



# Réseau Instrumentation Faisceau Réunion annuelle 27-28 mars 2019

Recensement diagnostics et instrumentation faisceau au LAL

Réunion RIF 2019 - 27-28 mars 2019 - IPN, Lyon

Sandry Wallon, Nicolas Delerue, LAL, Orsay

... et de nombreux contributeurs du LAL : P. Bambade, C. Bruni, L. Burmistrov, S. Chancé,  
V. Chaumat, A. Faus-Golfe, V. Kubytskyi, H. Monard, A. Natochii, V. Puil, F. Zomer...

# Sommaire

1. Présentation (courte) du LAL
2. Les accélérateurs au LAL
3. Diagnostics par le LAL
4. Instrumentation faisceau par le LAL
5. Conclusion

# Sommaire

- Fondé en 1956, situé sur le campus de l'Université Paris-Sud (bassin Paris Saclay).
- 1er accélérateur opérationnel en 1959.
- Contribution au LEP, CLIO...
- L'accélérateur linéaire du LAL a cessé ses activités fin 2003. Des accélérateurs plus petits sont en fonctionnement (PHIL) ou en construction (ThomX).
- "R&D accélérateurs" sur plusieurs machines : ATF2, CLIO, SuperKEKB, Soleil, Pitz, SPS...

# Diagnostiques et instrumentation faisceau au LAL

Activés instrumentation faisceau et diagnostics :

- Groupe **GIPSYD** (Groupe Instrumentation, Plateformes et Systèmes de Détections)
- Et principalement au sein du **Département accélérateurs (Depacc)**

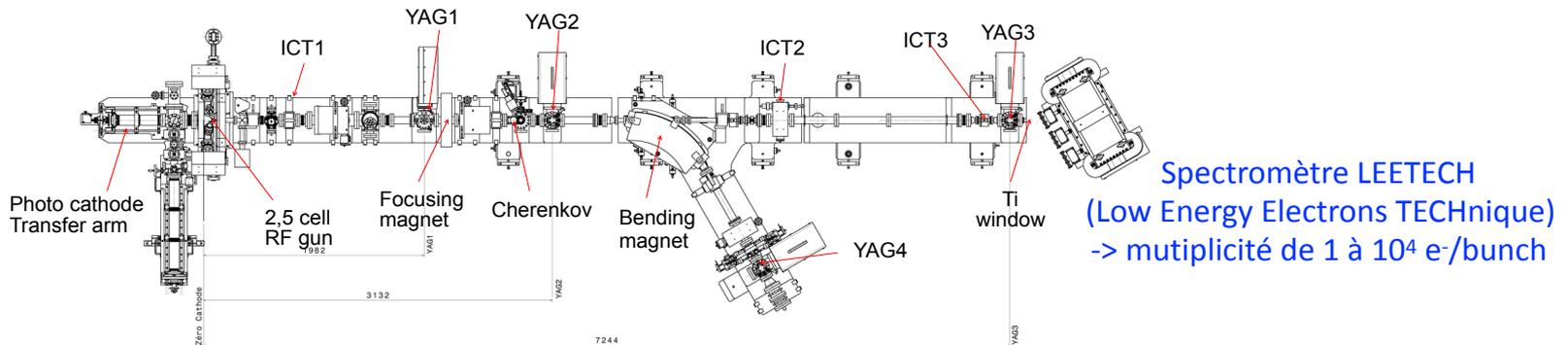
Le **Depacc** du LAL couvre un large champ d'expertise reposant sur **51 pers.** réparties en **5 groupes** :

- Technologies RF (structure RF ; sources de puissance)
- Diagnostiques et instrumentations
- Physique des faisceaux
- Technologies du vide et des surfaces
- Optique et source Compton

# Les accélérateurs au LAL

# Accélérateur d'e- PHIL @LAL

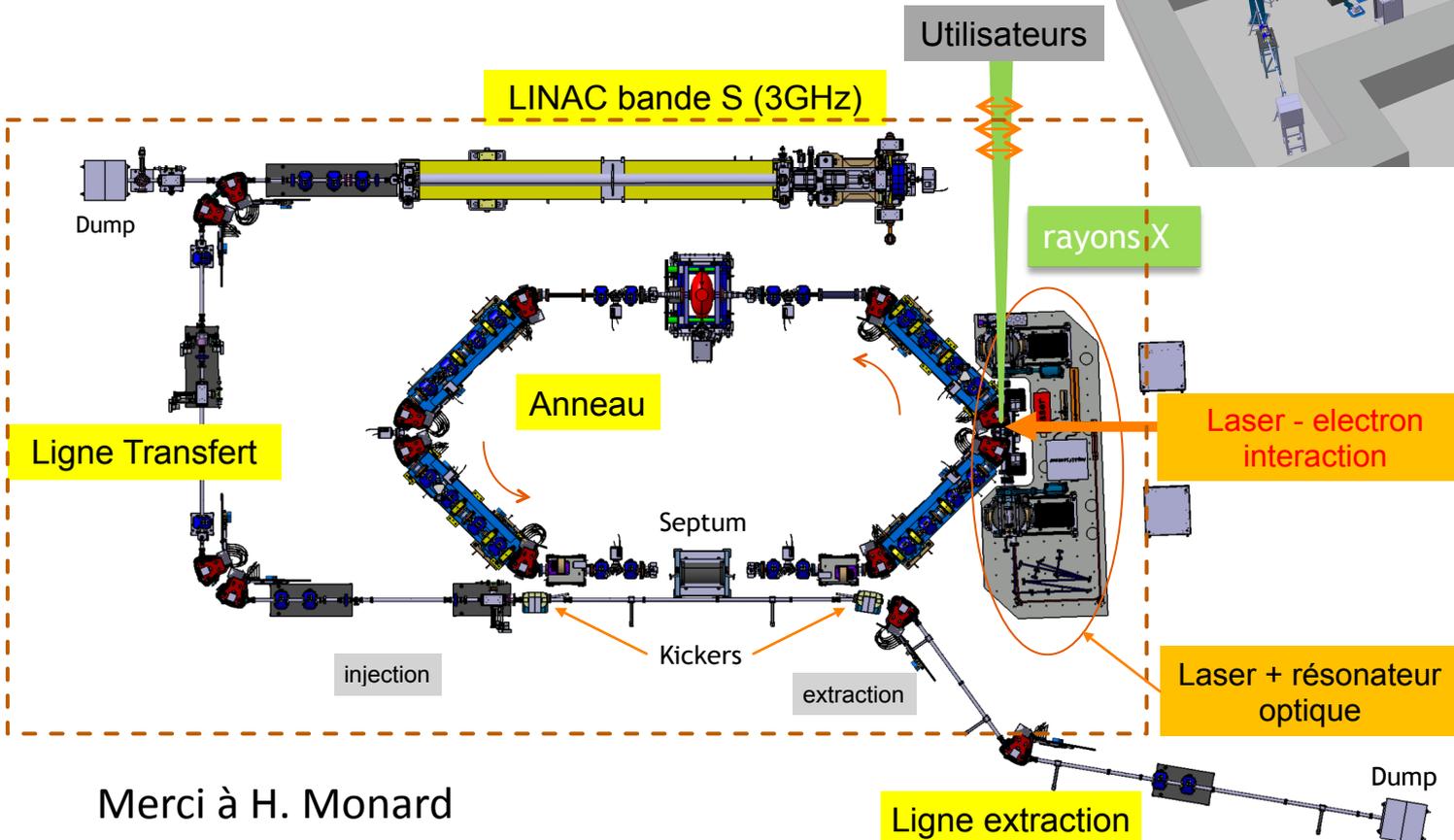
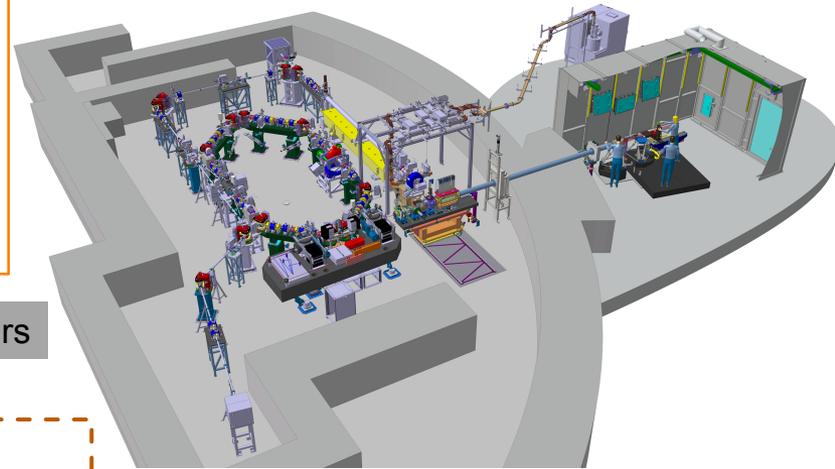
Mots clés : accélérateur linéaire techno RF 3 GHz ; photo-injecteur



	Avenir	Aujourd'hui
Energie	9 MeV (booster)	4 MeV
Dispersion	< 0,4%	~0.2% @ 100 pC
Durée d'impulsion	0,1ps (laserix) < t < 10 ps	0,1ps (laserix) < t < 10 ps
F rep.	10 Hz	5 Hz
Charge	10 pC à 2 nC	10 pC à 1.5 nC
$\epsilon$ (rms)	5 < $\epsilon$ < 15 mm.mrad	Emin ~ 3 mm.mrad
Diamètre	2 < d < 10 mm	2 < d < 10 mm

