DACTOMUS: R&D for laser-driven multistage plasma acceleration

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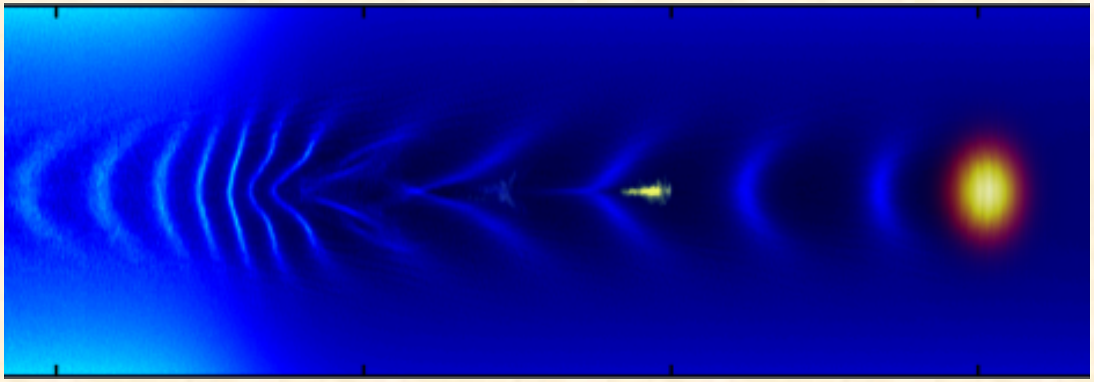
on behalf of the DACTOMUS collaboration

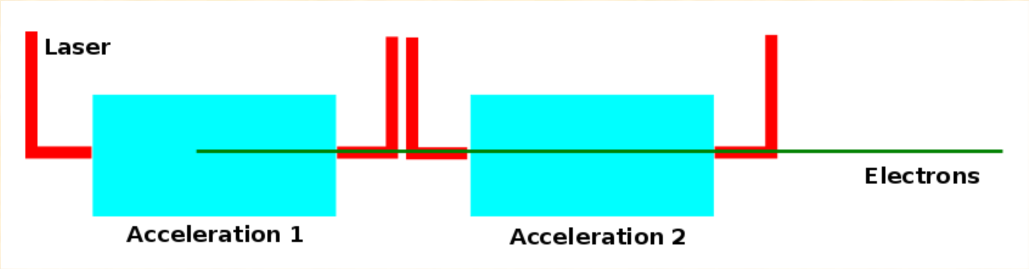
Laser-driven plasma acceleration



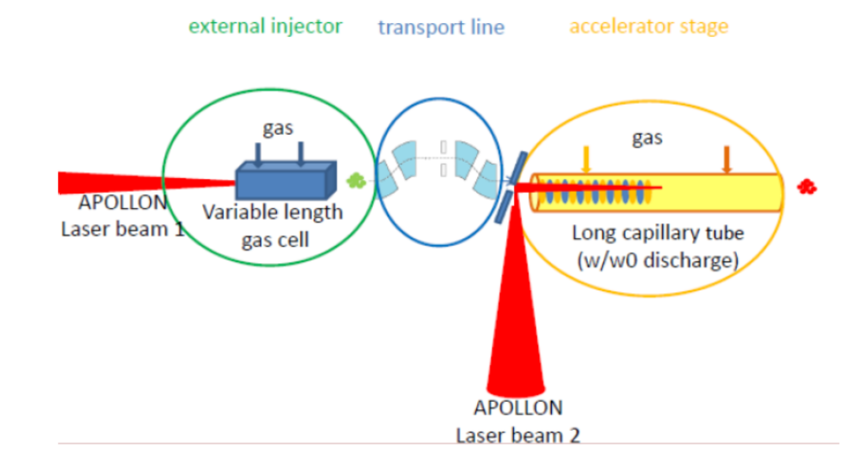
Source: https://www2.physics.ox.ac.uk/research/plasma-accelerators

- A powerful laser can be used to induce a wakefield in a plasma.
- Electrons from the plasma or injected from a source can then be accelerated.
- Laser-driven plasma acceleration has the potential of reaching gradients much higher than those of current accelerators.
  => This will be presented tomorrow morning.

