Travaux sur les collisionneurs

- Collisionneurs e^+e^- linéaires : ILC, CLIC (ATF)
- Collisionneurs e^+e^- circulaires: SuperKEKB
- Collisionneurs pp: LHC/UA9, FCC-pp
- Instrumentation associée

Philip Bambade

Laboratoire de l'Accélérateur Linéaire
Université Paris 11, Orsay, France

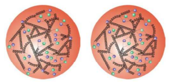
Remerciements : Laurent Brunetti (LAPP), Iryna Chaikovska (LAL), Angeles Faus-Golfe (IFIC/LAL), Walid Kaabi (LAL), Véronique Puill (LAL), Cécile Rimbault (LAL), Isabelle Ripp-Baudot (IPHC)

Conseil Scientifique de l'IN2P3 Paris 16 Juin 2016

Main collider facilities for HEP (1)

motivations, pros/cons, issues, outlook

proton-proton (hadrons) $\leftrightarrow$ electron-positron



parasitic processes / backgrounds

ENERGY REACH

knowledge / control of initial state (momentum, spin)
precision...

MODEL INDEPENDENCE

energy $\leftrightarrow$ precision frontiers

directly probing new phenomena/particles

detecting deviations (via higher order quantum effects...)

electron-positron: linear $\leftrightarrow$ circular

cost & size $\rightarrow$ E **or** E^2 **(synchrotron radiation** $\rightarrow \frac{E^4}{R}$**)**

Luminosity (LC) $\rightarrow$ $\dfrac{efficiency \times power}{E}\sqrt{\dfrac{energy\ spread}{vertical\ emittance}}$

Main collider facilities for HEP (2)

motivations, pros/cons, issues, outlook

proton-proton

LHC → LHC high luminosity — **operating**

FCC-pp (LHC energy upgrade ?) / SPPC — conceptual design study

electron-positron

SuperKEKB (4 × 7 GeV, L = 8 10^{35} cm^{-2} s^{-1}) — **2016-2017 commissioning**
2018 → operation

FCC-ee & CEPC (90 → 250/340 GeV) — conceptual design study

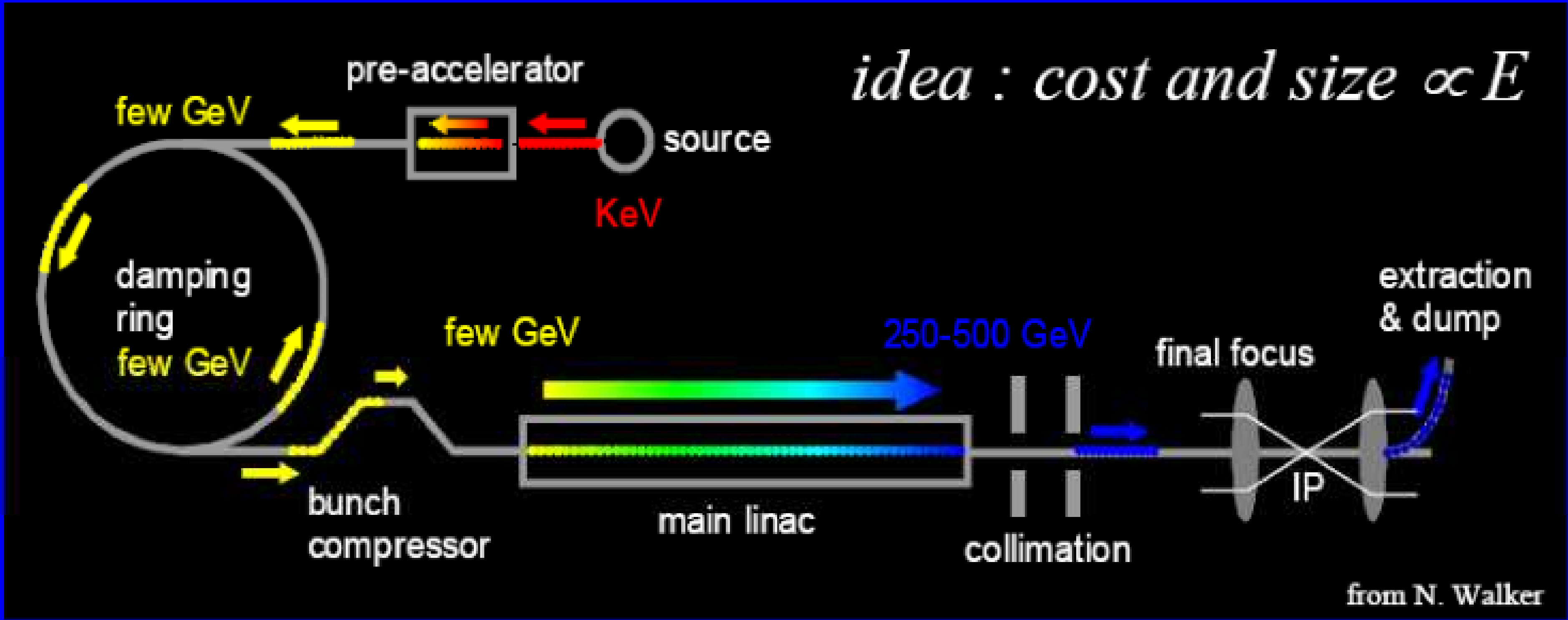
ILC & CLIC (200 → 500 → 1000 → 3000 GeV) — ILC → design is mature
2018: Japan may propose hosting ILC

validation + special R&D : **XFEL/LCLS2 + ATF2 CTF** — **commissioning/plan + operating**
instrumentation **PHIL/PRAE…**

Present IN2P3 contributions

[XFEL coupler production / quality assurance → *talk by D. Longuevergne*	ILC techno. validation + extrapolation	LAL]
Nanobeam handling	ATF2	LAL
Stabilization techniques	CLIC ATF2	LAPP LAPP, LAL
Beam instrumentation	SuperKEKB, LHC ATF2, PHIL CTF3	LAL LAL LAPP
Luminosity monitoring & feedback	SuperKEKB	LAL
Beam loss / induced backgrounds	SuperKEKB ATF2	IPHC, LAL LAL/IFIC
Beam collimation	LHC/UA9, FCC ATF2	LAL, IPNO, LAL/IFIC LAL/IFIC
Intense production of e^+	ILC/CLIC	LAL, IPNL

Linear collider concept



focus
- RF technology (gradient, efficient power transfer)
- beam phase-space control and stability

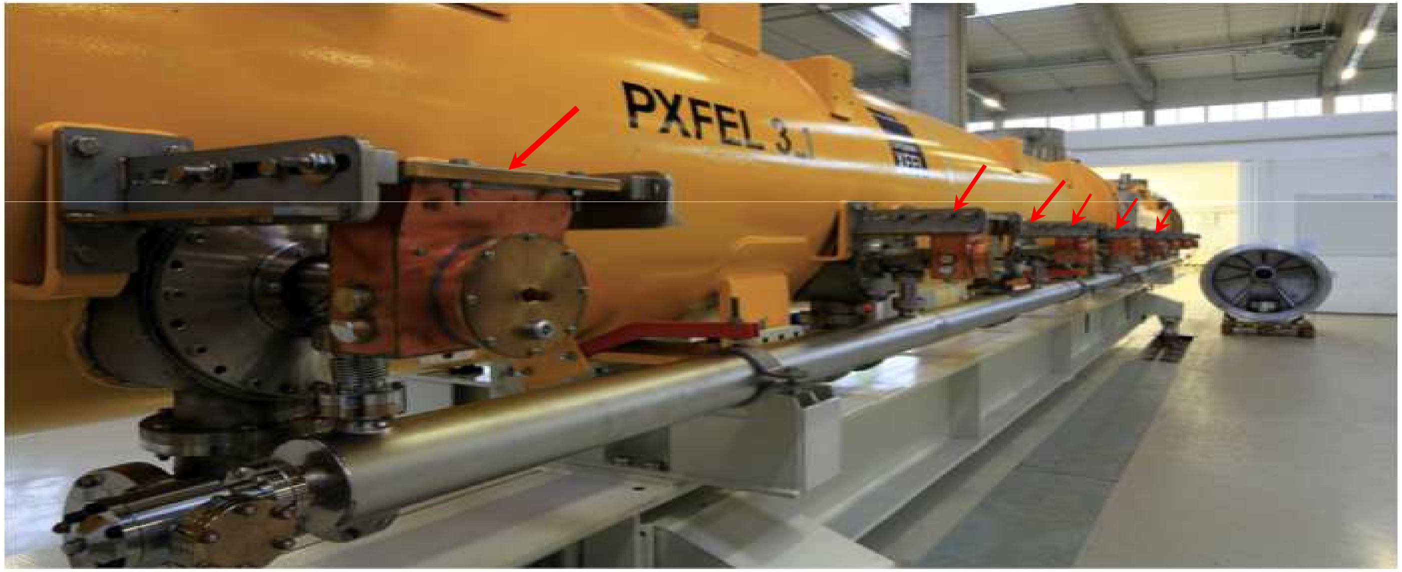
Luminosity $\rightarrow \dfrac{efficiency \times power}{E}\sqrt{\dfrac{energy\ spread}{vertical\ emittance}}$

XFEL at LAL

800 power couplers 1.3 GHz are needed to equip **100 XFEL cryomodules**.

XFEL couplers are produced by 2 suppliers at 3 production sites:

- **Consortium Thales-RI** (Thonon les bains-France and Koln-Germany): **670** units.
- **CPI** (Beverly-Massachusetts-USA): **150** units.