# Accélérateur ThomX @LAL

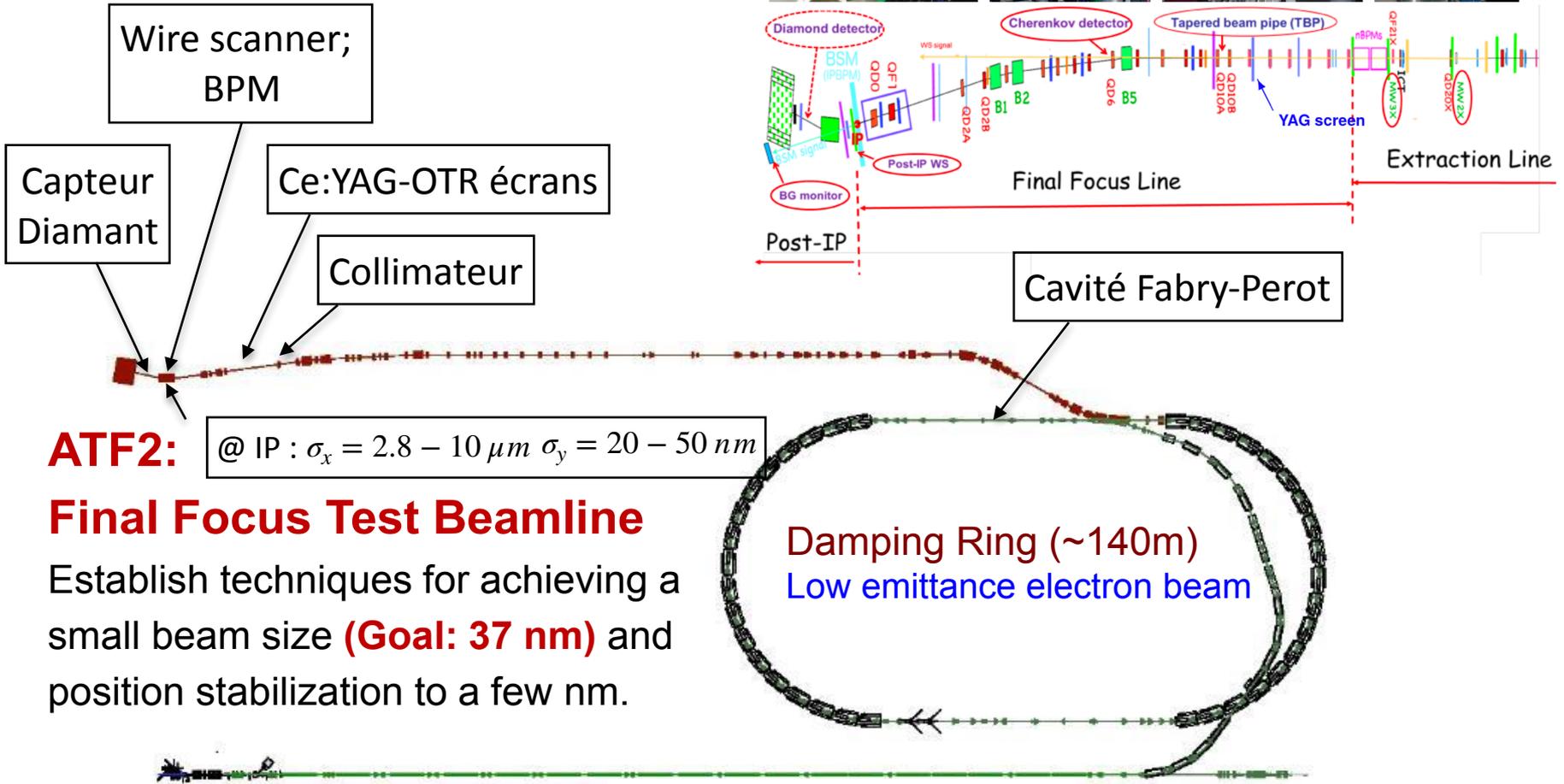
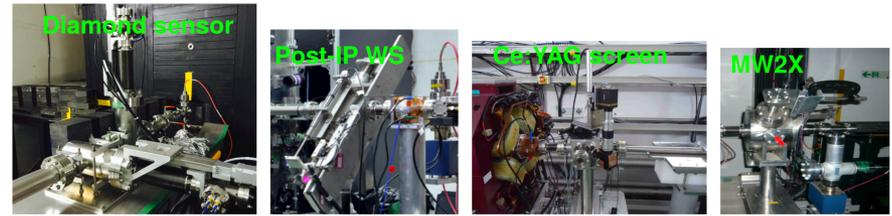
Mots clés : source rayons X à 45 keV ; produits par diffusion Compton inverse (-> source compacte [70 m<sup>2</sup>]) ; interaction faisceau d'e<sup>-</sup> à 50 MeV avec laser (500 kW) ; cavité optique Fabry-Perot (résonateur) ; Linac + Anneau ; dvpt compétence anneau à l'IN2P3



1<sup>er</sup> faisceau  
prévu en 2019

Merci à H. Monard

# Accélérateur à forte implication du LAL : ATF2



**ATF2:** @ IP :  $\sigma_x = 2.8 - 10 \mu m$   $\sigma_y = 20 - 50 nm$

## Final Focus Test Beamline

Establish techniques for achieving a small beam size (**Goal: 37 nm**) and position stabilization to a few nm.

1.3 GeV S-band Electron LINAC (~70m)

# Les diagnostics par le LAL

# Mesure de charge @ ThomX

## ▶ 3 Integrated Current Transformer (ICT)

### > Location:

- ▶ @ LINAC entrance
- ▶ @ Linac exit (before first TL bending magnet)
- ▶ @ Transfer Line (before injection dipole)

### > Type:

- ▶ In-flange integrating current transformer from Bergoz
- ▶ Dedicated electronics BCM-IHR provides analog voltage proportional to the beam charge
- ▶ Acquisition to be integrated in the control system (by Wavecatcher)



*In-flange ICT*

## ▶ 2 Faraday Cups (FC)

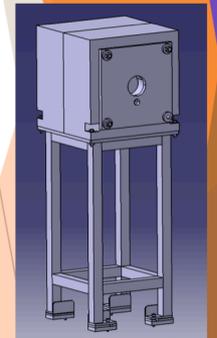
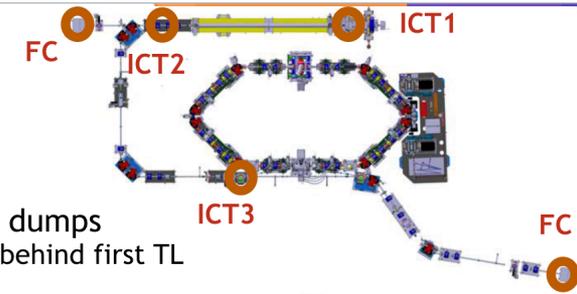
### > Location: in the beam dumps

- ▶ @ the end of Linac (behind first TL bending magnet)
- ▶ @ the end of extraction line

### > Acquisition:

- ▶ Few tens of ns pulse to be acquired synchronously to injection or extraction trigger
- ▶ Use of Low Pass filtering and acquisition with the Wavecatcher board ( BW 500 MHz; 3.2 Gech/s). Tango device ready.

Expected resolution <1 pC



*Beam dump w/  
integrated FC*

## Récapitulatif diag. mesure charge

- PHIL : **ICT** et **FC** [achat ICT et FC, conception et opération] - Électronique LAL
- ThomX : **ICT** et **FC** [achat ICT et FC conception et opération] - Électronique LAL

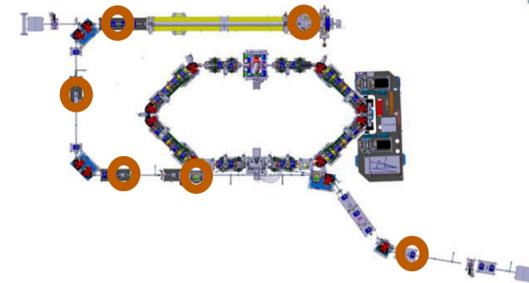


# Mesure de position @ ThomX

## Position measurement (BPM)

BPM : Beam Position Measurement (moniteur de position)

- ▶ 6 Striplines for injector
  - 1 stripline on the LINAC
  - 4 striplines on the transfer line
  - 1 stripline on the extraction line
  
- ▶  $\lambda/4$  @ 500 MHz -> Electrode length = 150 mm
- ▶ Resolution requirements: < 100  $\mu\text{m}$  for 1 nC
- ▶ 4 electrodes @  $45^\circ$  covering  $\sim 2/3$  of circumference
- ▶ Linac stripline has different design due to larger vacuum chamber diameter
- ▶ Mechanics and soldering (feedthroughs) are done at LAL
- ▶ Electrical tests and calibration done at SOLEIL

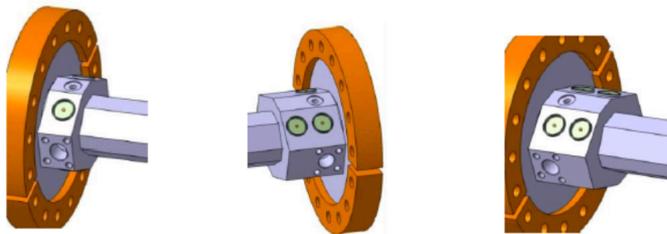
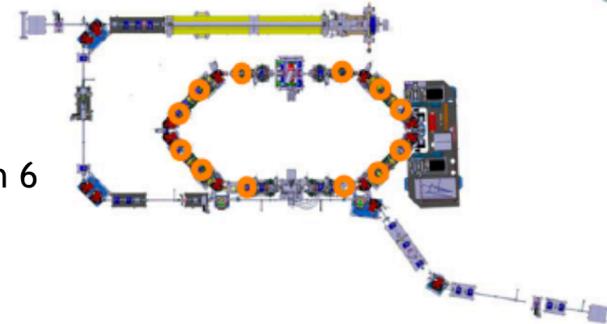


Merci à N. Delerue, I. Chaikovska

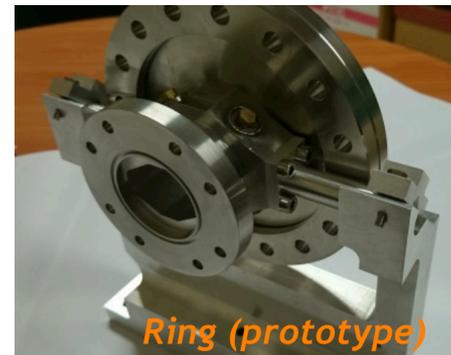
# Mesure de position @ ThomX

## Position measurement (BPM)

- ▶ 12 button BPMs for the storage ring (4 BPM with 8 buttons, 4 BPPM with 6 buttons and 4 BPM with 4 buttons)
  - Resolution  $\sim 1 \mu\text{m}$  @ 10 Hz
  - Prototype done at LAL
  - Mechanics and soldering are done by RIAL Vacuum
  - Additional electrodes on double BPM for:
    - ▶ Transverse and longitudinal bunch by bunch feedbacks
    - ▶ Polarization for ion cleaning



4, 6 and 8 buttons BPMS



Ring (prototype)