Multi-stage acceleration



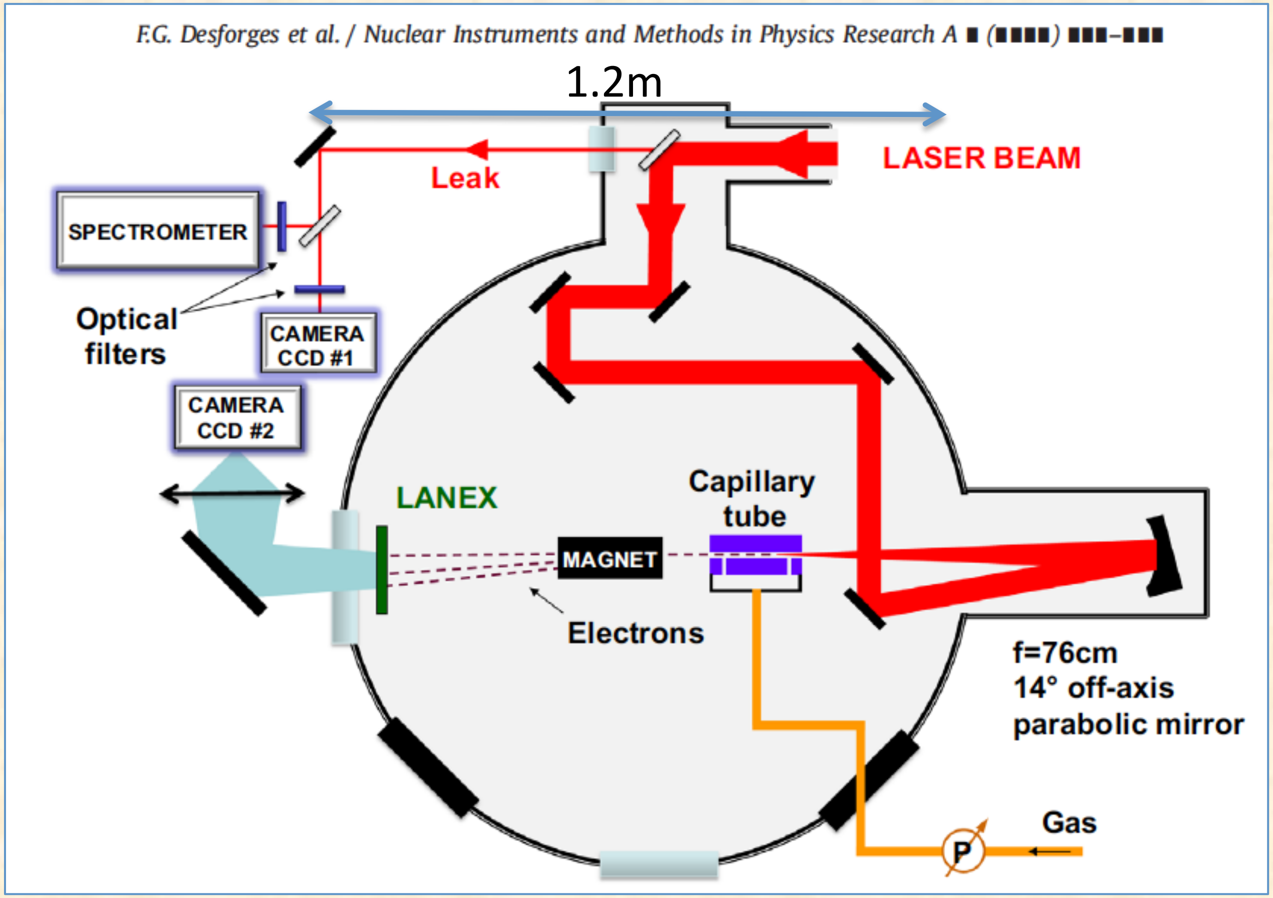
- So far this acceleration is limited to a few GeV.
- To reach the energy required by HEP several stages of acceleration are needed.
- This is theoretically possible but remains to be demonstrated experimentally.
  => DACTOMUS project



