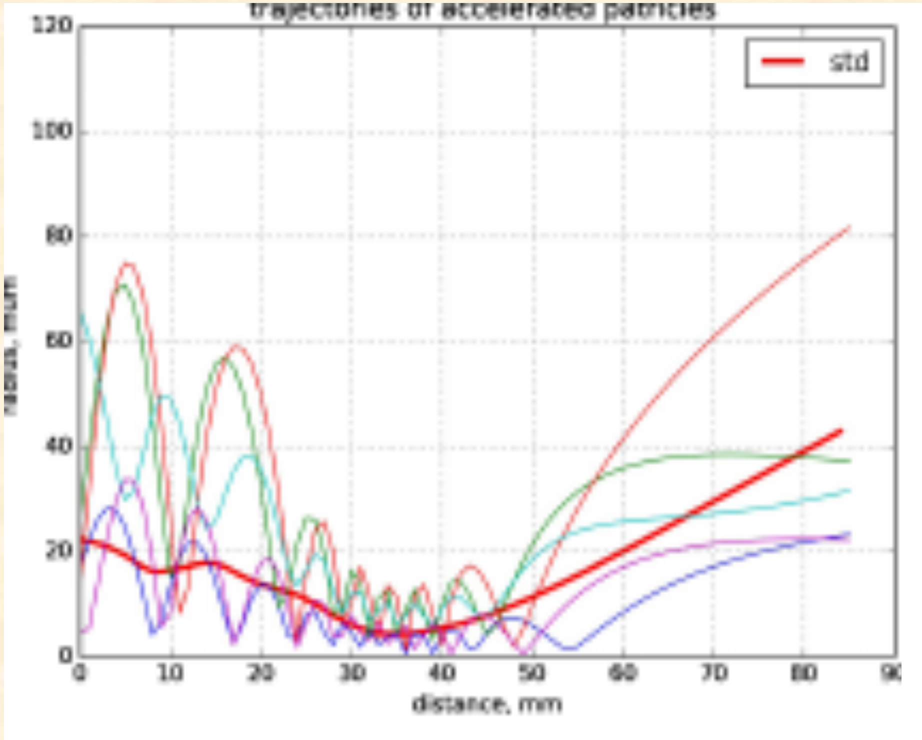
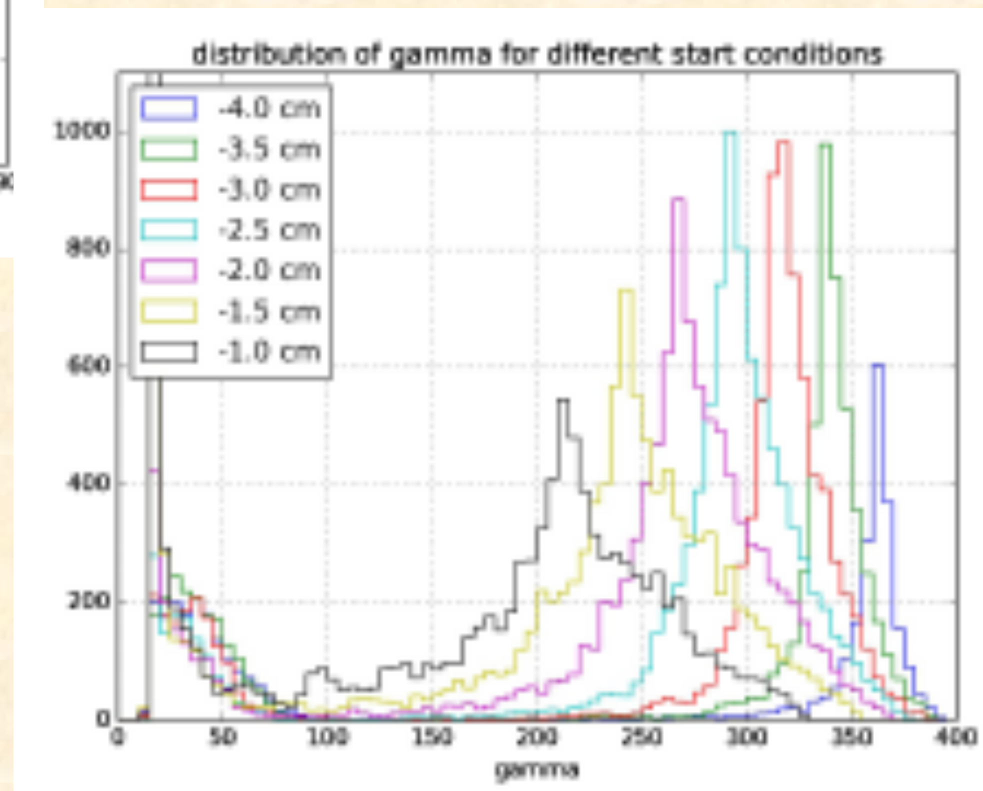