Merci à N. Delerue, I. Chaikovska

# Récapitulatif diag. mesure de position

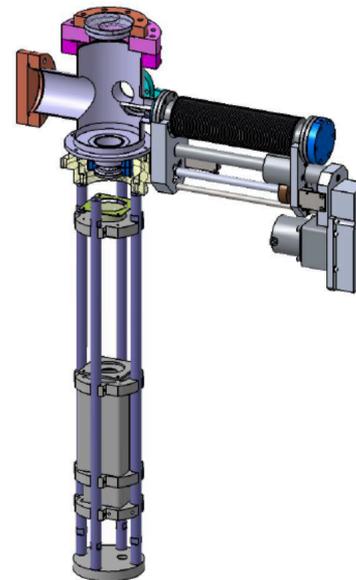
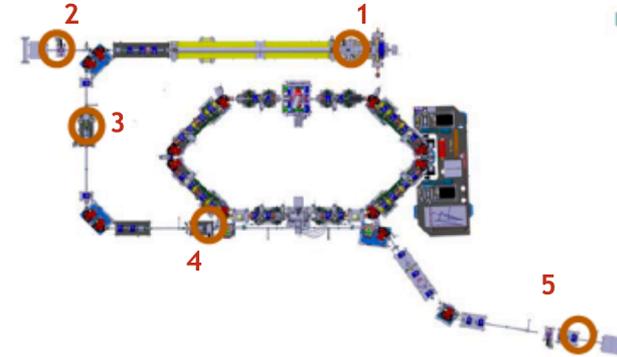
Expérience des BPM à électrodes longues, électrodes boutons, cavité ; capacité à tester et calibrer des BPM

- ThomX : bouton et stripline BPM [conception, **réalisation (stripline)** et opération] - électronique achetée à l'extérieure (Libera Brillance+ de Instrumentation Technologies)
- **Banc de test de BPM au LAL**
- ATF2 : **cavity BPM** [opération et aide à la conception mécanique (BPM) ; conception, réalisation (système positionnement nanométrique)]

# Mesure de profil transverse @ThomX

## Diagnostic stations

- ▶ Location
  - 5 stations on Linac, Transfer Line and Extraction Line
- ▶ Purpose:
  - Beam size, emittance and energy measurement
- ▶ Principle:
  - Screen translation stage
    - ▶ Calibration plate
    - ▶ YAG (Ce): 25 mm diameter, 100  $\mu\text{m}$  thick
    - ▶ OTR : 25 mm diameter, 100  $\mu\text{m}$  aluminised silicon wafer
    - ▶ Sapphire screen (station 2 @ end of Linac)
  - View port: Fused Silica DN 60 CF
  - Imaging system
  - Gigabit Ethernet triggered CCD



Screen translation stage

Merci à N. Delerue, I. Chaikovska

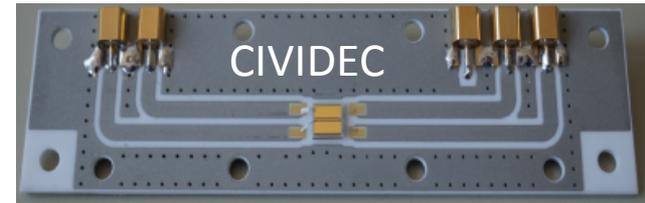
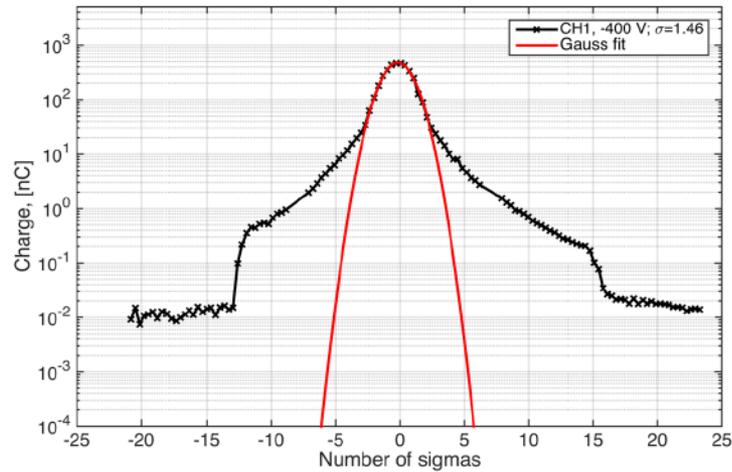
ThomX - Diagnostics

I. Chaikovska (LAL) for Diagnostics group - LAL, 29/11/2018

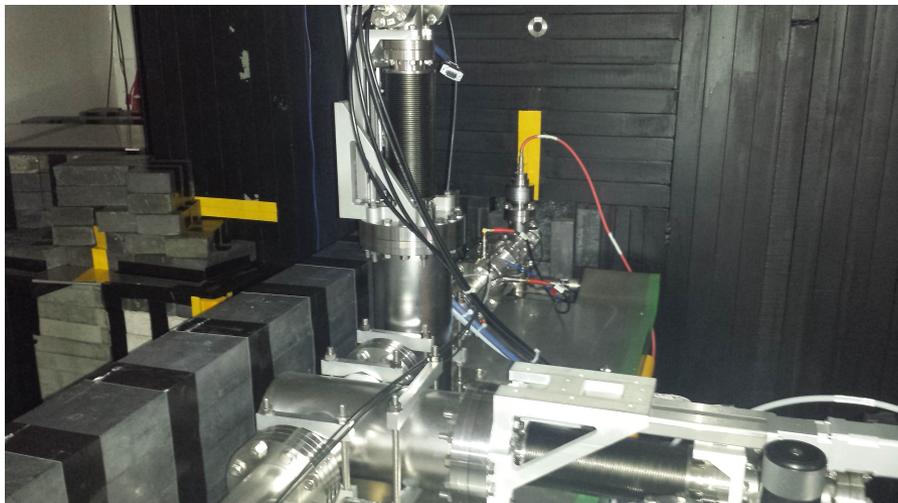
8



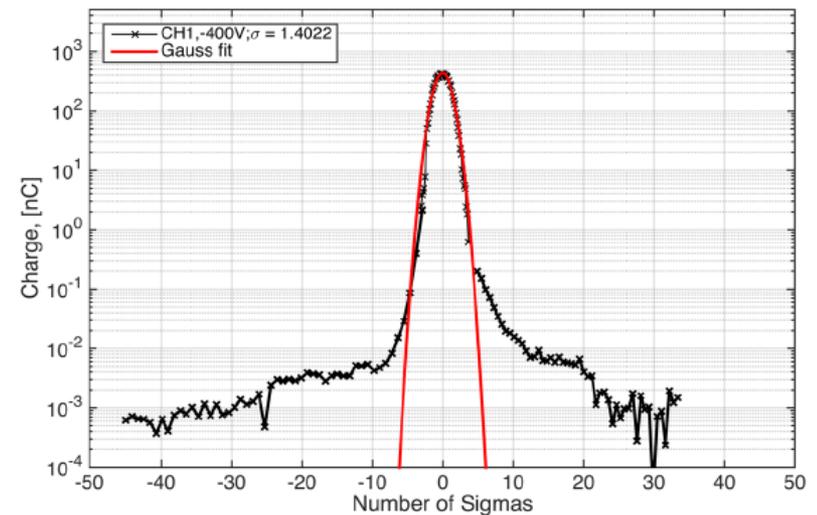
# Mesure du halo du faisceau d'e<sup>-</sup> par capteur diamant @ ATF2



4 channels in-vacuum Diamond Sensor from CIVIDEC.



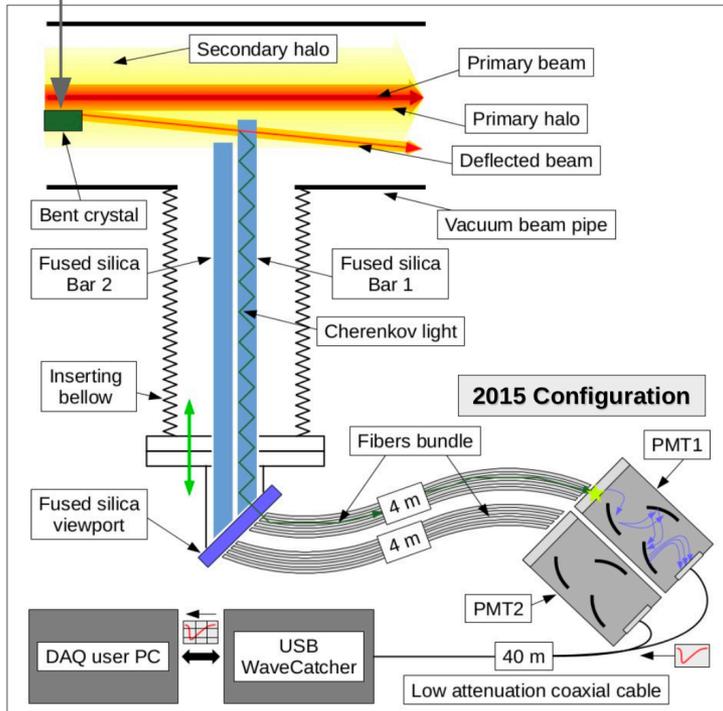
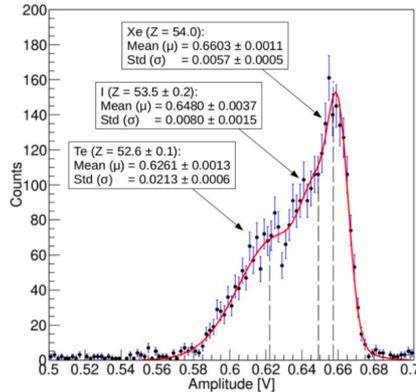
Horizontal and vertical Diamond Sensors



# Mesure de profil transverse @SPS (UA9)

CpFM (Cherenkov detector for proton Flux Measurement)

270 ZGeV/c Xe ion calibration at SPS  
Beam contamination study



## Timepix

### Timepix3:

- a hybrid pixel detector;
- Silicon/Carbon layer;
- 14×14 mm<sup>2</sup> bump bonded read-out chip;
- a matrix formed by 256×256 pixels;
- each pixel is 55×55 μm<sup>2</sup>;
- Clock 40 MHz (25.0 ns) + 640 MHz fast Clock (1.56 ns)

Each Timepix pixel can work in one of three modes:

- **ToA+ToT mode** (ToA 18 bit & ToT 10 bit)
- **ToA mode** (ToA 18 bit)
- **Event count & Integral ToT** (iToT 18 bit & eCount 10 bit)

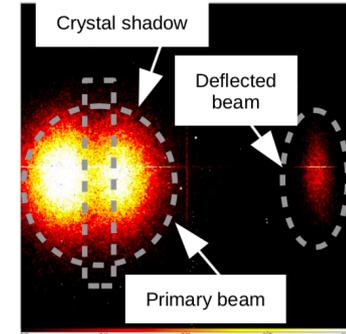
**Readout:** Katherine, Ethernet embedded readout interface, 15 Mbits/s