DACTOMUS

- Project involving several HEP & laser labs:
  LAL, LLR, SACM/IRFU/CEA
  LPGP, SPAM/CEA
- Aim: demonstrate that electrons can be re-injected in a second acceleration cell and further accelerated.
- Funding (for the beam instrumentation):
  grant from P2IO.

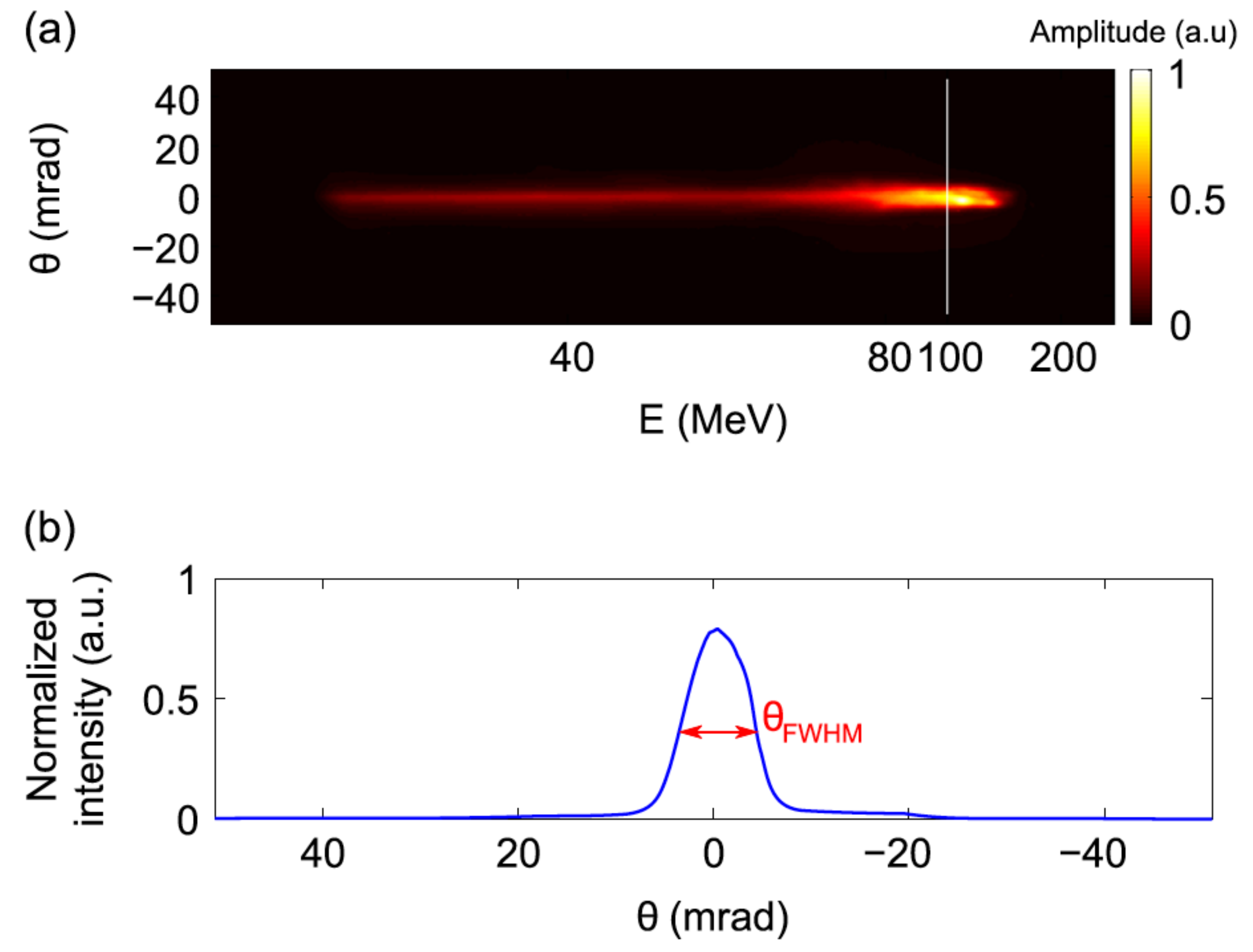
Typical "laser driven plasma accelerator"