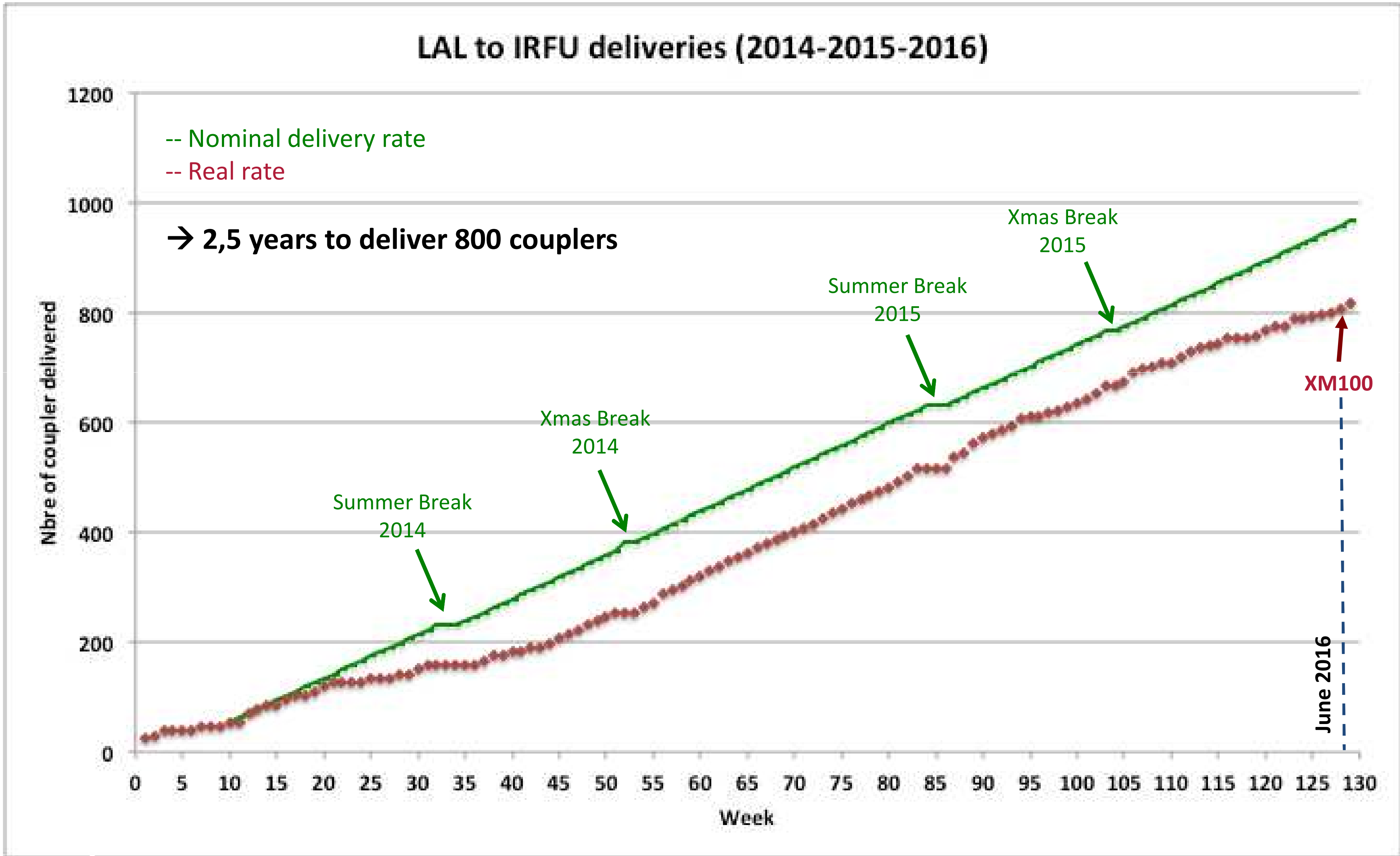
LAL-Orsay has in charge:

- The **production monitoring** and the **quality control** at Thales-RI sites.
- The **RF conditioning** of all the couplers at Orsay and the weekly **delivery of 8 couplers/week** to IRFU-CEA (increased rate to **10 couplers/Week** since **January 2015**) .

XFEL at LAL

Process optimization (coupler preparation and RF conditioning), infrastructure (70 m^2 clean room), equipment (RF station, Baking ovens), tools and manpower allow LAL to process up to 12 couplers/week.

XFEL at LAL


LAL to IRFU deliveries (2014-2015-2016)
-- Nominal delivery rate
-- Real rate
→ 2,5 years to deliver 800 couplers
Summer Break 2014
Xmas Break 2014
Summer Break 2015
Xmas Break 2015
XM100
June 2016
Nbre of coupler delivered
Week
0
200
400
600
800
1000
1200
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130

XFEL at LAL

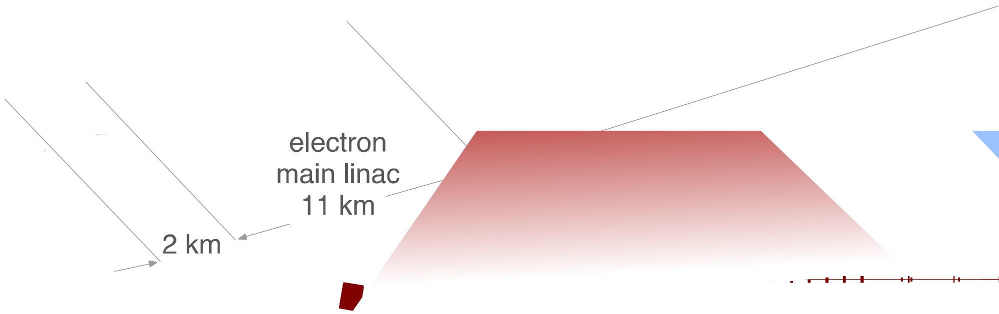
Extrapolation to ILC:

	XFEL	ILC
Energy	17 GeV	500 GeV
Modules	100	2000
Couplers	800	16000

XFEL is considered as a good training and a major asset for LAL-IN2P3/CNRS to be a key player in ILC construction

5% of ILC components were produced within XFEL project

Nanometre scale beam handling at ATF/ATF2



tor Test Facility

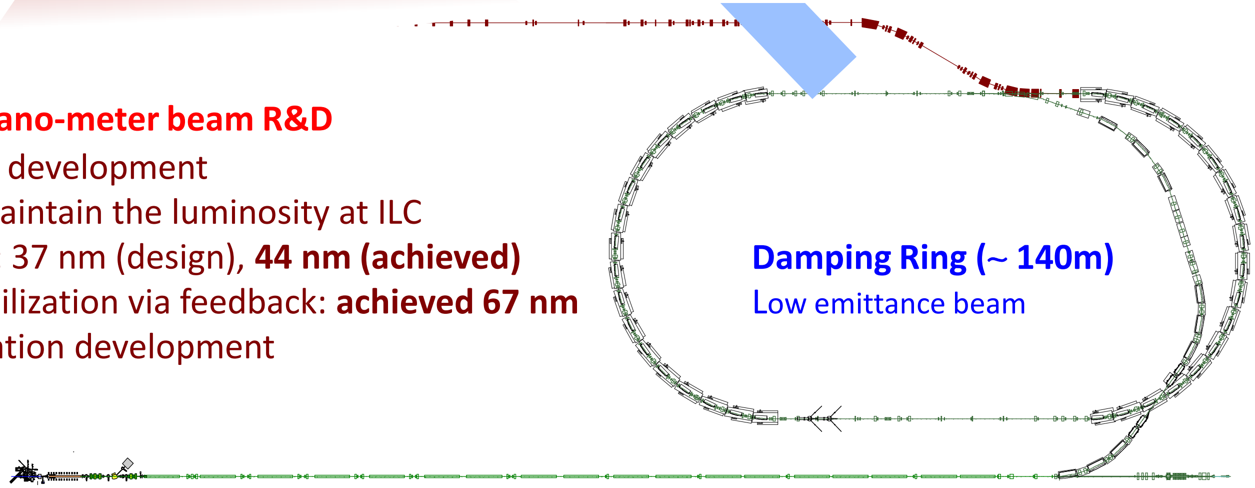
Hz

^{0} e-/bunch

1~20 bunches/pulse

Design emittance:

1 nm(H) / 10 pm(V), Achieved 4 pm(V)



ATF2 beamline: Nano-meter beam R&D

Final focus system development

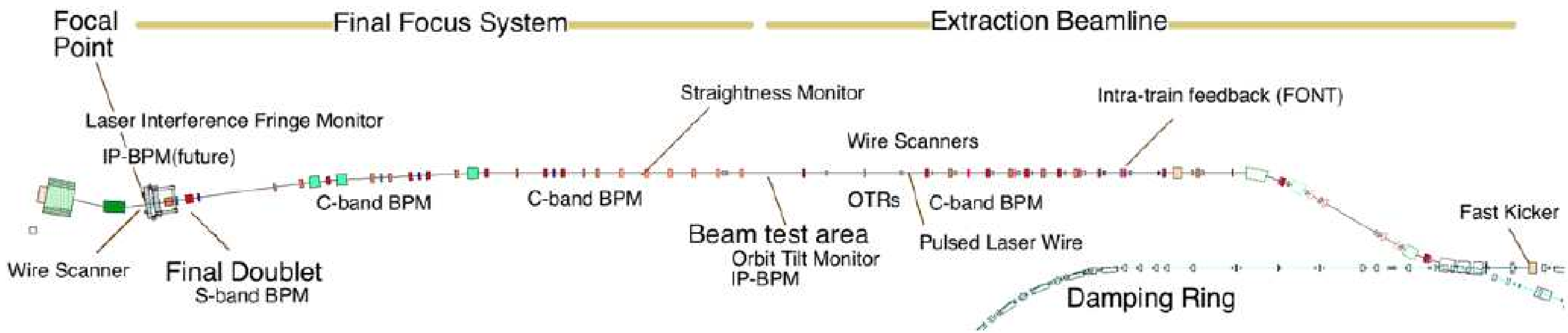
Technologies to maintain the luminosity at ILC

Goal 1: Beam size: 37 nm (design), **44 nm (achieved)**

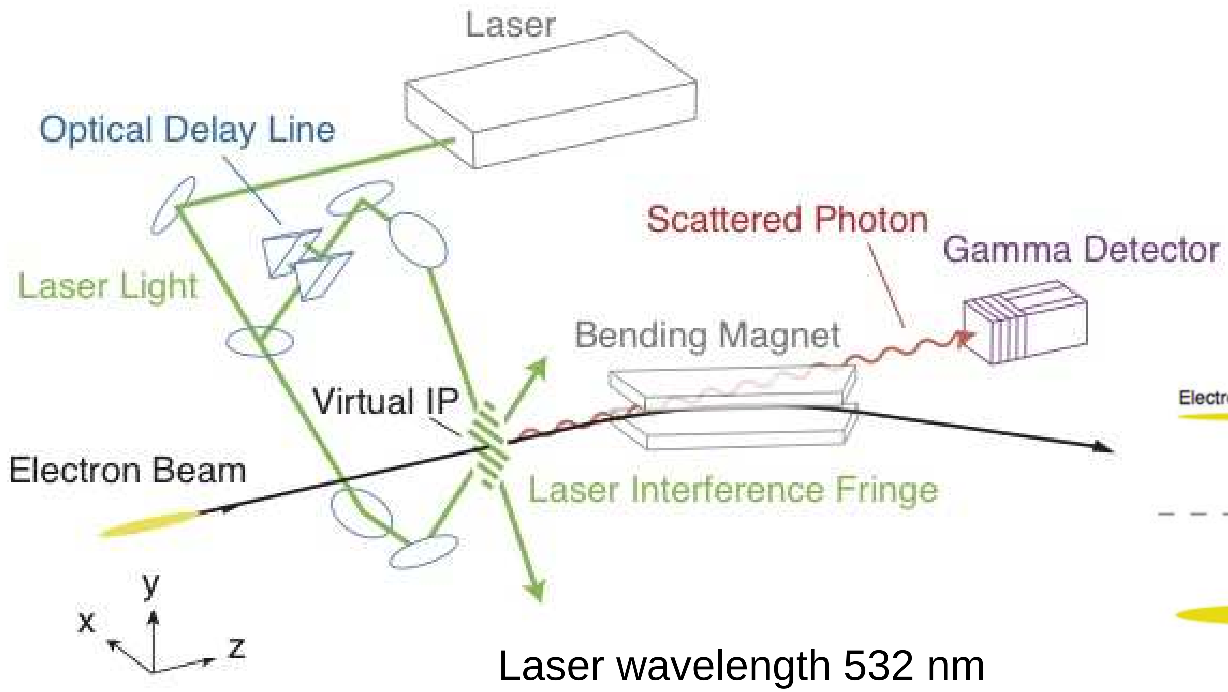
Goal 2: Beam stabilization via feedback: **achieved 67 nm**