FIGURE 3: Lorentz factor of the electron versus their longitudinal positions (black points and left axis) and longitudinal electric field in reduced units (blue curve, right axis) at four different distances of propagation. entrance of the plasma (a) ; after 2 cm (b) ; at the focal plane (c) and at the exit of the plasma (d). The focal plane is situated at 4 cm from the entrance of the plasma and the total cell length is 9 cm.

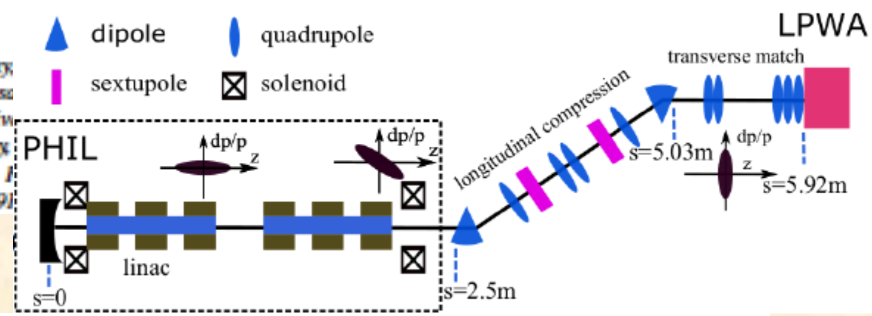

std
distance, mm
0
10
20
30
40
50
60
70
80
20
40
60
80
100
120

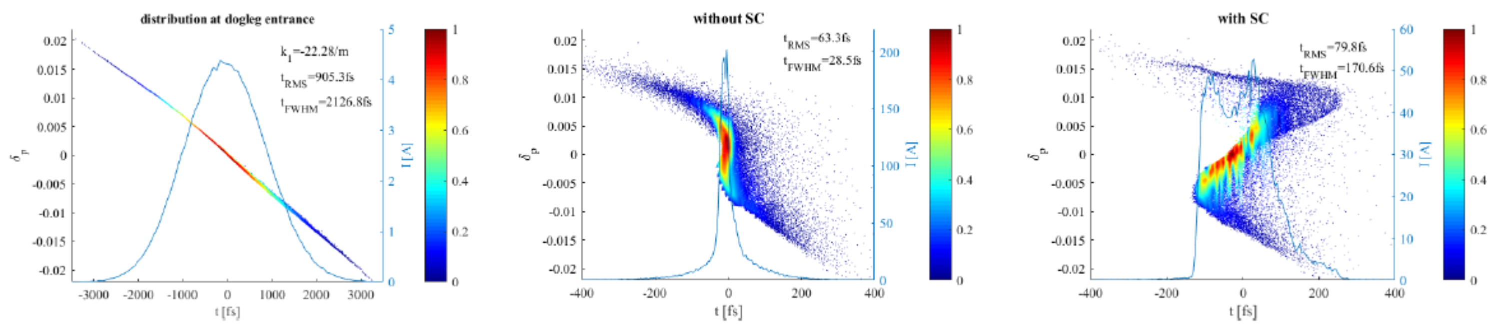

distribution of gamma for different start conditions
-4.0 cm
-3.5 cm
-3.0 cm
-2.5 cm
-2.0 cm
-1.5 cm
-1.0 cm
gamma
0
50
100
150
200
250
300
350
400
200
400
600
800
1000