Reproducibility of electron beams from laser wakefield acceleration in capillary tubes
F. Desforges et al *NIM A740, pp:54-59* (2014) http://dx.doi.org/10.1016/j.nima.2013.10.062

Unlike typical accelerator, there is some material in the beam line
=> GEANT4 simulations needed to understand the scattering induced by collisions with mirrors & gas.

Example of beam



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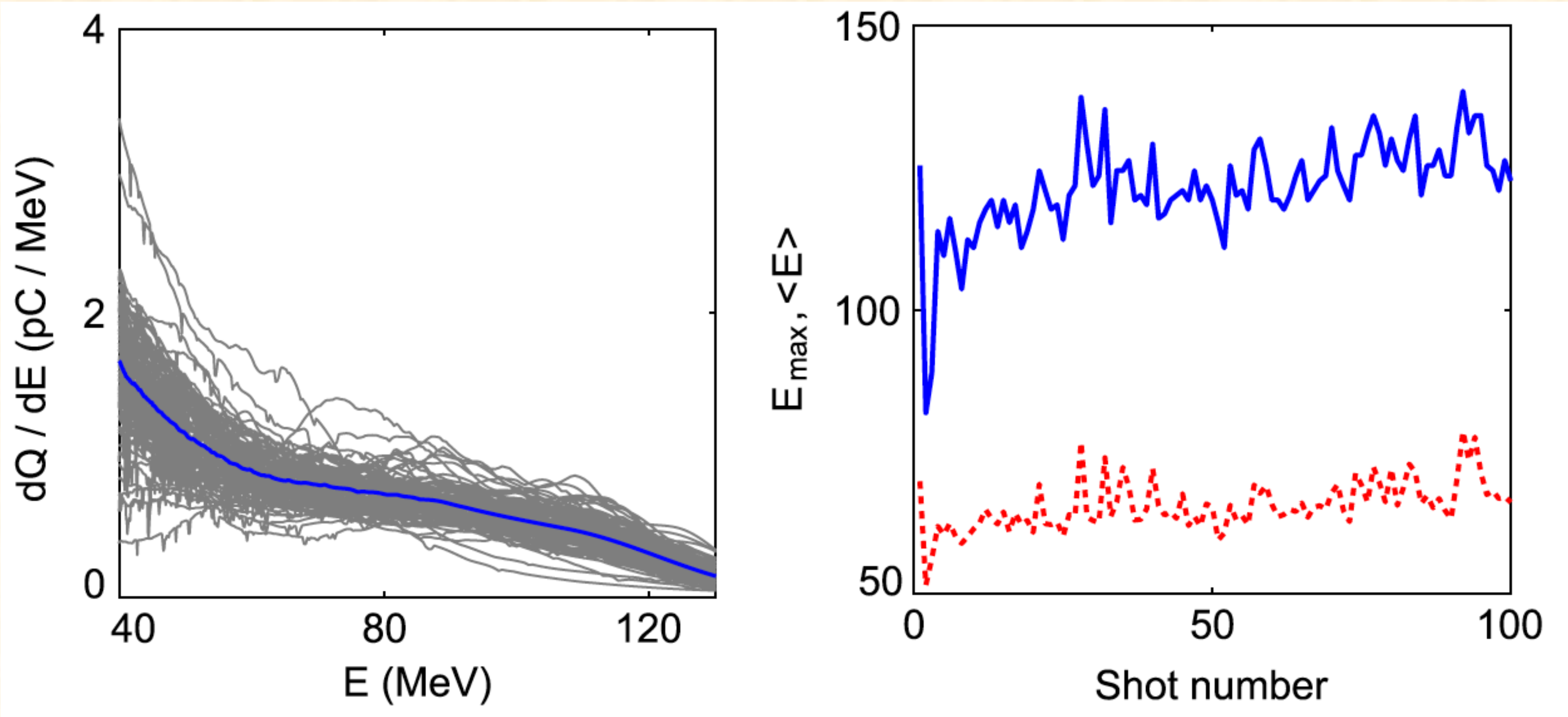
Challenges