Beam instrumentation development

Measuring nanometre beam sizes at ATF2

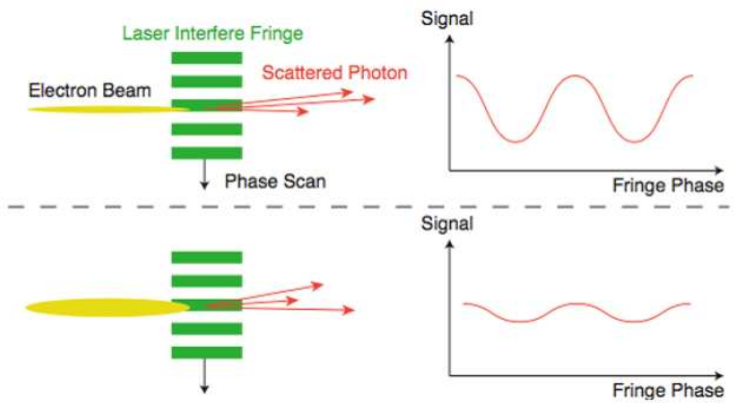


→ 37 nm vertical size

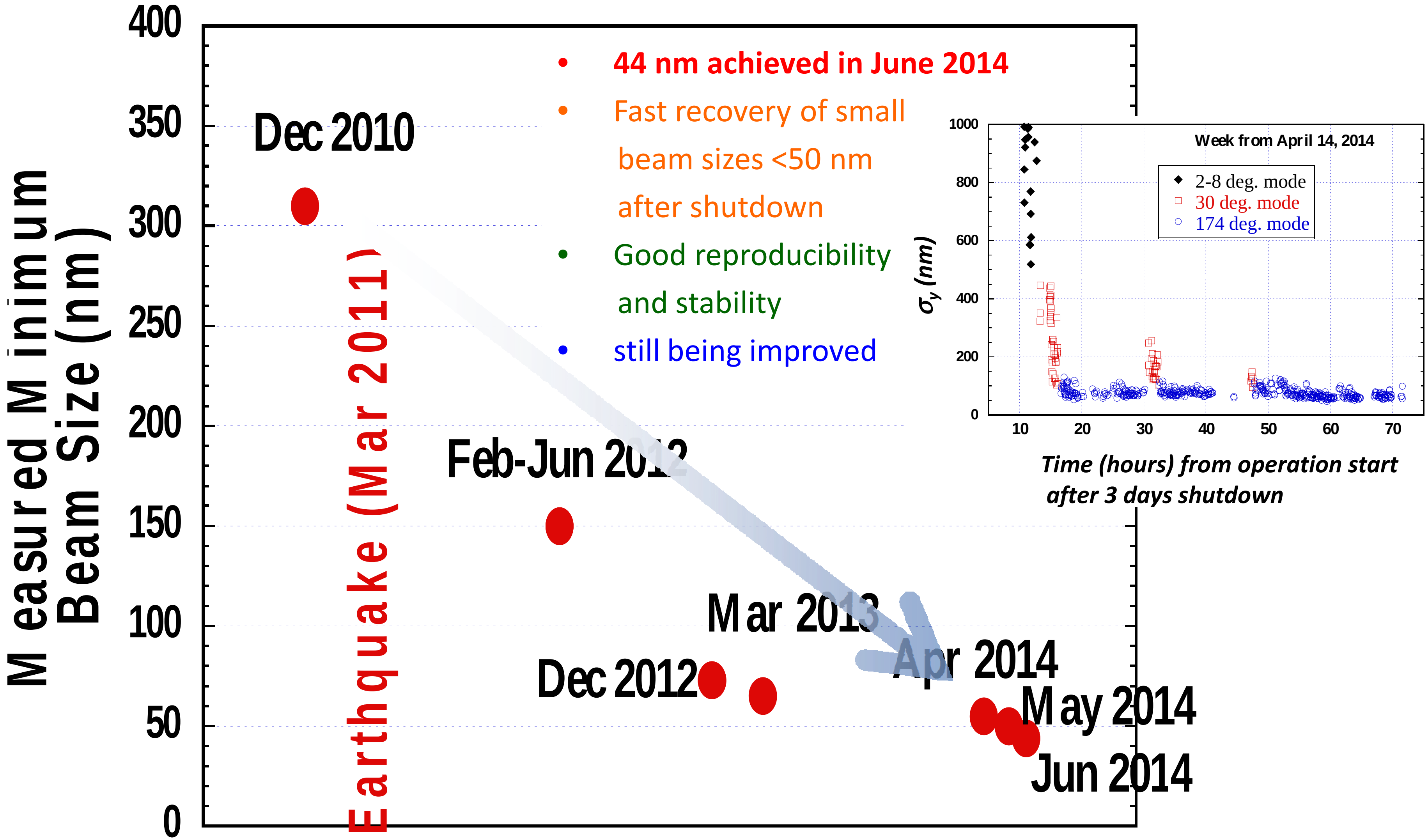


Laser wavelength 532 nm

Modulation of Compton scattered photon rate from beam interaction with laser interference fringe pattern



History of minimum beam size in ATF2

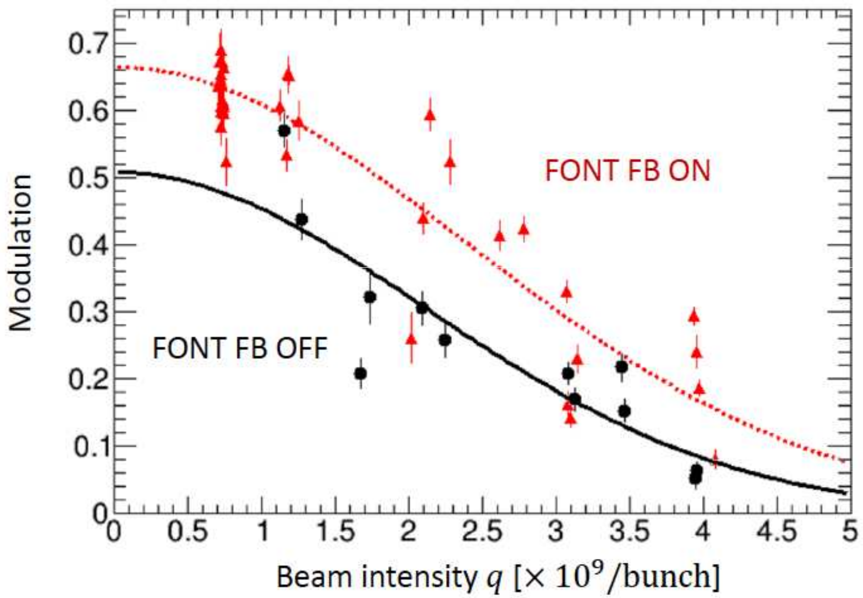


IN2P3 contributes to ATF2 since 2006

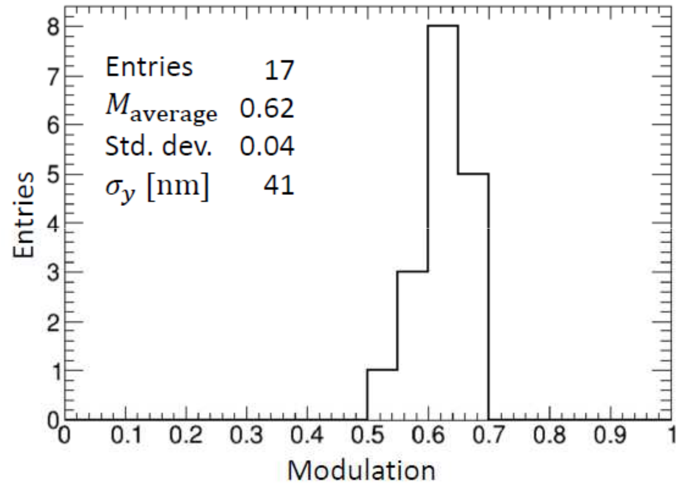
Vertical injection feedback stabilization of 2nd bunch

Stabilize the second and later bunches by using the first bunch as a pilot bunch for the intra-train fast feedback (FONT)→ ILC-like intra train feedback

Result of beam intensity dependence



Result of consecutive measurements with FONT upstream feedback on



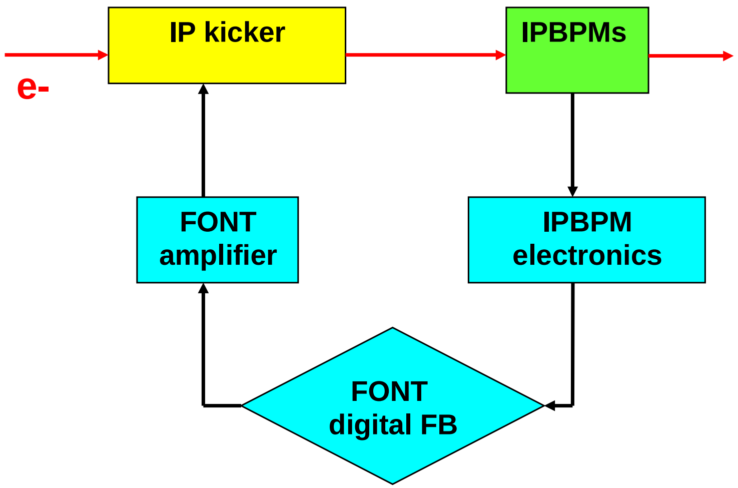
Beam intensity = 0.7×10^9 /bunch
ATF2(MFB1FF) FB off