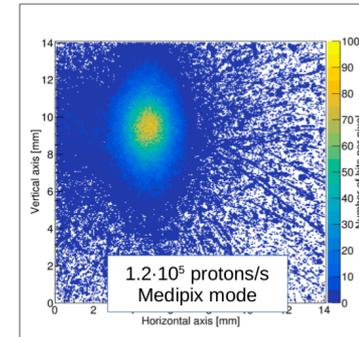
P. Burian <sup>a,b</sup>, P. Brouilim <sup>a</sup>, V. Georgiev <sup>a</sup>, M. Jara <sup>a</sup> and B. Bergmann <sup>b</sup>  
<sup>a</sup> Faculty of Electrical Engineering, University of West Bohemia, Univerzitni 26, Pilsen, Czech Republic  
<sup>b</sup> Institute of Experimental and Applied Physics, Czech Technical University in Prague, Horská 3a/22, Prague, Czech Republic

UA9 Collaboration

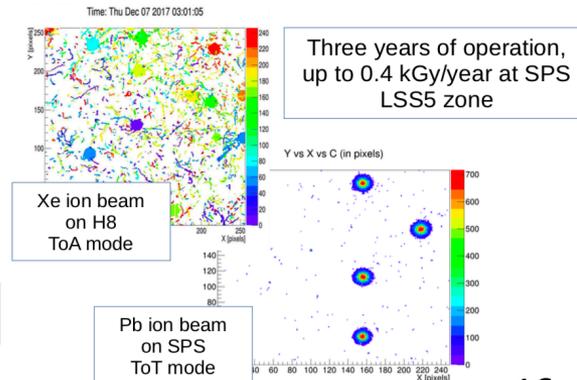
Merci à A. Natochii, V. Puil



Quadrip (4 Timepix chips)  
Placed ~50 m from the crystal  
400 GeV/c protons



The image of the proton  
270 GeV/c beam at SPS,  
deflected by the crystal.



# Récapitulatif diag. mesure de profil transverse

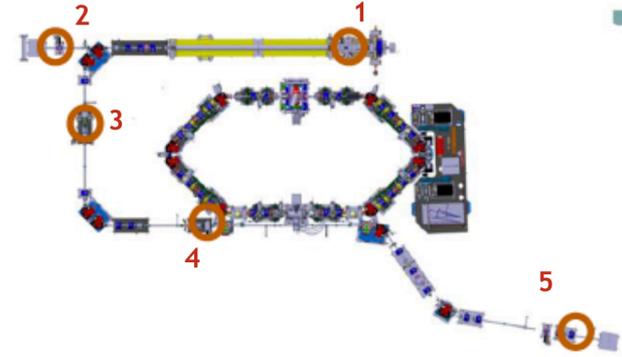
Compétences en YAG:Ce, OTR, Diamant, Timepix,  
CpFM, Rayonnement Synchrotron

- PHIL : écrans [conception, réalisation, opération]
- ThomX : écrans et **MRSV** (**M**oniteur de **R**ayonnement **S**ynchrotron **V**isible) [conception, réalisation, opération]
- ATF2 : écrans [conception et réalisation partagées avec KEK, opération]
- ATF2 : **capteur diamant** [conception, réalisation, opération]
- Laser-Plasma : écrans [conception, réalisation, opération]
- **Support manip : calibration d'écrans (mesure à faible charge [10 pC])**
- UA9 : Timepix et Timepix3 détecteurs (Medipix collaboration) : opération
- UA9 et **R&D Cherenkov Lab** : CpFM (Cherenkov detector for **p**roton **F**lux **M**easurement) [conception, réalisation, opération]... fonctionne avec ions, e<sup>-</sup> à partir de 3 MeV

# Mesure d'émittance @ ThomX

## Diagnostic stations

- ▶ Transverse size measurements
- ▶ **Emittance measurement**
  - Using Quadrupole scan method
    - ▶ Measure beam size vs Qpole strength
    - ▶ Required resolution: 10 pixels/sigma
    - ▶ Devices: 1 quadrupole + screen + CCD
    - ▶ Location: @ Diag stations 2, 3 and 4
- ▶ **Energy measurement:**
  - Passing through dipole magnet → dispersion
    - ▶  $\langle x \rangle \rightarrow E = \text{energy}$
    - ▶  $dx \rightarrow dE = \text{energy spread}$
  - Device:



## Récapitulatif diag. mesure émittance

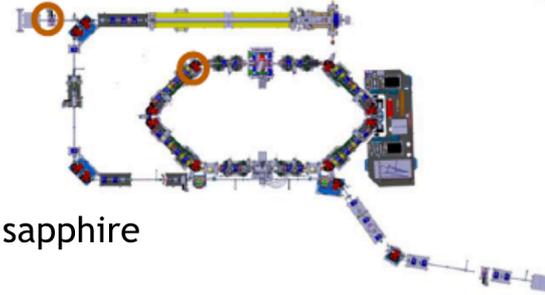
- Méthodes **Solénoïde-scan** (PHIL), **Quadrupole-scan** (ThomX)... méthode utilisable également avec un **système de 3 écrans** (PHIL...) donnant alors l'émittance en un seul passage [conception, réalisation et opération]
- Méthode Poivrière



# Récapitulatif diag. mesure de pertes

- SuperKEKB: **capteur diamant** [capteur achat CIVIDEC, conception, réalisation, opération] - (DAQ, gestion en ligne des données... -> deep learning?)
- PHIL : **FBLM (Fiber Beam Loss Monitor)** [conception, réalisation et opération - Électronique LAL] - validation
- ThomX : **FBLM** [conception, réalisation et opération - Électronique LAL]

# Mesure de longueur de paquet @ ThomX



End of Linac (~4 ps expected):

▶ **Cherenkov radiation** produced when the electron beam passes through the sapphire screen

▶ Sapphire window to extract light

▶ Transport the radiation to a streak camera to measure the photon pulse length.

Storage Ring (4 to 20 ps expected):

▶ **Synchrotron radiation** produced when the electron beam changes its trajectory in the bending magnet

▶ Sapphire window to extract light

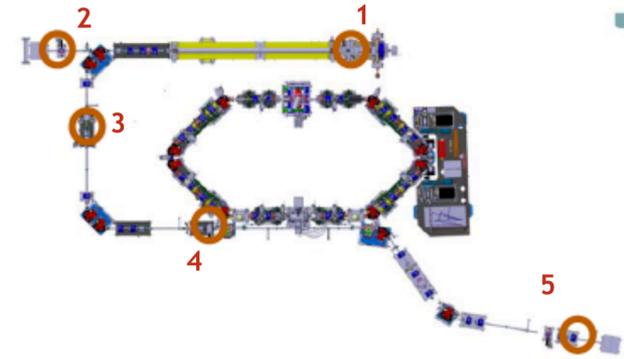
▶ Transport the radiation to a streak camera to measure the photon pulse length.

## Récapitulatif diag. mesure longueur de paquet

- ThomX : Caméra à balayage avec un radiateur Cherenkov [opération]
- Méthode par manipulation de l'espace de phase avec cavité RF (PHIL) [opération]
- **R&D** : Mesure en se basant sur du rayonnement cohérent [conception, réalisation, opération]



# Mesure d'énergie @ ThomX



- ▶ Transverse size measurements
- ▶ Emittance measurement
  - Using Quadrupole scan method
    - ▶ Measure beam size vs Q pole strength
    - ▶ Required resolution: 10 pixels/sigma
    - ▶ Devices: 1 quadrupole + screen + CCD
    - ▶ Location: @ DiaStation 2, 3 and 4

- ▶ **Energy measurement:**
  - Passing through dipole magnet → dispersion
    - ▶  $\langle x \rangle \rightarrow E = \text{energy}$
    - ▶  $dx \rightarrow dE = \text{energy spread}$
  - Device:
    - ▶ Dipole + screen + CCD
  - Location: @ middle of transfer line (DiaStation 3) and @ dump 2 (DiaStation 5)

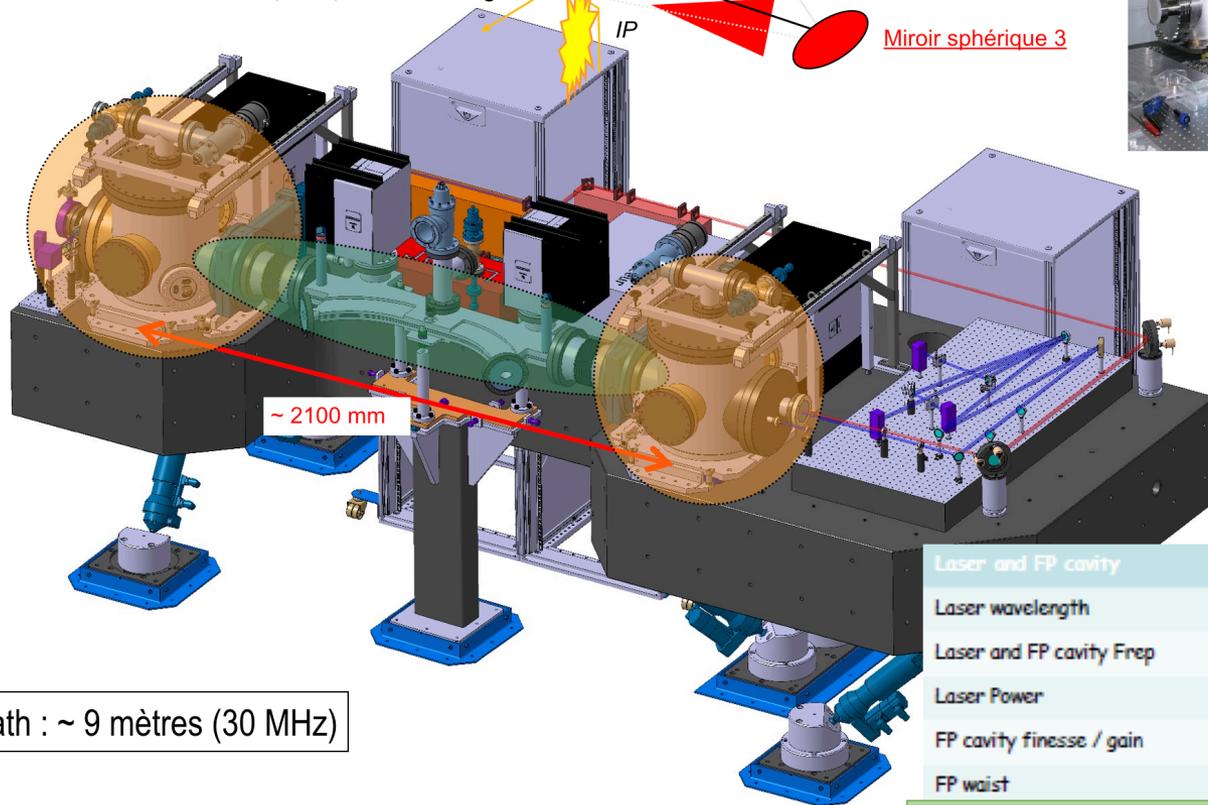
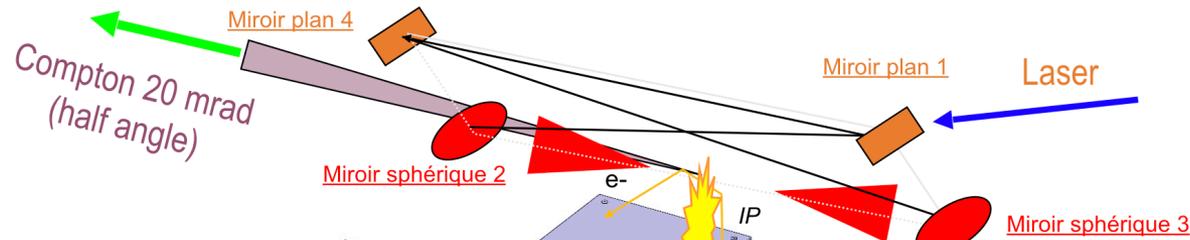
## Récapitulatif diag. mesure d'énergie