Beam generated by laser-driven plasma accelerators is different from typical beans:
- Less stable than usual: small parameters change from shot to shot
- Typical energy 50 MeV – 1 GeV
- Large energy spread (10%)
- Large divergence (several mrad)
- Pointing fluctuation
- Magnets must fit in the vacuum chamber!
- Space constraint
- Laser must be separated from the electrons
- Time structure must also be conserved

=> refocusing beam line needs to take into account these constraints.

About beam stability & energy spread

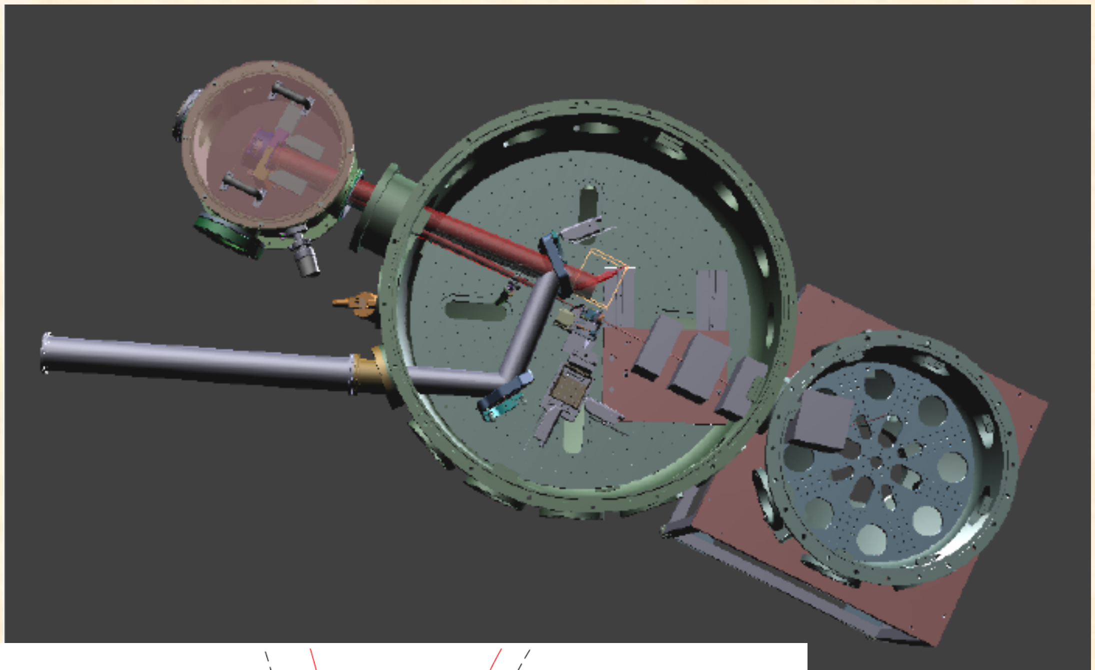


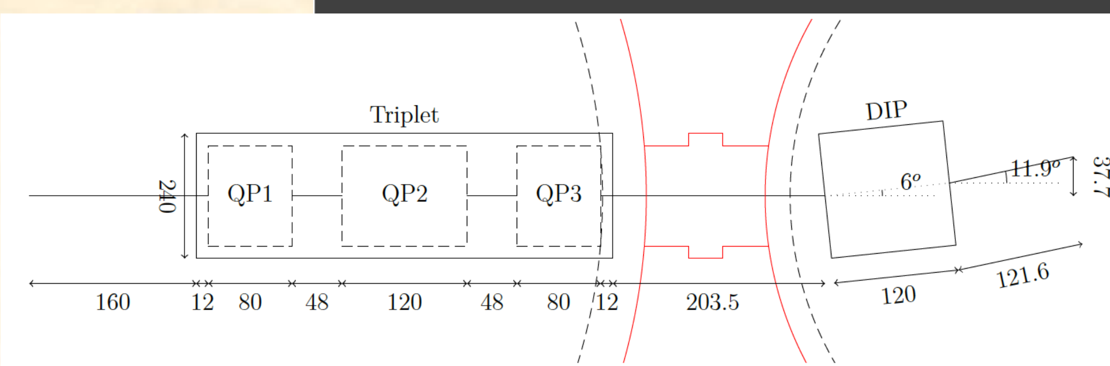
F. Desforges et al *NIM A740, pp:54-59* (2014)