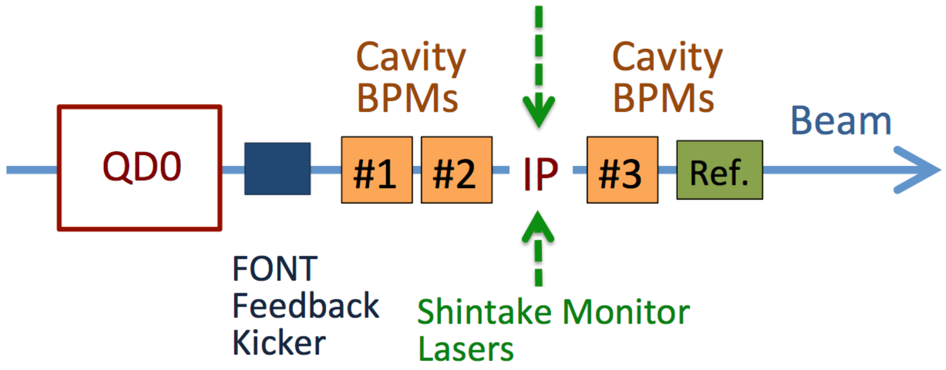
Largest Modulation was achieved

Preliminary : $\sigma_y \sim 41$ nm

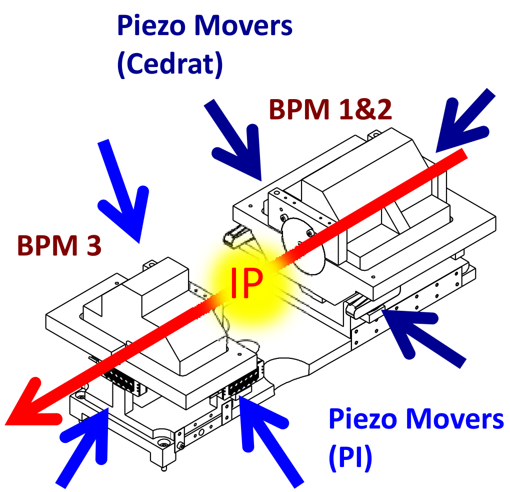
smallest vertical beam size ever achieved

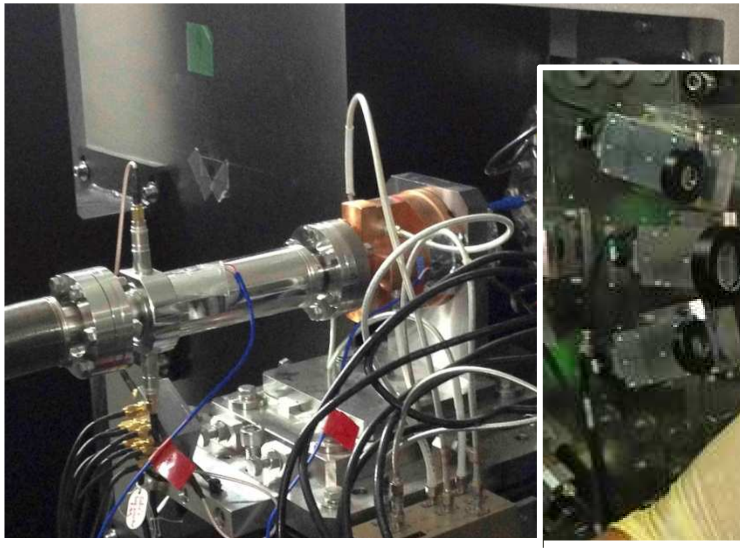
Nanometer stabilization at ATF2 IP





Oscar Blanco
PhD @ LAL





stripline feedback kicker

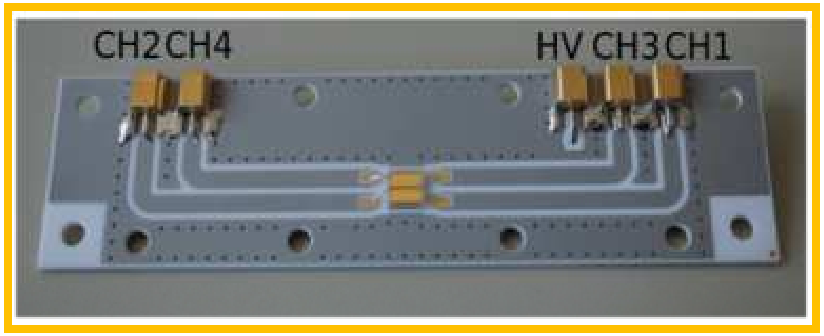
IP-BPM with mover in a vacuum chamber

Diamond sensor scanners at ATF2/PHIL

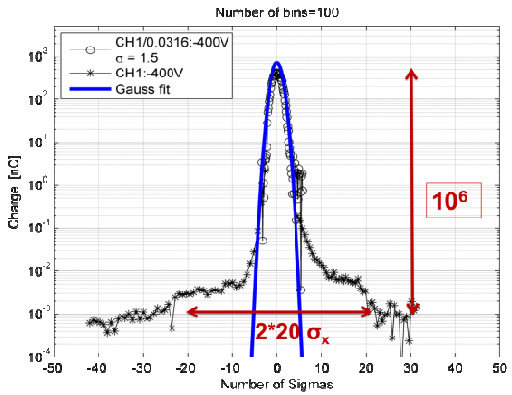
horizontal & vertical

Shan Liu + Renjun Yang
PhD @ LAL

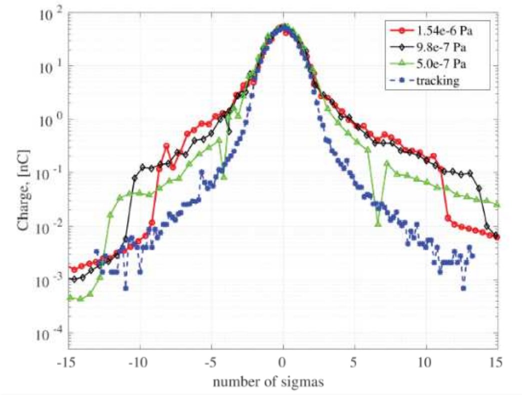
Measure the beam halo distribution with high dynamic range (~ 10^6)

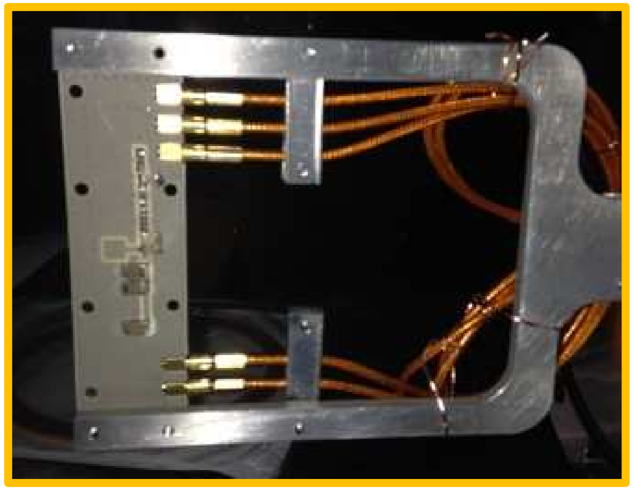


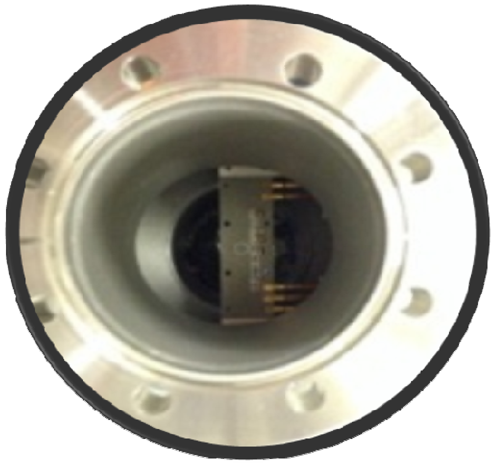
collaboration with CIVIDEC

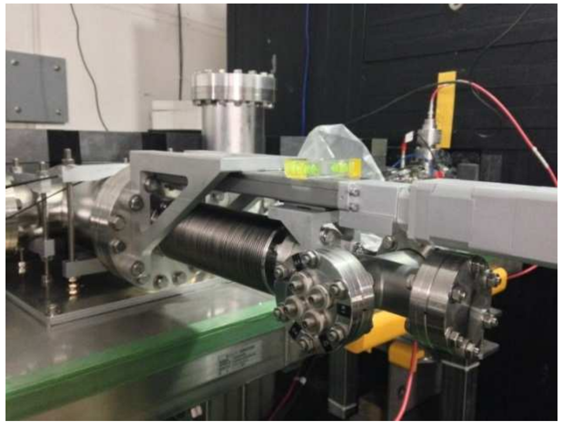


Dependence with ATF ring vacuum pressure





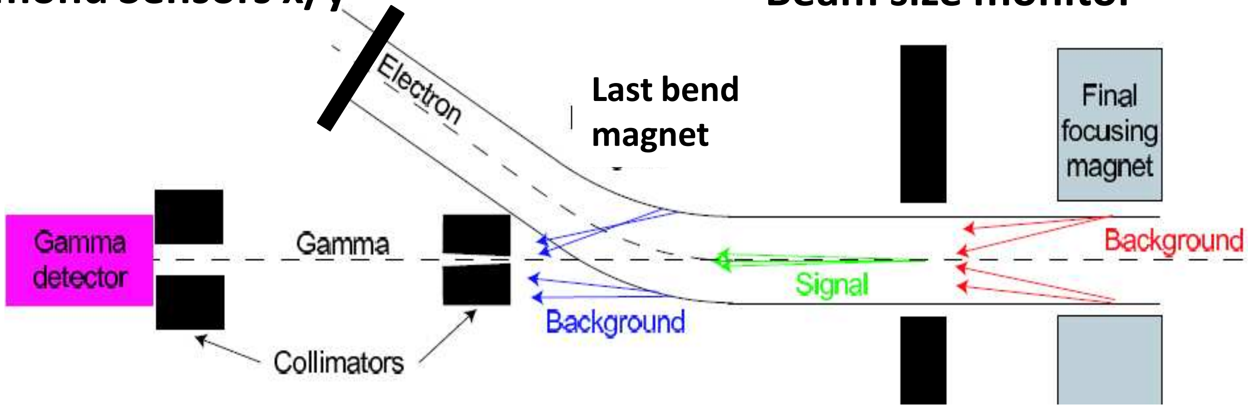




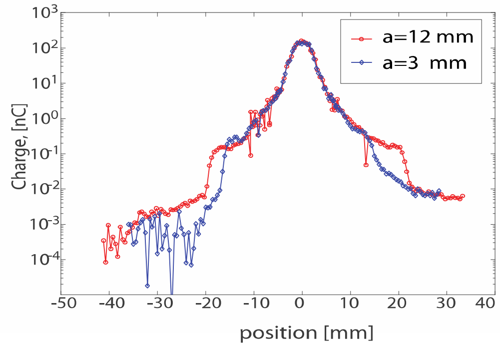
Collimator for beam halo & background control