Longitudinal compression and transverse matching of electron bunch for external injection LPWA at ESCULAP

K.Wang[a,f,*], E.Baynard[b], C.Bruni[a], K.Cassou[a], V.Chaumat[a], N.Delerue[a], J.Demailly[c], D.Douillet[a], N.El.Kamchi[a], D.Garzella[e], O.Guilbaud[c], S.Jenzer[a], S.Kazamias[c], V.Kubytskyi[a], P.Lepercq[a], B.Lucas[c], G.Maynard[c], O.Neveu[c], M.Pittman[b], R.Prazeres[d], H.Purwar[a], D.Ros[c]

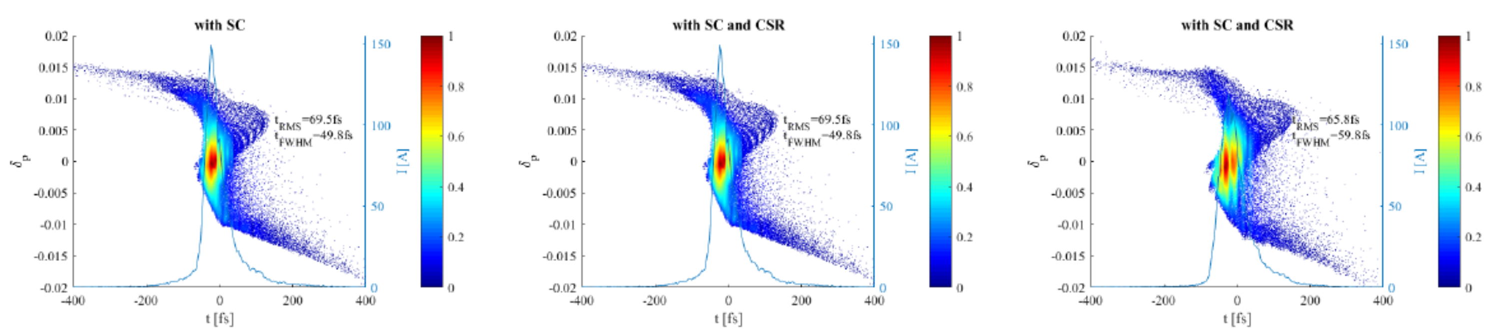
[a]LAL, Univ. Paris-Sud, CNRS/IN2P3, Université Paris-Saclay
[b]CLUPS, Univ. Paris-Sud, Université Paris-Saclay, Ors
[c]Laboratoire de Physique des Gaz et des Plasmas, Univ. Paris-Sud, CNRS, Univ
[d]CLIO/LCP, Univ. Paris-Sud, CNRS, Université Paris-Saclay
[e]CEA/DRF/LIDYL, Université Paris-Saclay, Saclay, F
[f]Institute of Fluid Physics, China Academy of Engineering Physics, P.O. Box 91