- Energy spread and shot to shot stability different from typical accelerator.

Beam line

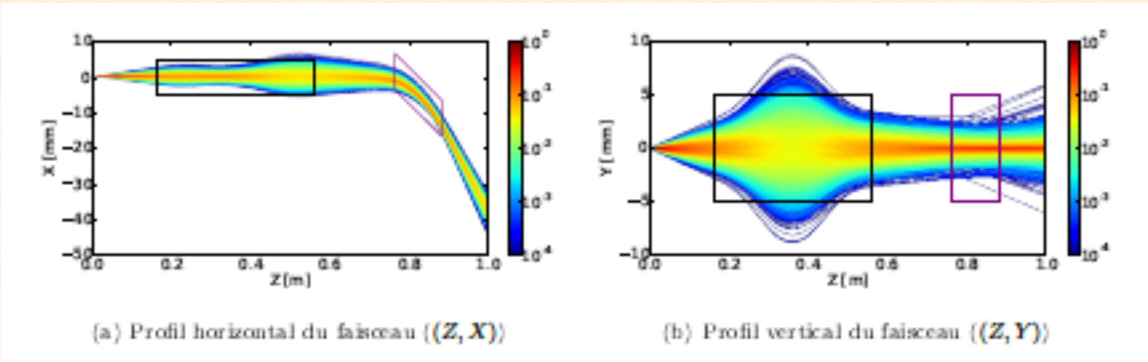
- Typical focusing triplets but with 2 dipoles to ensure laser separation.
- The optics needs to have large energy & position acceptance.





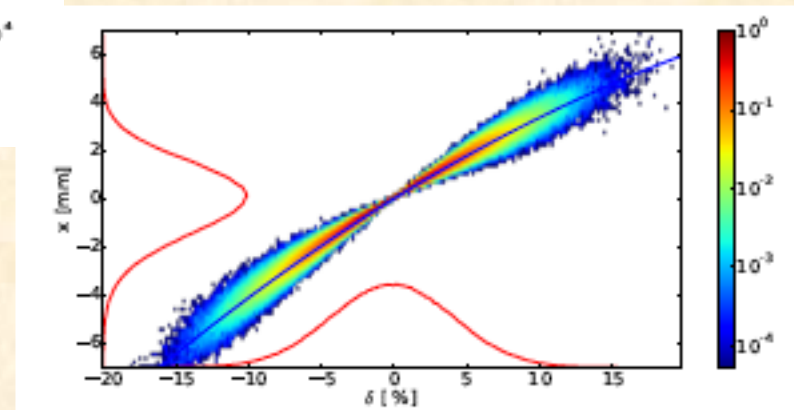
Courtesy of A. Chancé, adapted from NIM A http://dx.doi.org/10.1016/j.nima.2013.10.036

Beam after transportation



(a) Profil horizontal du faisceau ((Z, X))

(b) Profil vertical du faisceau ((Z, Y))



- Bunch length after transport 60fs (10fs before)
- Particle losses due to limited acceptance.