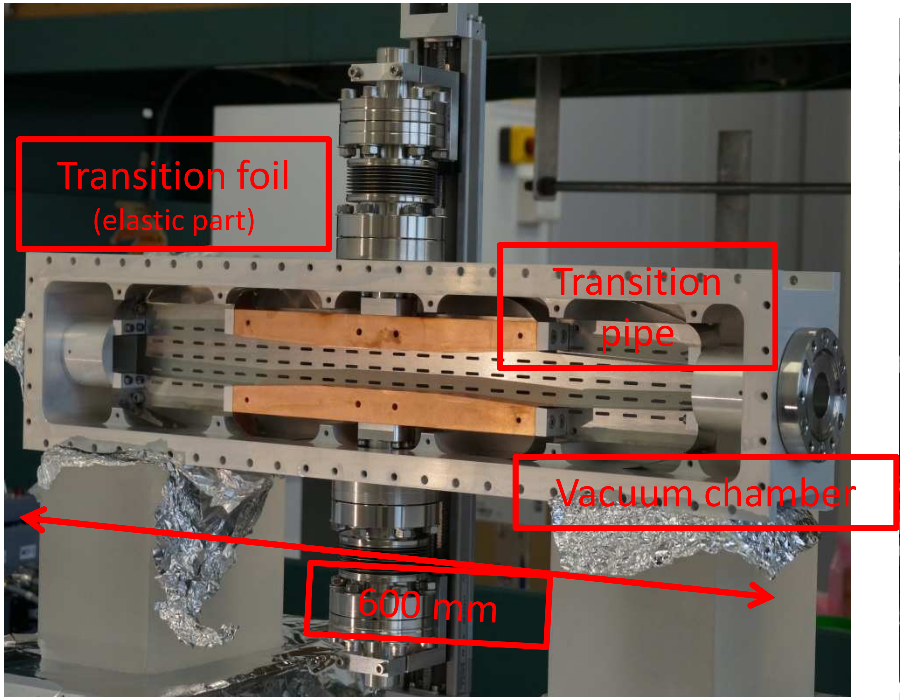
Diamond Sensors x/y

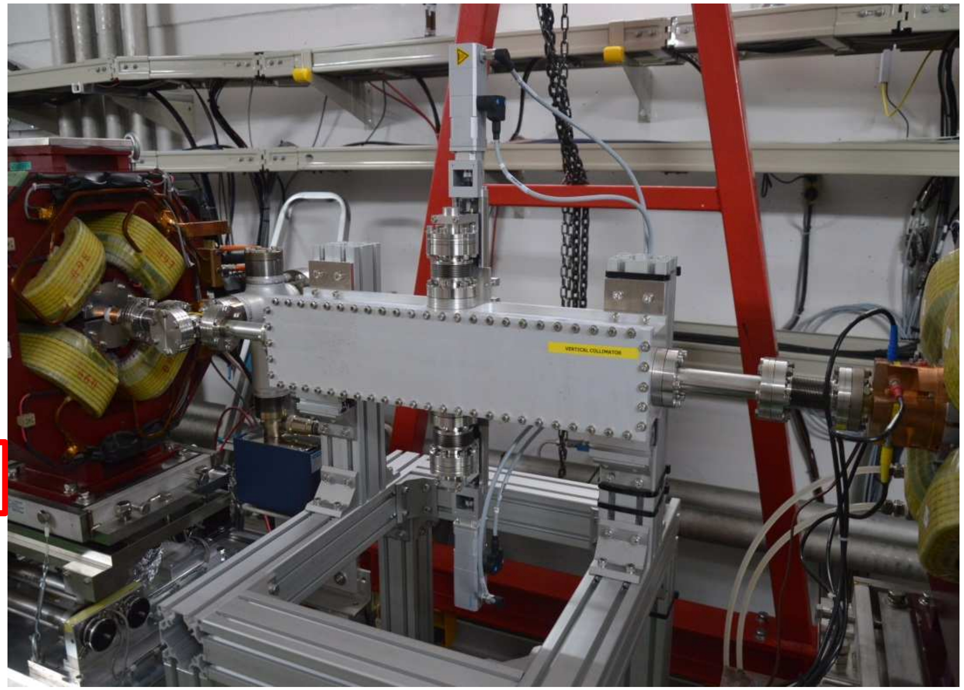
Beam size monitor



Halo distribution with/without collimation





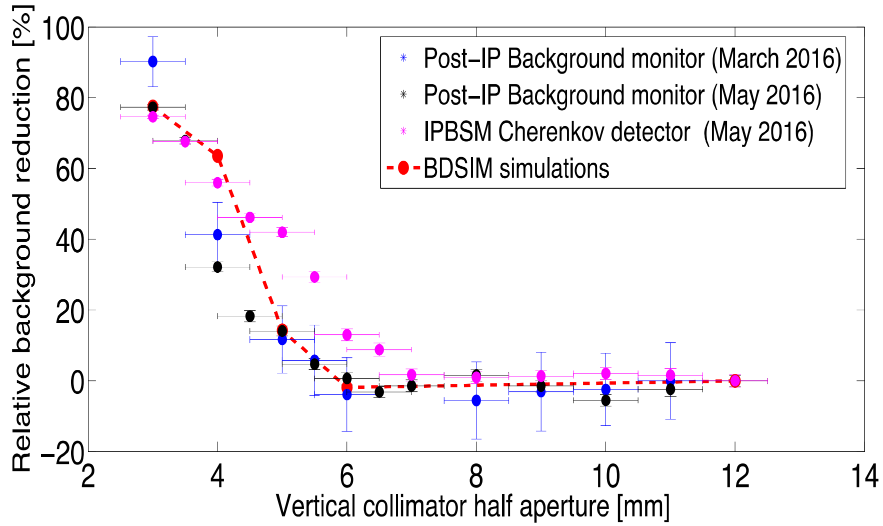


Collimator performance studies and first comparison

Nuria Fuster, PhD IFIC + LAL

❑ **Collimator efficiency studies**

❑ Benchmarking of MADX and BDSIM/GEANT4 tracking simulations with real measurements



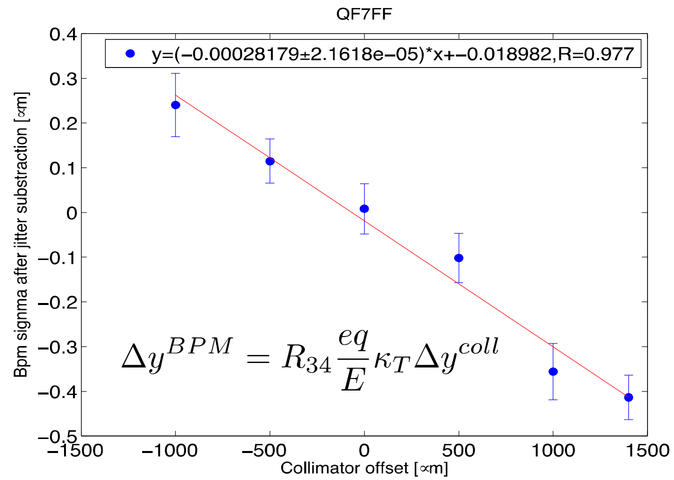
❑ **Collimator wakefield studies**

- **Collimation → tradeoff between efficiency and induced wakefields**
- **ILC betatron collimation system** requires small apertures for efficient halo cleaning while mitigating induced wakefields
- ATF2 **vertical collimation system** based on a first mechanical **design for ILC**

- Collimator orbit wakefield impact measurements (March and May 2016)

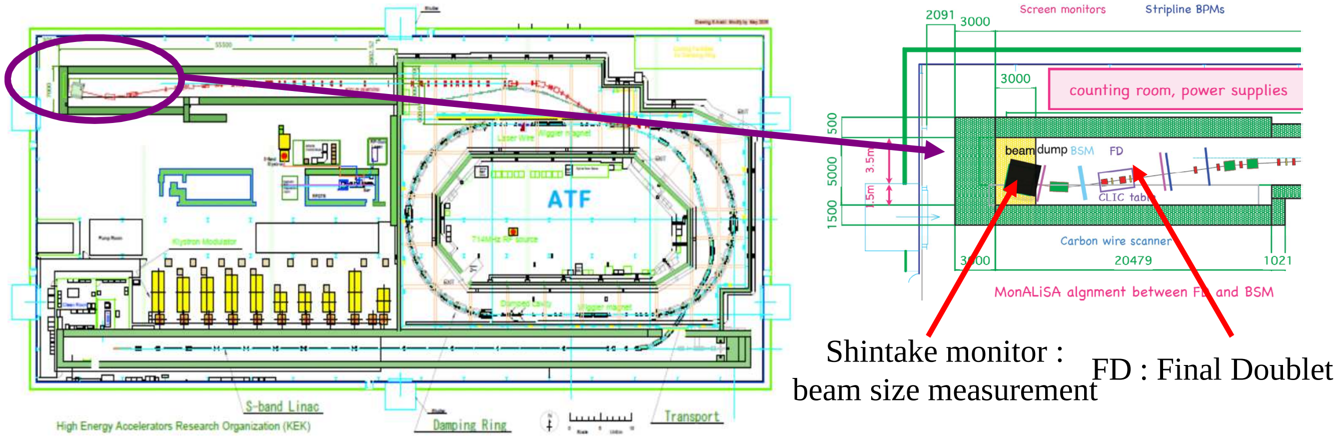
❑ Benchmarking with theoretical models and numerical simulations