- PHIL et ThomX : spectromètre [conception et opération]
- Laser-Plasma : spectromètre [conception et opération] Note: il y a une compétence plus forte sur ce point au LLR (avec la réalisation en plus)



# Instrumentation faisceau au/du LAL

# Cavité optique Fabry-Perot @ThomX



Optical path : ~ 9 mètres (30 MHz)

Laser and FP cavity	
Laser wavelength	1030 nm
Laser and FP cavity Freq	36 MHz
Laser Power	50 - 100 W
FP cavity finesse / gain	30000 / 10000
FP waist	70 $\mu\text{m}$

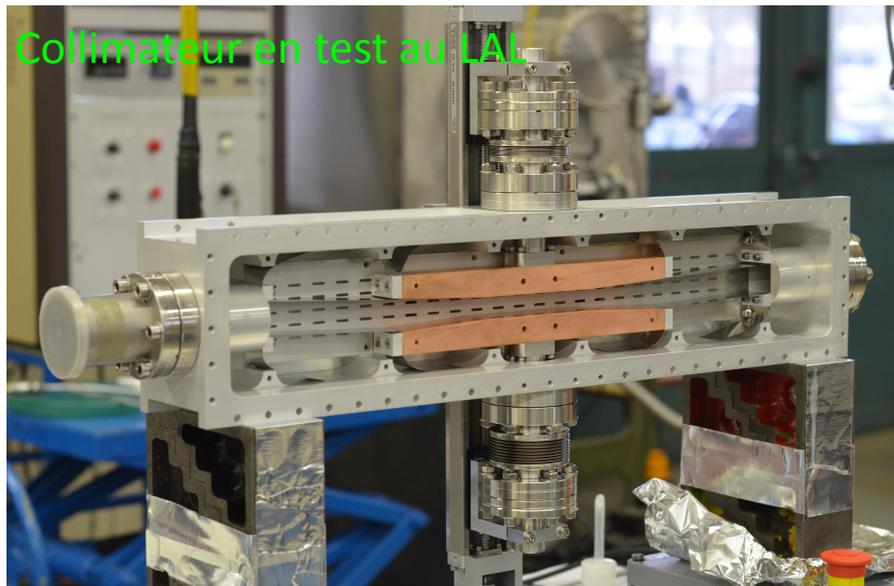
→ Laser oscillator rep. rate & CEP locking  
@  $\Delta\nu/\nu \sim 10^{-12}$

Merci à F. Zomer

# Apport du LAL en instrumentation faisceau



Cavité Fabry-Perot à ATF2



Collimateur en test au LAL

- ATF2 (MightyLaser / R&D pour ILC), ThomX : **Cavité Fabry-Perot** pour production de rayonnement Compton [conception, réalisation, opération]
- ATF2 : **Collimateur** [conception sur **inspiration design ILC**, réalisation, opération]
- PRAE : Dechirper [conception au stade d'avant projet]

# Conclusion

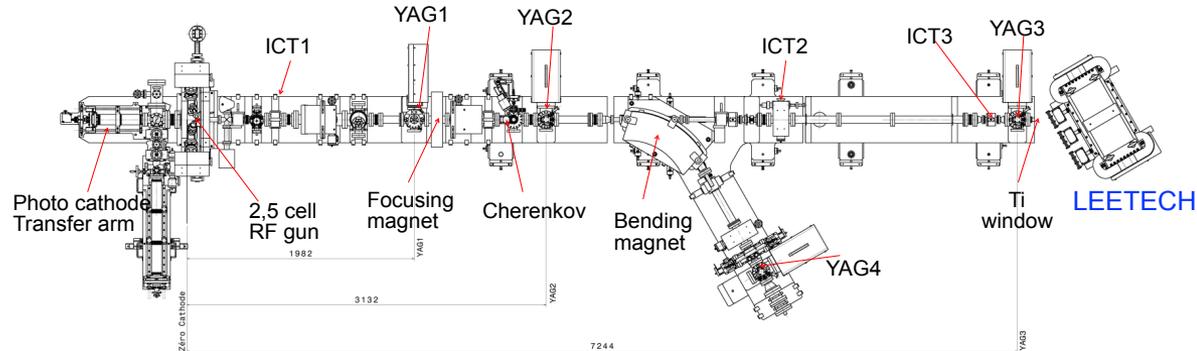
- Les compétences du LAL, en **conception, réalisation et opération**, couvrent les **principaux diagnostics** d'un accélérateur e-.
- Compétences en instrumentation, en particulier sur les **cavités optiques**.
- La **compétence opérationnelle** sur l'accélérateur **PHIL** du LAL est un atout... prochainement étendu avec la mise en service de **ThomX** en 2019.

# Questions-Réponses & Diapositives additionnelles

# Accélérateur d'e- PHIL @LAL

Plateforme PHIL repose sur :

- une salle de contrôle informatique reliée à des automates
- une source de puissance RF 3GHz/ 20MW/5Hz (modulateur 220kV+klystron TH2104)
- systèmes auxiliaires (alimentation, timing, contrôle vide...)
- laser  $\lambda=262\text{nm}$ ,  $E=80\mu\text{J}$  maxi,  $T=9\text{ps}$  (FWHM)
- photo-injecteur 5MeV (100MV/m)
- deux lignes de transport (directes et déviées) équipées :
  - focalisation
  - mesureur de charge
  - mesureur de dimension
  - mesureur d'énergie (dipôle)
  - mesureur de longueur de paquet



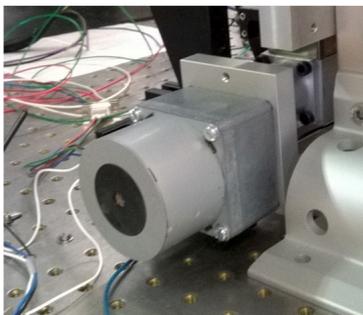
	Avenir	Aujourd'hui
Energie	9 MeV (booster)	4 MeV
Dispersion	< 0,4%	~0.2% @ 100 pC
Durée d'impulsion	0,1ps (laserix) < t < 10 ps	0,1ps (laserix) < t < 10 ps
F rep.	10 Hz	5 Hz
Charge	10 pC à 2 nC	10 pC à 1.5 nC
$\varepsilon$ (rms)	$5 < \varepsilon < 15$ mm.mrad	$E_{min} \sim 3$ mm.mrad
Diametre	$2 < d < 10$ mm	$2 < d < 10$ mm