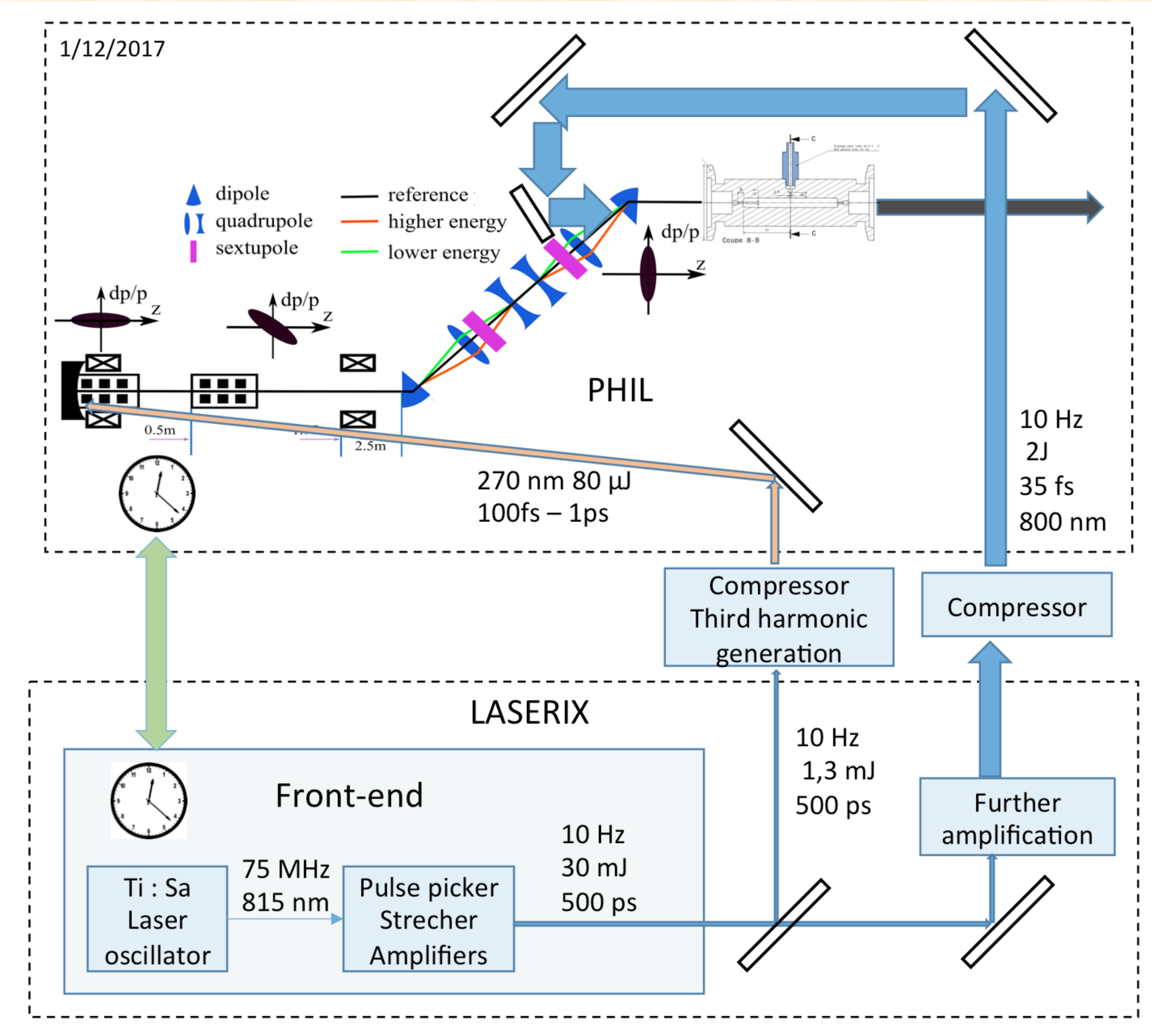
(a) *Electron bunch at the dogleg entrance* (b) *Electron bunch at the dogleg exit* (c) *Electron bunch at the dogleg exit*

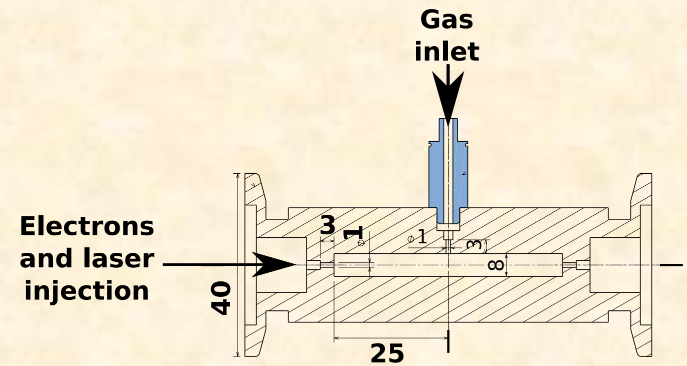
Figure 4: *Longitudinal distribution of electron bunch, a) at the dogleg entrance (s=2.5m), and at the dogleg exit (s=5.08m) tracked with ImpactT, b)without self-force, c)with space charge*



(a) *Tracked with ImpactT* (b) *Tracked with ImpactT* (c) *Tracked with CSRtrack*

ESCULAP: perspective





Applications

Contexte Européen

A European Strategy for Accelerator Innovation

PRESENT EXPERIMENTS

Demonstrating **100 GV/m** routinely

Demonstrating **GeV** electron beams

Demonstrating basic **quality**

EuPRAXIA INFRASTRUCTURE

Engineering a high quality, compact plasma accelerator

5 GeV electron beam for the 2020's

Demonstrating user readiness

Pilot users from FEL, HEP, medicine, ...