Courtesy of A. Chancé, published in NIM A
http://dx.doi.org/10.1016/j.nima.2013.10.036

Magnet type

Courtesy of A. Chancé, published in NIM A
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Permanent magnets vs Electromagnets

DACTOMUS - Transport line

A. Chancé

Permanent magnets	Electro-magnets
☺ Compactness	☺ Variable fields: more flexible
☺ No power supply	☹ Needed power supply
☺ No cooling	☹ Bigger
☺ Possibility of very small inner radius	☹ Inner radius larger
☹ Fixed field	☹ Needed cooling
	☹ Needed beam pipe (vacuum)

$\Rightarrow$ We have chosen to use permanent magnets.

A Halbach structure has been studied.

Permanent magnets

Irfu

Permanent magnets

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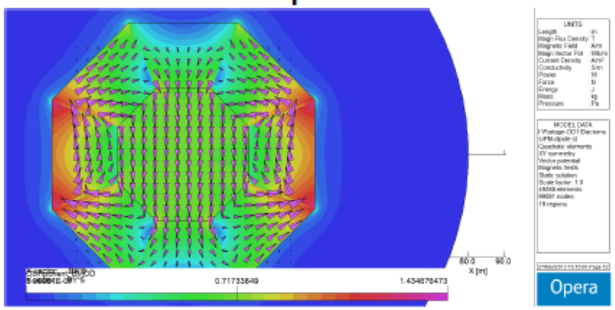
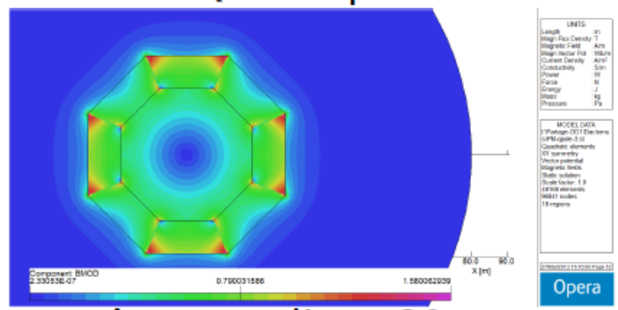
A. Chancé

- Introduction
- Transfer lines
- Diagnostics
- **Magnets**
- Conclusion

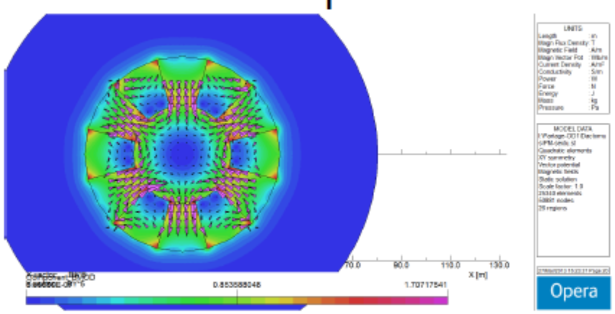
Dipole



Quadrupole



Sextupole



Courtesy: O. Delferrière

- Inner radius: 20 mm.
- Dipole field: 0.7 T (we need 0.56 T)
- Sextupole gradient: 1600 T/m^2 (we need 690 T/m^2)
- We have margin! The magnets are doable.