# Banc de tests de BPM

## Montage mécanique

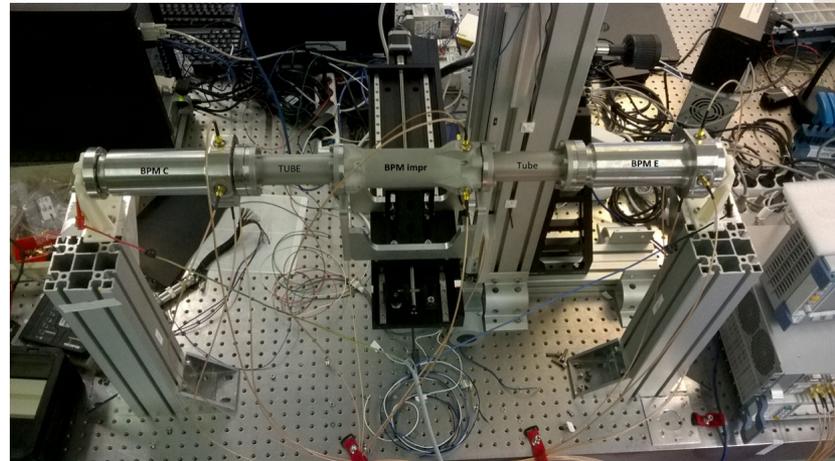


Moteur  
Horizontal



Moteur  
Vertical

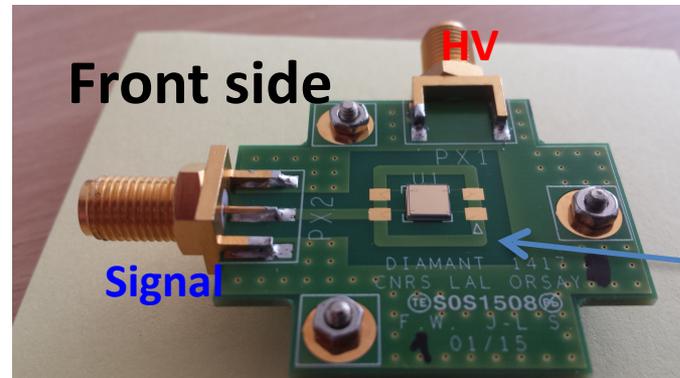
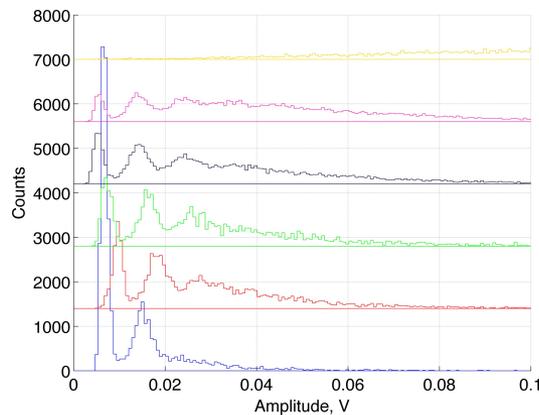
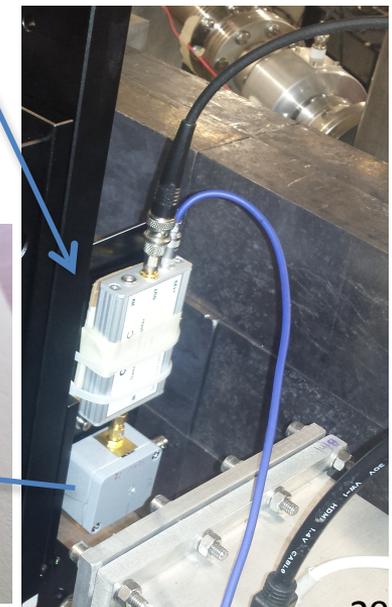
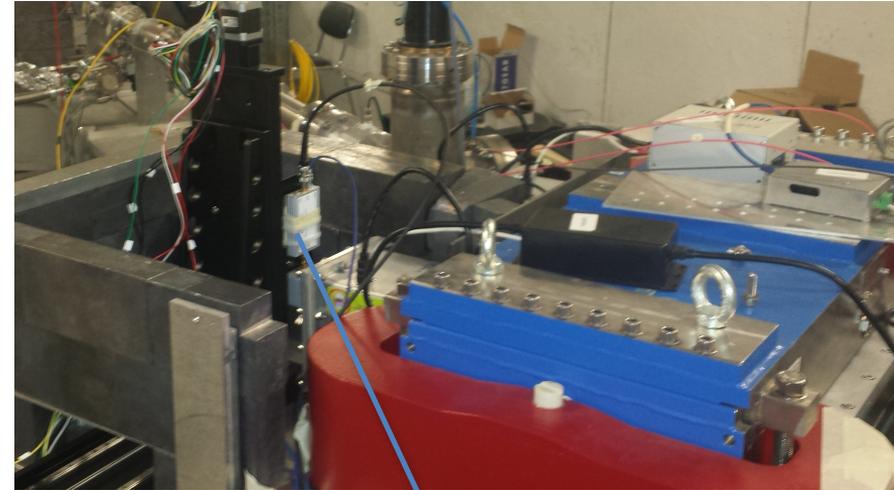
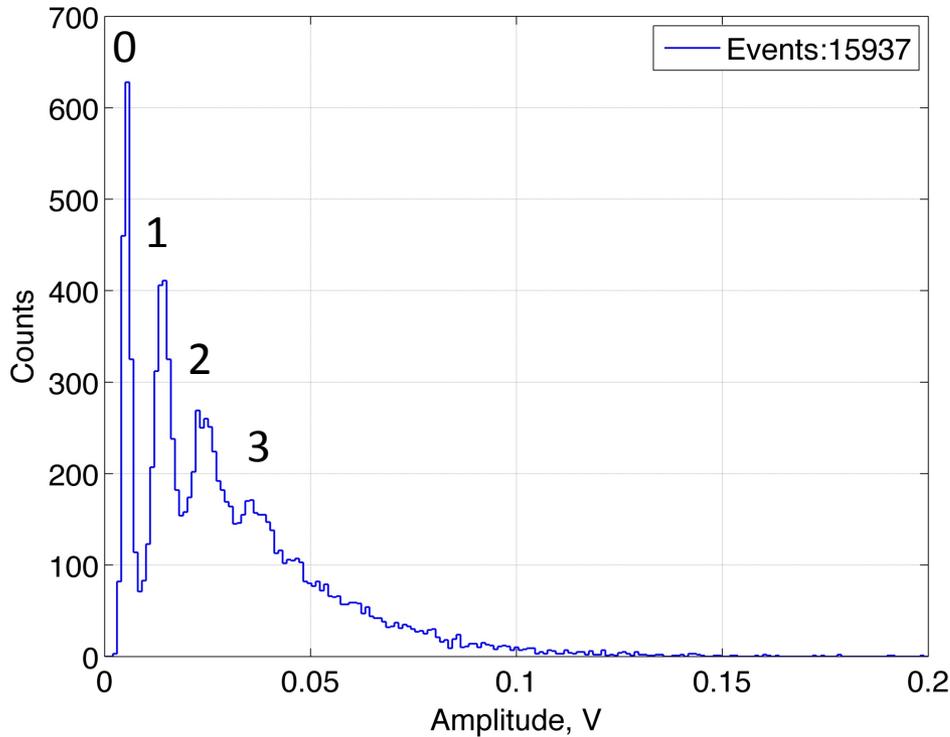
BPM et fil



# Mesure par capteur diamant de 1, 2, 3 e- @ PHIL (LEETECH)

Spectromètre LEETECH : Low Energy Electrons TECHnique

PHIL:  $10^9$  electrons of 3.5 MeV

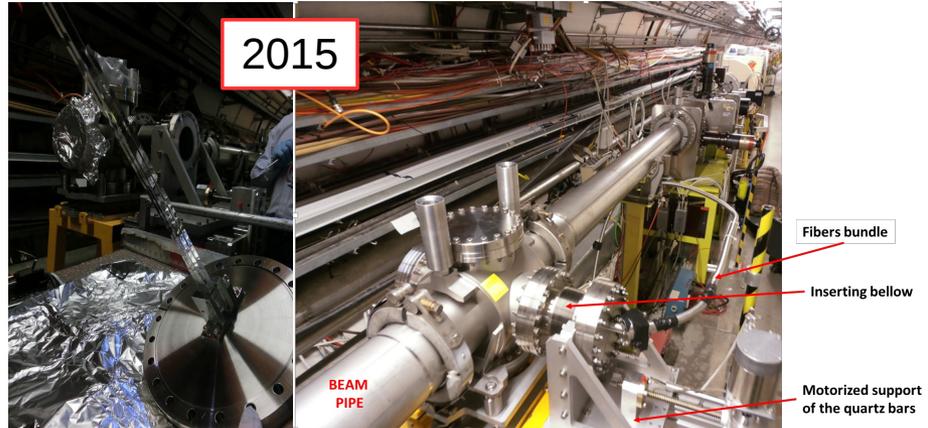
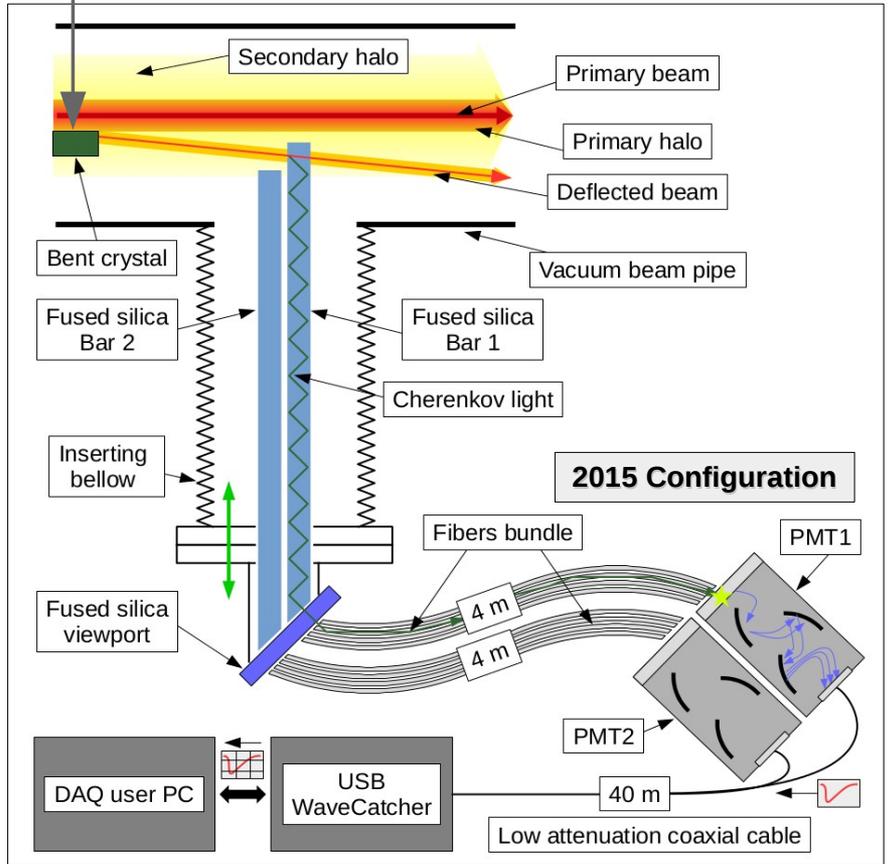
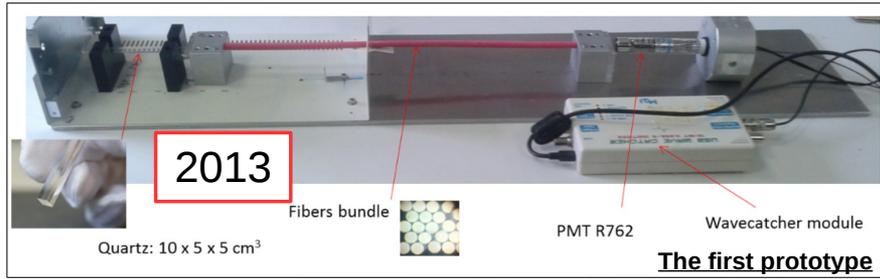
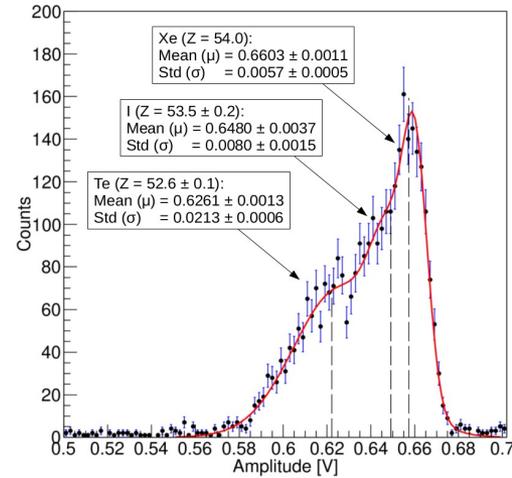
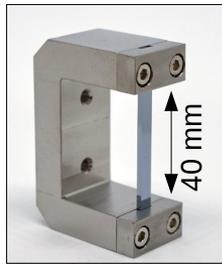