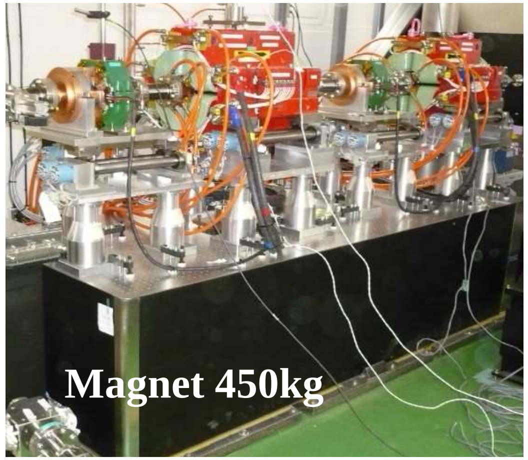
❑ Scaling the impact to the ILC scenario



➢ *ATF2* LAViSta – Beam Vibration control at the interaction point

- **Final doublet relative displacement**

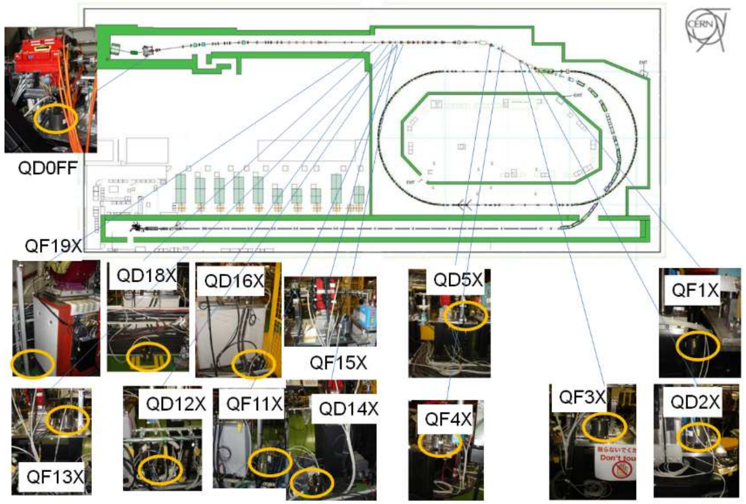




- Relative motion between Shintake monitor and final doublets of 6 nm RMS @ 0,1 Hz in the vertical axis.
- Analysis of the upgrades influences and of the drift (new QF1 support).
- Reducing by a factor 4 to 6 the vibration level (vertical rms from 21nm to 6nm at 1Hz)

Benoit Bolzon, PhD LAPP

- **Feedforward study**



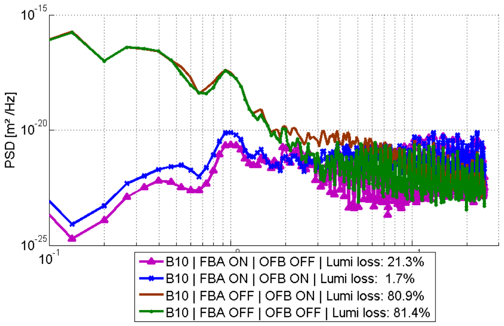
➢ Processing 14 Guralp 6T GM sensors

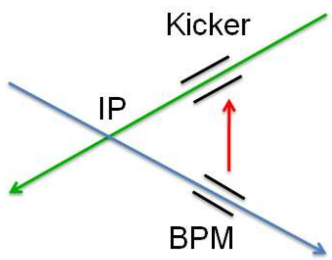
- Vibration sources identification
- Feedforward study: correlation between the ground and the beam motions.

- *Pfingstner et al, « Mitigation of ground motion effects in linear accelerators via feed-forward control", Phys. Rev. ST Accel. Beams 17, 122801, December 2014.*

➢ *CLIC R&D* LAViSta – Beam Vibration control at the interaction point

- **Trajectory control of the beam:**

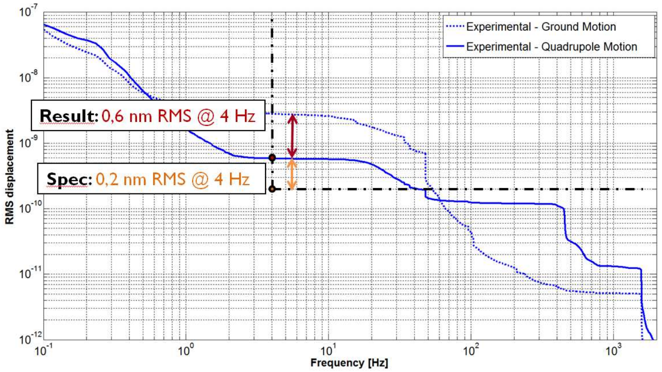




➢ **Simulation results (PLACET - CERN)**
0,1 nm RMS @ 0,1Hz

- *G. Balik (LAPP) et al, Integrated simulation of ground motion mitigation, techniques for the future compact linear collider (CLIC), Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 700 (2013) 163-170.*
- *B. Caron, G. Balik, L. Brunetti, A. Jérémie, "Vibration control of the beam of the future linear collider", Control Engineering Practice 20 (2012) 236*

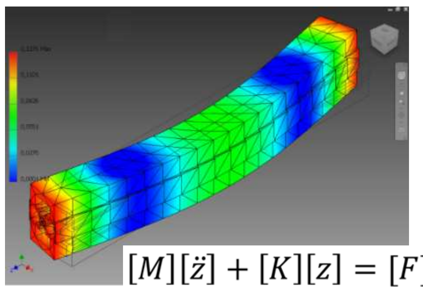
- **Demonstration of a mechanical sub-nanometer active control:**
  - Development of a prototype with piezoelectric actuators, commercial sensors (geophones and accelerometers) managed by complex control laws.
  - **Obtained results: 0,6 nm RMS@4Hz** **(vs specifications of 0,1 nm RMS@4Hz)**



➢ *Performances limitation due to the instrumentation…*

- *G. Balik (LAPP) et al, Sub-nanometer active seismic isolator control, Journal of Intelligent Material Systems and Structures 24 (15) (2013) 1785-1795.*
- *R. Le Breton et al, Nanometer scale active ground motion isolator, Sensors and Actuators A: Physical, 2013.*

- **Simulation of the whole system (IP) and control of QD0**
  - Development of the whole simulation (magnet, sensor, actuator, ADC, DAC, Data processing…. And seismic motion model and its coherence) with the control loops → specifications of actuators and sensors
  - Control of a dummy magnet at a real scale

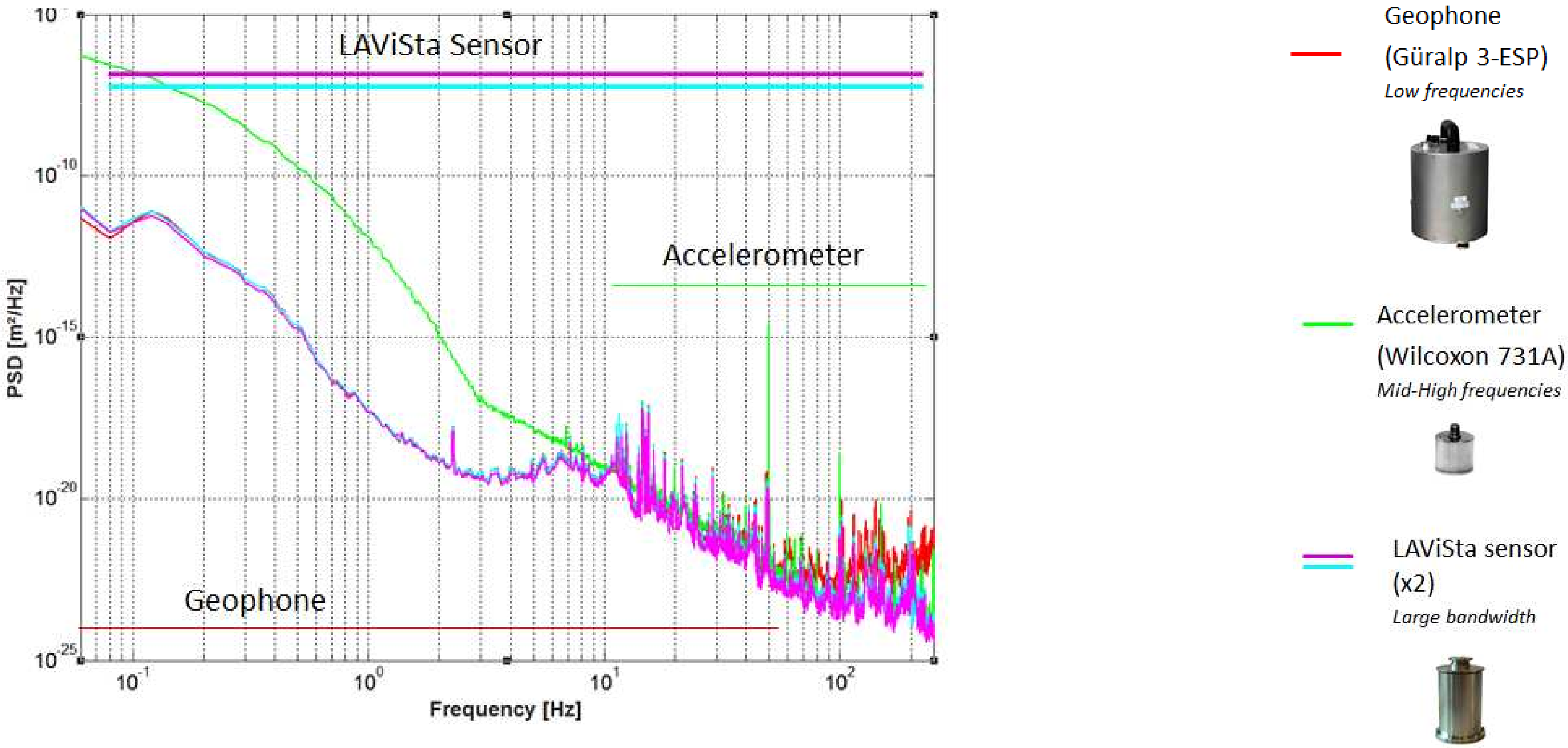


$$[M][\ddot{z}] + [K][z] = [F]$$

➢ *CLIC R&D* LAViSta – Beam Vibration control at the interaction point

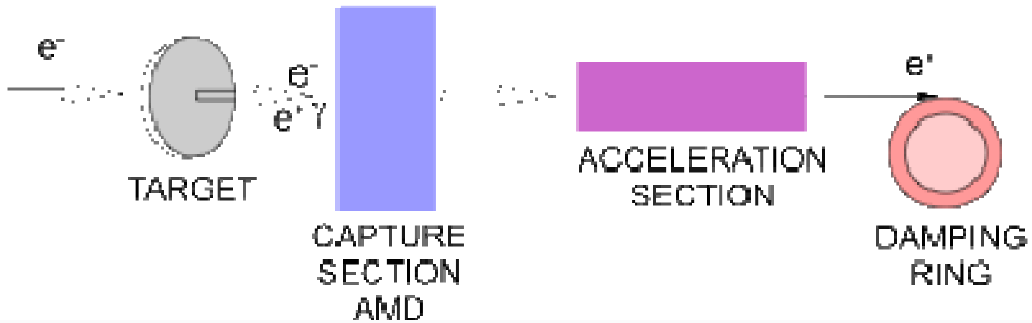
- **Development of a vibration sensor:**
  - Promising results (similar to the best commercial sensors on a larger bandwidth)
  - **French patent (FR 13 59336), PCT extension in progress**
  - Optimized version in test (measurement in vertical or horizontal) for measurements and for active control
  - Triaxial version in progress
  - Outreach with the SATT of Grenoble (Linksium)

Developed prototypes



Positron Sources

Conventional positron source: bremsstrahlung and pair conversion



Energy deposition in target => Heating
Inhomogeneous energy deposition => Peak Energy Deposition Density (PEDD) => mechanical stresses => target failure!