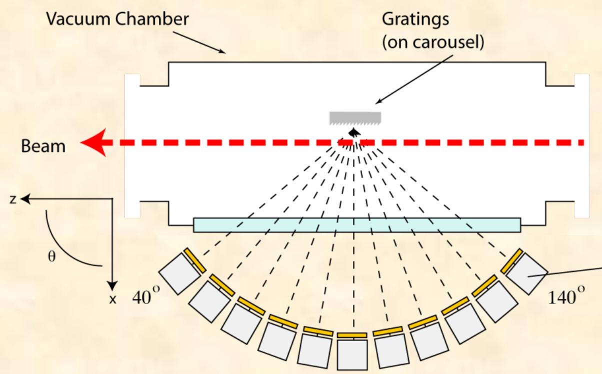
Courtesy of A. Chancé, published in NIM A http://dx.doi.org/10.1016/j.nima.2013.10.036

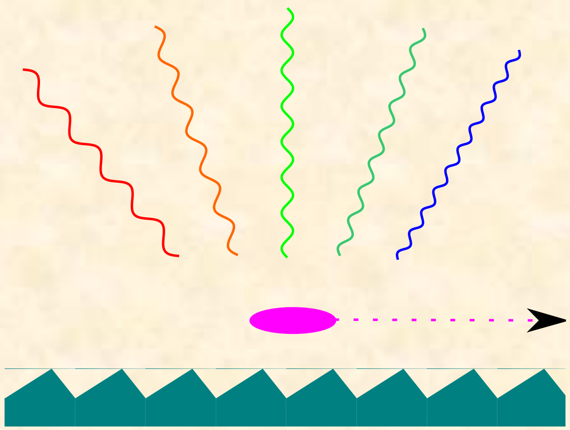
Schedule

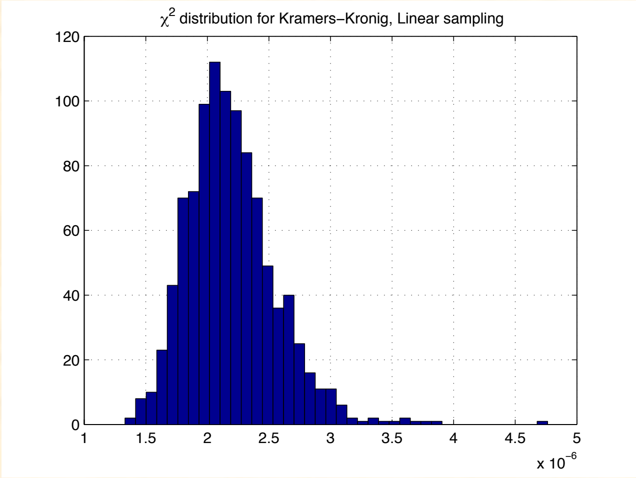
- Tests of the first electron accelerator are ongoing.
- Permanent magnets are being produced at the moment.
- Delivery expected ~end 2014
- 1-2 months to map the magnetic field
- Aim: Tests in the first half of 2015, demonstrate refocusing by the end of 2015.

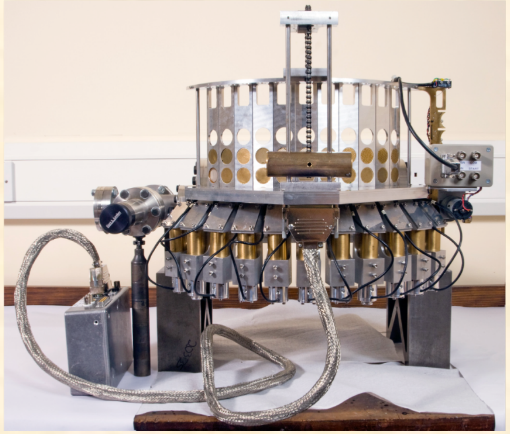
Other R&D for plasma accelerators: Beam profile measurements

- Bunch length measurement is important for some applications such as Free Electrons Lasers and general understanding of the beam.
- Collaboration with Kyiv university on this measurement.
- See presentation given during the workshop last summer in Lviv.
- Work at SLAC (FACET) recently approved for 1 further year.
- Beam tests planned this year at Frascati.









Outlook

- One of the next step in laser-driven plasma acceleration is to demonstrate that the beam can be accelerated in several stage.
- The DACTOMUS collaboration gathers plasma physicists and accelerator physicists to demonstrate that this can be done.
- Beam line is under construction and will be tested in 2015.
- Other R&D is in progress to produce diagnostics to measure such beam.