Merci à V. Kubytzkyi

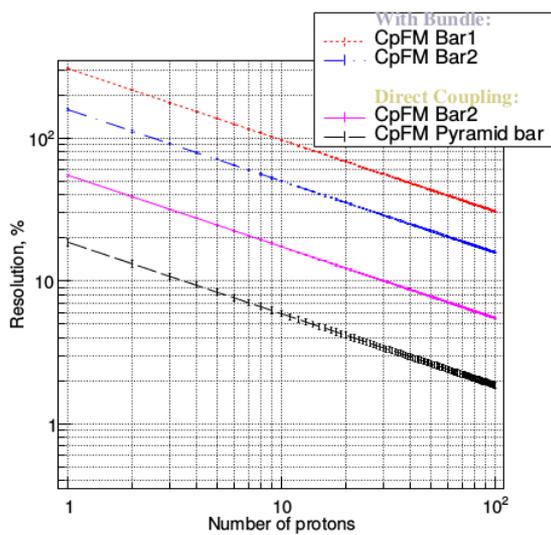
# Cherenkov detector development

- The goal:**  
To have a device for the quantitative characterization of the deflected particle beam.
- Environment:**  
Circulating machine (SPS & LHC)
- Requirements:**
1. Vacuum compatibility:  $10^{-9}$  mbar for SPS and  $10^{-11}$  mbar for LHC.
  2. Fast enough detector response for the particle counting during a single bunch of **1-3 ns** duration (*it is not necessary to measure each bunch in a train*): revolution frequency of **43 kHz** for SPS and **11 kHz** for LHC.
  3. Counting range: from 1 up to  **$10^3$  particles/turn**.
  4. Radiation hardness: neutron flux of about  $10^{12}/\text{cm}^2$  and  $10^{15}/\text{cm}^2$  for SPS and LHC, respectively. Integrated dose up to **kGy/year**.
- Proposal:**  
Cherenkov detector for **proton Flux Measurement ( CpFM )**

## 270 ZGeV/c Xe ion calibration at SPS Beam contamination study



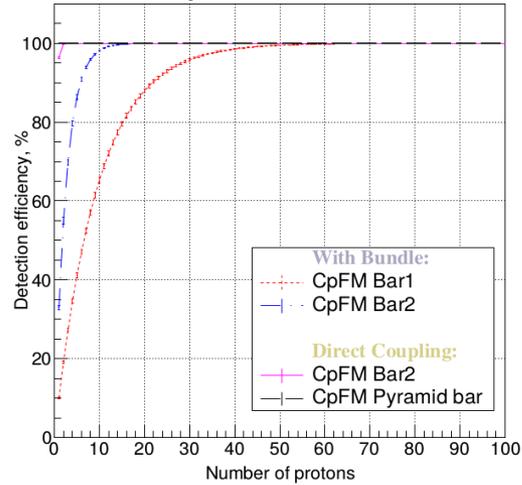
# SPS beam monitoring



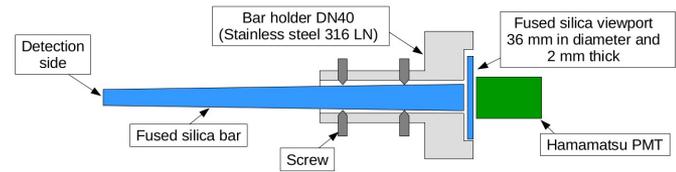
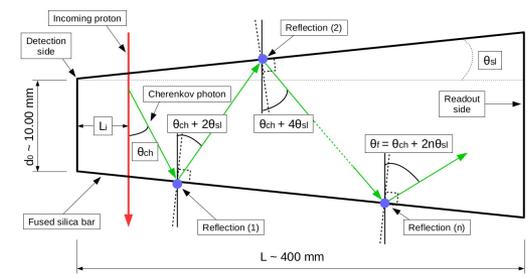
(b) Logarithmic scale in X-axis and Y-axis.

CpFM detection resolution as a function of the impinging protons number.

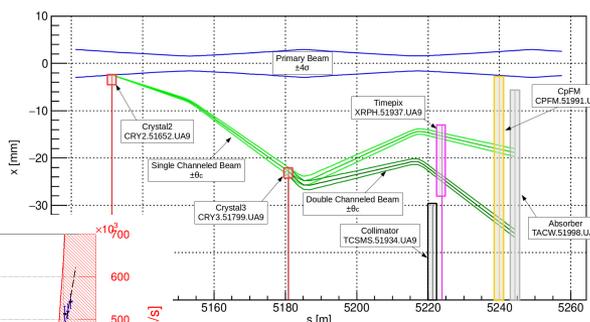
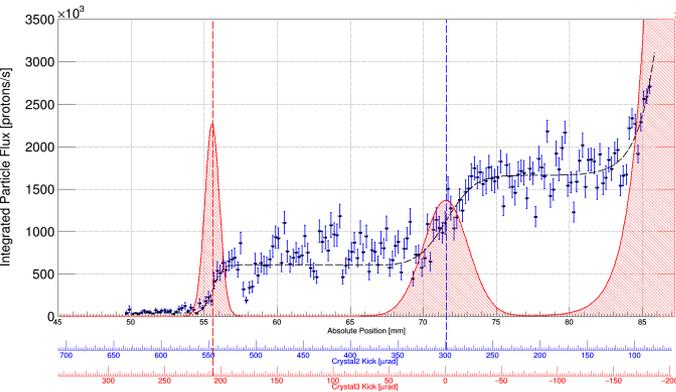
1. The final configuration of the CpFM detector has been developed.
2. The device is sensitive to a single proton with a resolution less than 20 %/proton.
3. Depending on the PMT voltage, particles detection range is  $1 - 10^3$  protons/turn ( $23 \mu s$ ).
4. Due to the high amount of the produced Cherenkov light, a self-calibration with protons can be performed "on fly".



CpFM detection efficiency as a function of the impinging protons number.



SPS 2018 run with 270 GeV/c protons  
Linear scan



CpFM  
Pyramid fused silica radiator with a PMT direct coupling



# Timepix detector

## Timepix:

- a **hybrid** pixel detector;
- **300 μm** thick Silicon layer;
- **14×14 mm<sup>2</sup>** bump bonded read-out chip;
- a matrix formed by **256×256 pixels**;
- each pixel is **55×55 μm<sup>2</sup>**;
- maximum digital counter is **11810 (13.5 bit)**;
- Clock 96 MHz (~10.4 ns).

Modes of the detector operation:

- **Medipix mode**
- **Time of Arrival (ToA) mode**
- **Time over Threshold (ToT) mode**

**Readout:** USB2.0 via FITPix, with a frame rate up to 90 frames/s



Timepix

Quadpix  
(4 Timepix chips)

## Timepix3:

- a **hybrid** pixel detector;
- Silicon/Carbon layer;
- **14×14 mm<sup>2</sup>** bump bonded read-out chip;
- a matrix formed by **256×256 pixels**;
- each pixel is **55×55 μm<sup>2</sup>**;
- Clock 40 MHz (**25.0 ns**) + 640 MHz fast Clock (**1.56 ns**)

Each Timepix pixel can work in one of three modes:

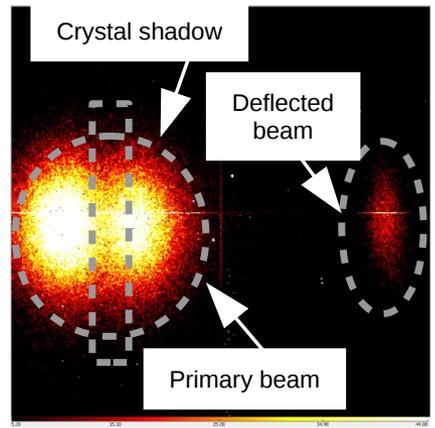
- **ToA+ToT mode** (*ToA 18 bit & ToT 10 bit*)
- **ToA mode** (*ToA 18 bit*)
- **Event count & Integral ToT** (*iToT 18 bit & eCount 10 bit*)

**Readout:** Katherine, Ethernet embedded readout interface, 15 Mhits/s

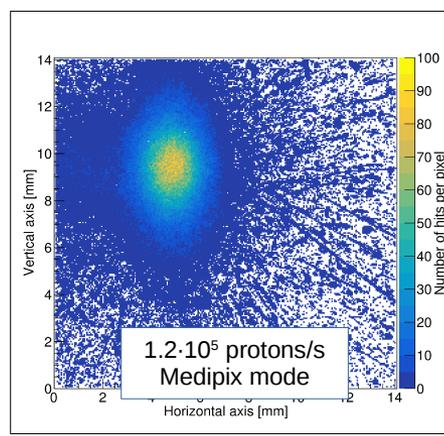


P. Burian<sup>a,b</sup>, P. Broulim<sup>a</sup>, V. Georgiev<sup>a</sup>, M. Jara<sup>a</sup> and B. Bergmann<sup>b</sup>  
<sup>a</sup> Faculty of Electrical Engineering, University of West Bohemia, Univeritni 26, Pilsen, Czech Republic  
<sup>b</sup> Institute of Experimental and Applied Physics, Czech Technical University in Prague, Horská 3a/22, Prague, Czech Republic

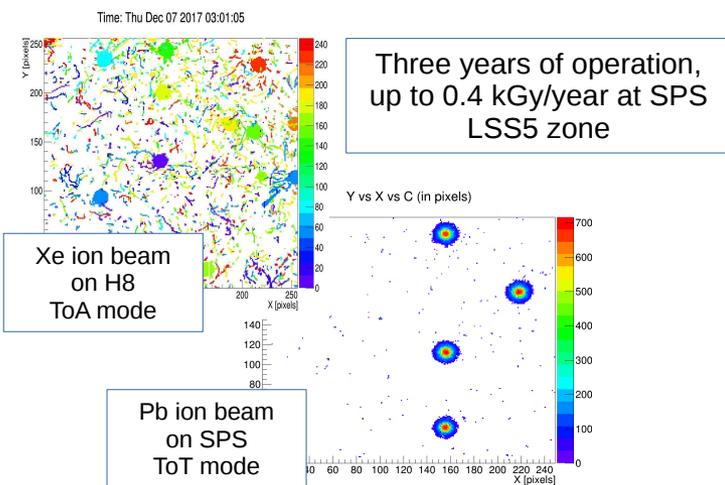
UA9 Collaboration



Quadpix (4 Timepix chips)  
Placed ~50 m from the crystal  
400 GeV/c protons



The image of the proton  
270 GeV/c beam at SPS,  
deflected by the crystal.