☞ Very difficult to realize for the future linear colliders due to the target thermal and mechanical stresses issues.

- SLC e+ source: ~ 3.5e10 e+/bunch & 1 bunch/train & 120 Hz => 0.042e14 e+/s
- CLIC e+ source: ~ 4e9 e+/bunch & 312 bunch/train & 50 Hz => 0.6e14 e+/s
- ILC e+ source: ~ 2e10 e+/bunch & 1312 bunch/train & 5 Hz => 1.3e14 e+/s

Better solution: Two-stage process to generate the positron beam.

First stage: γ-ray generation.

Second stage: e-/e+ and γ-ray beams are separated and the latter is sent to the target-converter.

The γ-rays can be generated by the following methods:

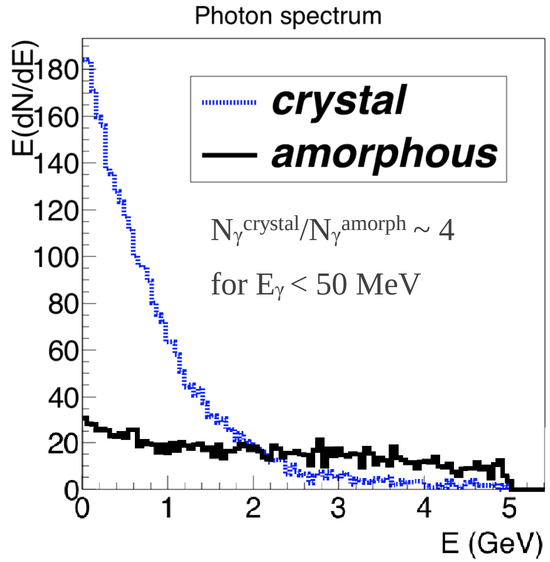
- **Radiation from helical undulator (polarized e+)**
- **Channeling radiation (unpolarized e+)**
- **Compton scattering (polarized e+)**

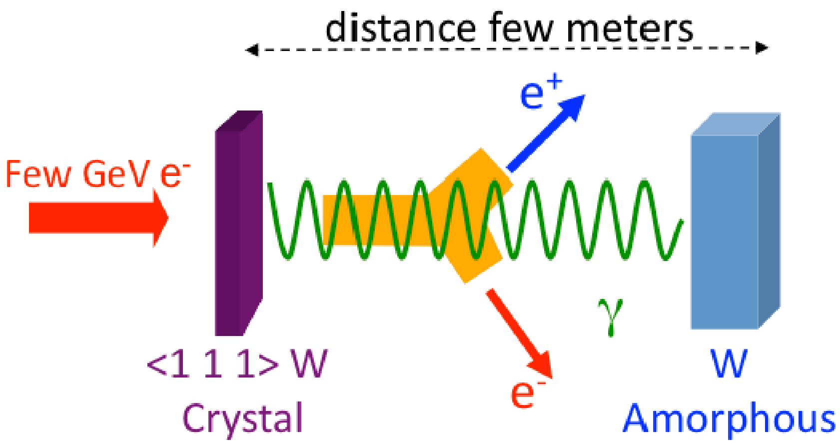
Iryna Chaikovska, PhD LAL

Unpolarized e+ Source: Hybrid Scheme

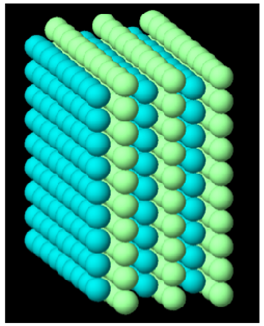
LAL, IPNL, CERN, IHEP and KEK
Original proposal : R. Chehab V. Strakhovenko and A. Variola

- Uses intense ***channeling*** radiation emitted by GeV electrons channeled along a crystal axis
- Soft photons are enhanced in the crystal compared to the amorphous target => mainly due to ***channeling***





Replace compact target by a **granular** one made of **small spheres** for the conversion



Granular target-converter

Granular target can provide **better heat dissipation** associated with the ratio Surface/Volume of the spheres and the **better resistance to the shocks**.

Hybrid scheme is adopted by the CLIC baseline design of the e+ source and can be a good candidate for the ILC e+ source backup solution.

Hybrid Scheme: Recent Investigations (1)

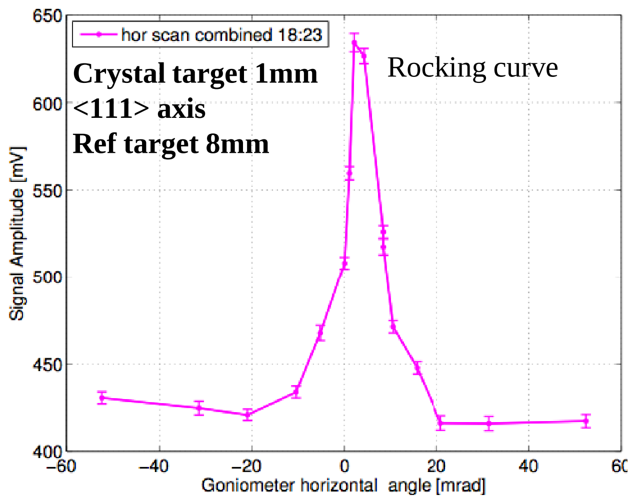
- Beam tests **of LAL granular converter** at KEKB injector

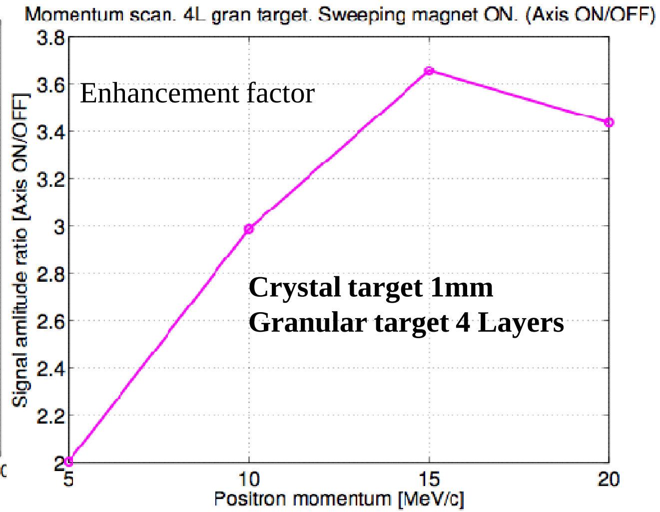
  October 2015 + October 2016 → systematic data

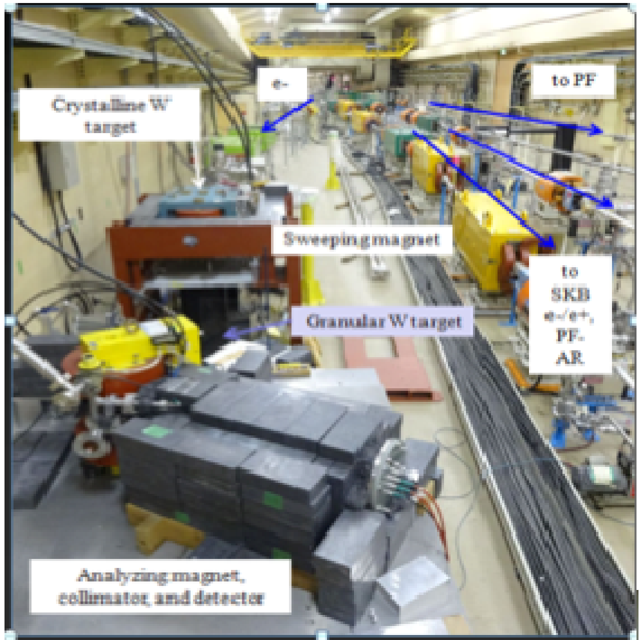
  E = 7 GeV, 1 mm rms beam size, 1nC, 25 Hz

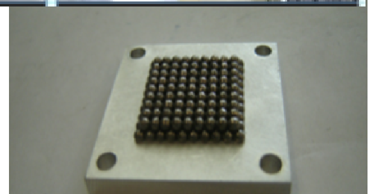
- **Goals: e+ yield and temperature rise measurements to compare different target-converters → assess e+ source performances**

Preliminary results








Granular targets for the experiment:

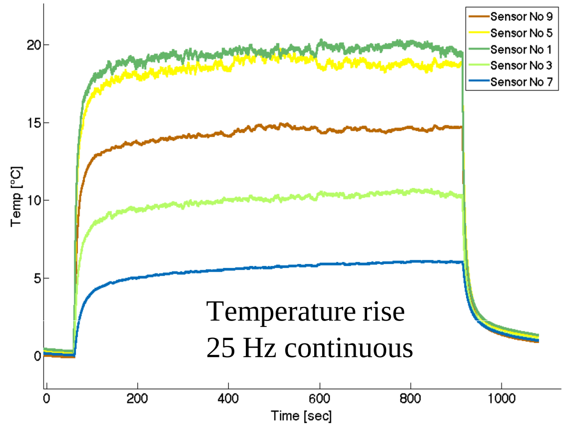
- e+ of 5-20 MeV were selected by magnetic analyzer and measured by Cherenkov detector
- Different configurations studied to characterize e+ production in the hybrid scheme

Geant4 to estimate the target energy deposition, e+ yield and detection acceptance → on-going