PRODUCTION FACILITIES

Plasma-based **linear collider** in 2040's

Plasma-based **FEL** in 2030's

Medical, industrial applications soon

HELMHOLTZ GEMEINSCHAFT

ATHENA

Project

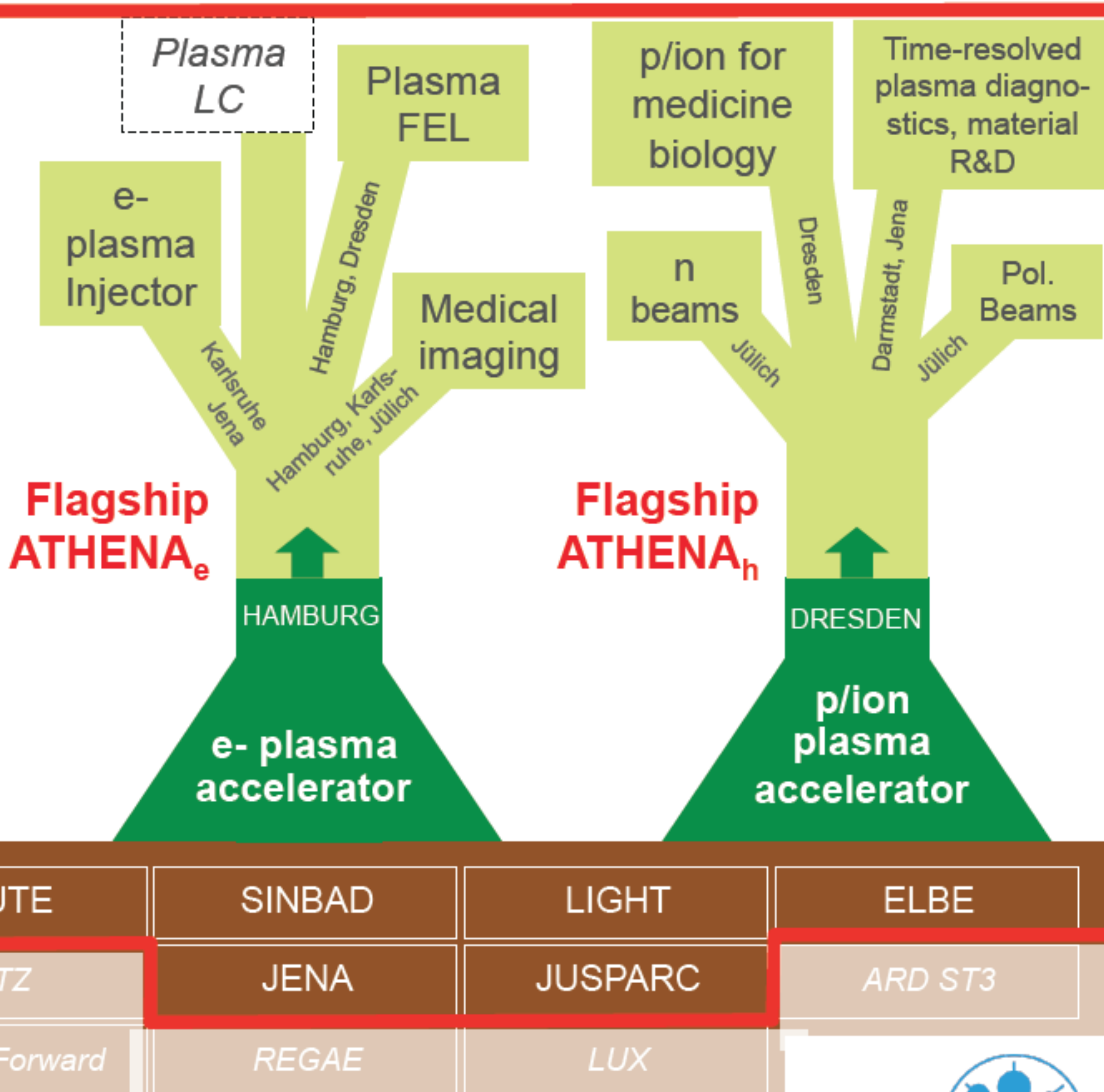
2018 – 2021, 30 M€

6 centers + 1 institute

Using infrastructures together

2 future technologies for the Helmholtz strategy

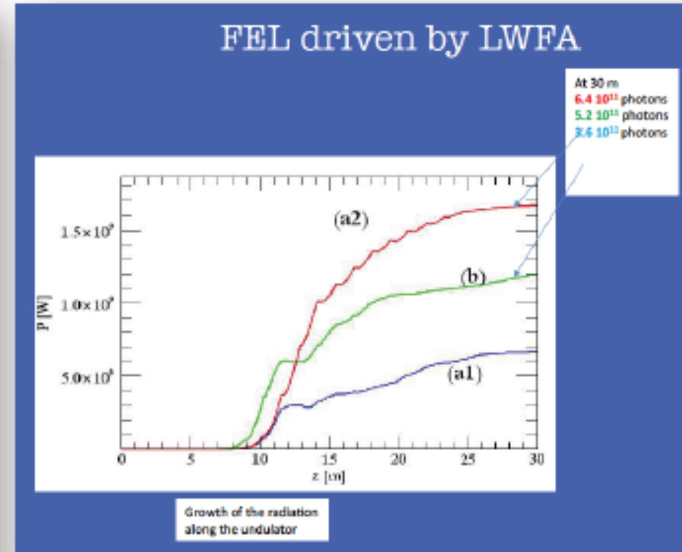
High relevance for applications in many centers.

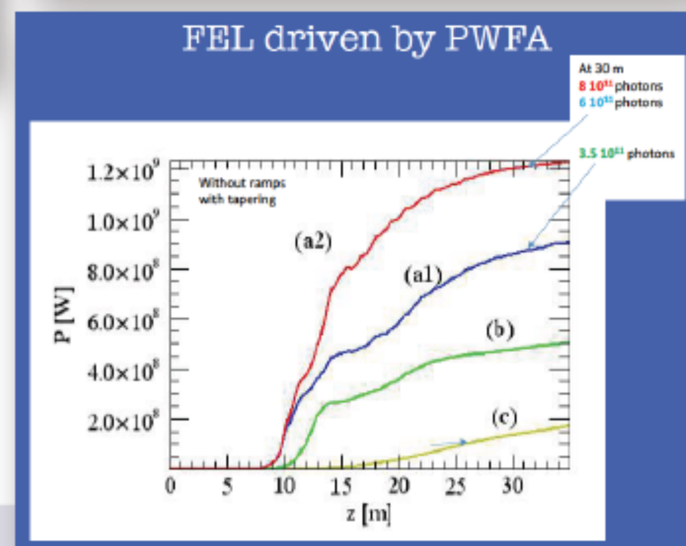


JÜLICH FORSCHUNGSZENTRUM · GSI · KIT Karlsruhe Institute of Technology · HZB Helmholtz Zentrum Berlin · HZDR · HI Jena Helmholtz Institute Jena · DESY

Political Landscape: INFN Frascati in Italy

Horizon2020





First start-to-end simulations plasma FEL

INFN strongly advancing scientific and political efforts towards an RF/plasma facility at Frascati that can host EuPRAXIA

Project timeline

09.2014	Proposal submission
07.2015	Approval
11.2015	**Start of EuPRAXIA project**
2016	Organization (collaboration agreements, …). Hiring dedicated personnel. Ten workshops on EuPRAXIA/EuroNNAc matters. Decision parameters for first study versions.
08.2019	Application to **ESFRI roadmap** for 2020 update
10.2019	Final **conceptual design report** and end design study
2020	*Construction decision*
2021 – 2025	*Construction*
2025 – 2035	*Operation*

ESFRI = European Strategy for Future Research Infrastructures