Three years of operation,  
up to 0.4 kGy/year at SPS  
LSS5 zone

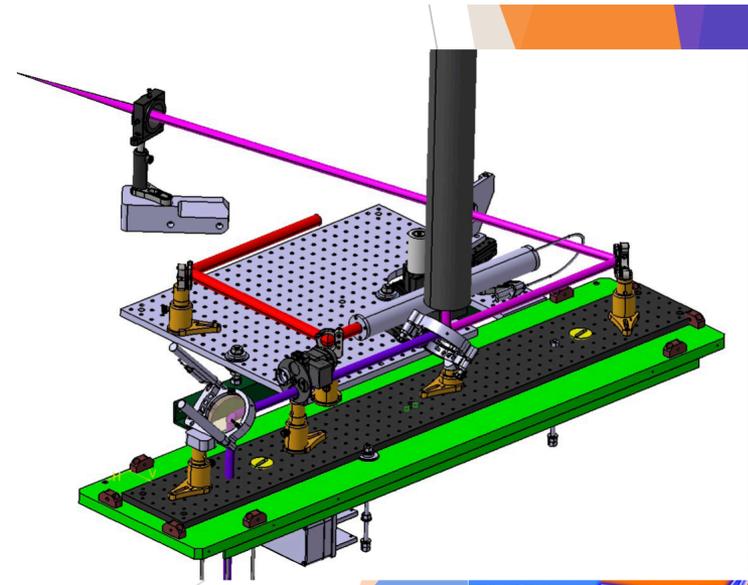
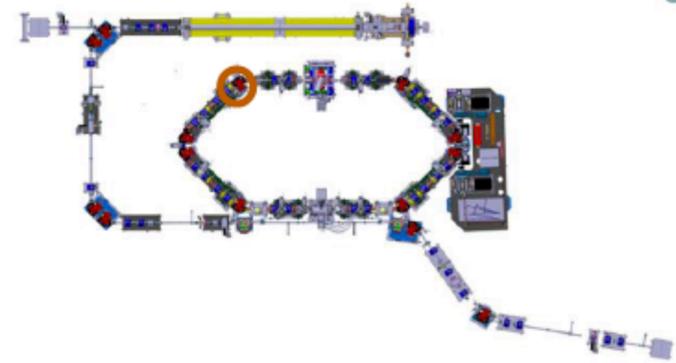
Xe ion beam  
on H8  
ToA mode

Pb ion beam  
on SPS  
ToT mode

# Mesure de profil transverse @ThomX

## Synchrotron Light Monitor (MRSV)

- ▶ **Moniteur de Rayonnement Synchrotron Visible (MRSV)**
- ▶ Visualization of the beam in the Storage Ring in transverse plane
- ▶ A focusing lens placed between the viewport and the CCD would enable the imaging of the stored beam
- ▶ Device:
  - Dipole + Lens + CCD



Cf. N. Delerue slides

ThomX - Diagnostics

I. Chaikovska (LAL) for Diagnostics group - LAL, 29/11/2018

10



# Principe physique

## ▶ **Moniteur de Rayonnement Synchrotron Visible :** **= MRSV**

- Dipole anneau → Rayonnement Synchrotron
  - Position point source = position faisceau
  - Image RS au point source = Image position faisceau
- ## ▶ Système d'**imagerie du point source** dans le dipôle :
- Lentille
  - Caméra

# Mesure de pertes @superKEKB

## Luminosity monitoring: two complementary techniques

**LumiBelle<sup>2</sup>**  
Luminosity Monitoring for Belle II

### LumiBelle2

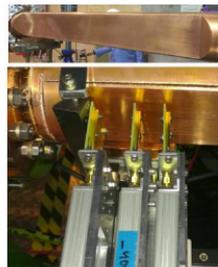
Both measure photons, recoiling electrons or positrons from the extremely forward-angle radiative Bhabha scattering, which has a large cross section ( $\sigma \approx 200 \text{ mbarn}$ ).

- Single crystal CVD diamond sensors;
- $4 \times 4 \times 0.5/0.14 \text{ mm}^3$ ;
- Fast charge/current amplifiers;
- Digital electronics.

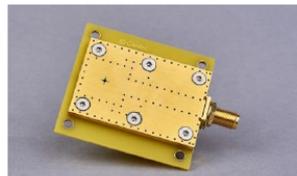
#### GOALS:

- TIL (Train Integrated Luminosity): 1% relative precision at 1kHz;
- BIL (Bunch Integrated Luminosity): monitoring with 1% precision at 1 Hz;
- Large dynamic range with high SNR :

$$L = 10^{32} - 10^{36} \text{ cm}^{-2} \text{ s}^{-1}$$

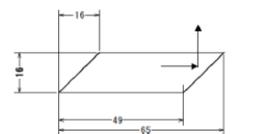


LER



### ZDLM (Zero Degree Luminosity Monitor)

- Cherenkov and scintillator detectors;
- $15 \times 15 \times 64 \text{ mm}^3$  ES-crystal (quartz) and LGSO non-organic scintillator ;
- Photomultipliers;
- Analog electronics;

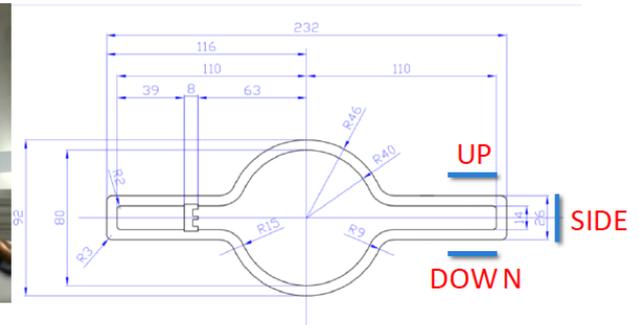
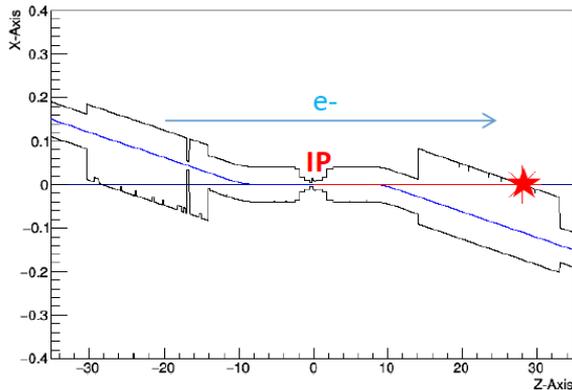


Case outer size:  
25x25x121



# HER (electron) side experimental setup

- Signal: Bhabha photons
- Background: Bremsstrahlung photons, Touschek electrons
- Platform: 30.5-30.8 m downstream of IP
- 3 sensors: up, down, side



# Mesure de longueur de paquets

## Principe physique

- ▶ Mesure de longueur du paquet dans l'anneau :
  - e- dans dipole anneau → **Rayonnement Synchrotron**
  - Longueur impulsion RS = longueur paquet
  - → Mesure longueur impulsion RS
- ▶ Mesure de longueur du paquet en fin de LINAC :
  - e- à travers saphir → **Rayonnement Cerenkov**
  - Longueur impulsion CR = longueur paquet
  - → Mesure longueur impulsion CR
- ▶ Mesure de longueur d'une impulsion lumineuse :
  - → **Streak Camera** → **Longueur paquet d'e-**

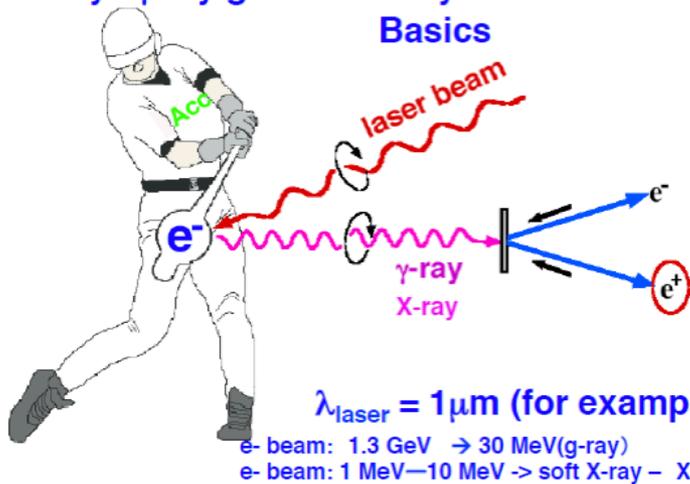
# Cavité Fabry-Perot @ATF2

Cavité (projet LAL  
MightyLaser) utilisée pour  
R&D source de positrons  
polarisés (-> ILC)



X-ray /  $\gamma$ -ray generation by laser-electron collision

Basics



SCIENTIFIC REPORTS

OPEN

High flux circularly polarized  
gamma beam factory: coupling a  
Fabry-Perot optical cavity with an  
electron storage ring

Received: 23 May 2016  
Accepted: 11 October 2016  
Published: 18 November 2016

I. Chaikovska<sup>1</sup>, K. Cassou<sup>2</sup>, R. Chiche<sup>2</sup>, R. Cizeron<sup>1</sup>, P. Cornebise<sup>1</sup>, N. Delerue<sup>1</sup>, D. Jehanno<sup>1</sup>,  
F. Labaye<sup>1</sup>, R. Marie<sup>1</sup>, A. Martens<sup>1</sup>, Y. Peinaud<sup>1</sup>, V. Soskov<sup>1</sup>, A. Variola<sup>1</sup>, F. Zomer<sup>1</sup>, E. Cormier<sup>1</sup>,  
J. Lhermite<sup>1</sup>, V. Dolique<sup>1</sup>, R. Flaminio<sup>1</sup>, C. Michel<sup>1</sup>, L. Pinard<sup>1</sup>, B. Sassolas<sup>1</sup>, T. Akagi<sup>1</sup>, S. Araki<sup>1</sup>,  
Y. Honda<sup>1</sup>, T. Omori<sup>1</sup>, N. Terunuma<sup>1</sup>, J. Urakawa<sup>1</sup>, S. Miyoshi<sup>1</sup>, T. Takahashi<sup>1</sup> & H. Yoshitama<sup>1</sup>

proof of principle experiment

M. Fukuda et al., Physical Review Letters 91, 164801 (2003)  
T. Omori et al., Physical Review Letters 96, 114801(2006)

Merci à F. Zomer