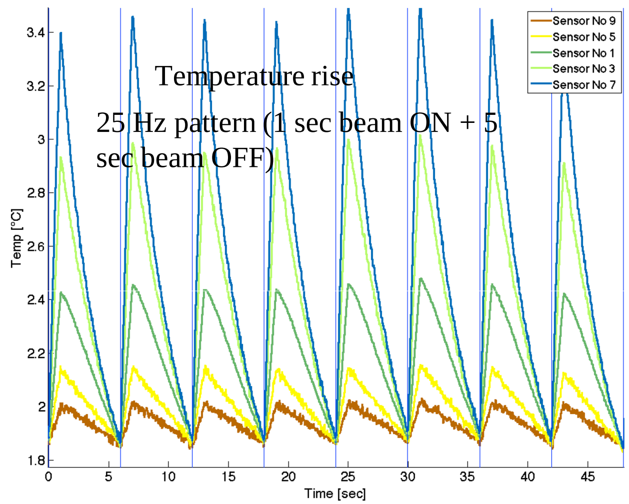
Hybrid Scheme: Recent Investigations (2)

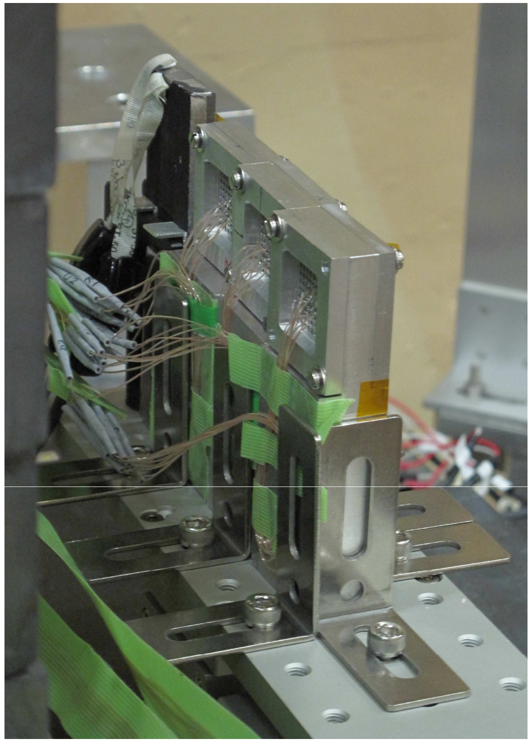
Thermocouples placed on granular target exit faces (adjacent spheres) to measure the temperature rise

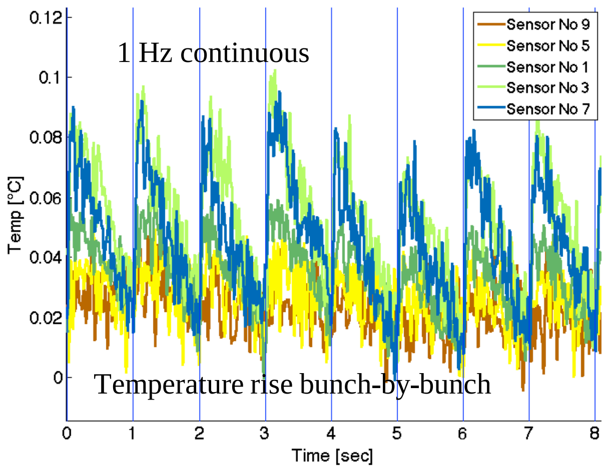
☞Temperature @ equilibrium → **Total Energy Deposition**
☞Bunch-by-bunch temp. rise → **Peak Energy Deposition Density (PEDD)**



Preliminary results







Regime	T rise [°C]
25 Hz	19.93 (1 meas)
25 Hz pattern	1.62 ± 0.04
1 Hz	0.08 ± 0.01

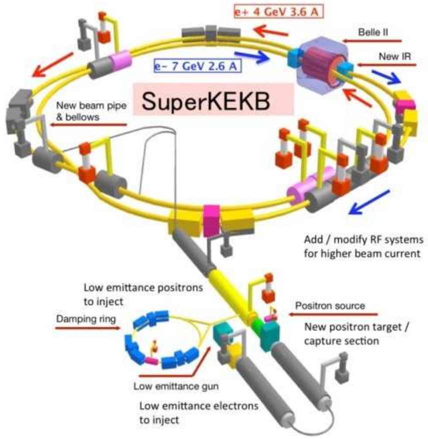
Temperature distribution and thermal shocks simulations in granular converter → on-going

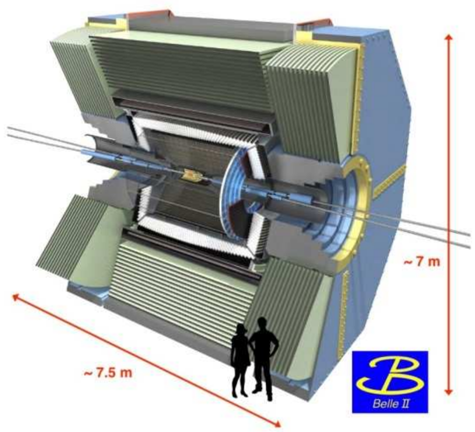
GOAL → improve understanding of thermal load and heat dissipation in the target

SuperKEKB / Belle-II Machine-Detector Interface

Scientific scope : Lumi × 40 → enhanced anomaly search, rare decays, especially missing energy channels

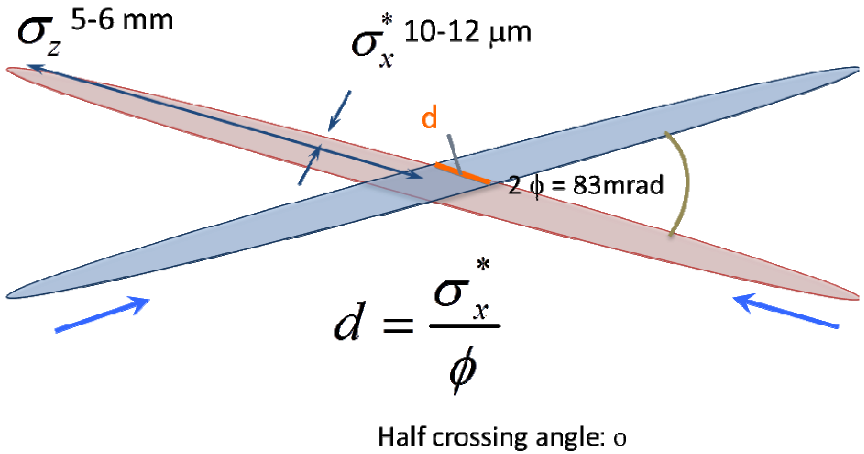
- Luminosity monitoring & tuning
- Control beam induced backgrounds
  1) Phase 1 : 2016/Feb. → Jun.
     - single beam commissioning, vac. scrubbing
     - no luminosity (no final focus), no detector
  2) Phase 2 : 2017/Nov. → 2018/Mar.
     - colliding beam commissioning, no vertex detector
  3) Phase 3 : from 2018/autumn
     - full luminosity for physics running





parameters		KEKB		SuperKEKB		units
		LER	HER	LER	HER	
Beam energy	E_b	3.5	8	4	7.007	GeV
Half crossing angle	φ	11		41.5		mrad
# of Bunches	N	1584		2500		
Horizontal emittance	ε_x	18	24	3.2	4.6	nm
Emittance ratio	κ	0.88	0.66	0.27	0.25	%
Beta functions at IP	β_x^*/β_y^*	1200/5.9		32/0.27	25/0.30	mm
Beam currents	I_b	1.64	1.19	3.6	2.6	A
beam-beam param.	ξ_y	0.129	0.090	0.088	0.081	
Bunch Length	σ_z	6.0	6.0	6.0	5.0	mm
Horizontal Beam Size	σ_x^*	150	150	10	11	um
Vertical Beam Size	σ_y^*	0.94		0.048	0.062	um
Luminosity	**L**	**2.1 x 10^{34}**		**8 x 10^{35}**		$cm^{-2}s^{-1}$

Nano-Beam Scheme SuperKEKB (design)



β_y = 300 μm   d ~ 300 μm

→ **mitigates beam-beam and hour-glass effects…**

Beam background at SuperKEKB

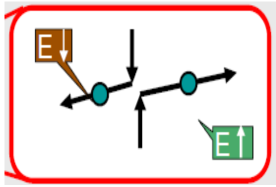
- At SuperKEKB with x 40 larger luminosity, beam background will also increase drastically

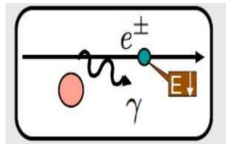
Beam-origin

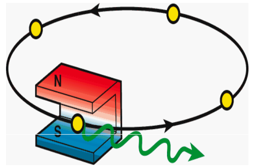
- – Touschek scattering
- – Beam-gas scattering
- – Synchrotron radiation

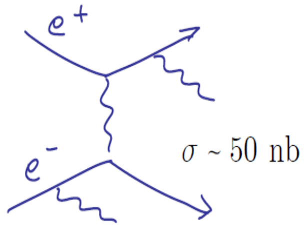
Luminosity dependent

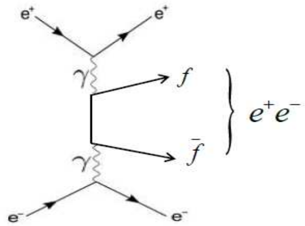
- – Radiative Bhabha event: emitted γ
- – Radiative Bhabha event: spent e+/e-
- – 2-photon process event: e+e-→e+e-e+e-
- – etc…

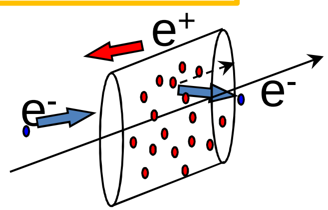








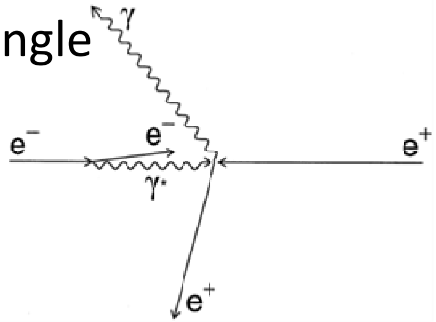




Fast Luminosity Monitoring with Diamond Sensors for Belle-II/SuperKEKB

- **Conception, development & installation of fast lumi monitor @ SuperKEKB rings for feedback in presence of dynamical imperfections, fine tuning and survey during physics runs.**

- aimed relative precision: $\delta L/L \sim 10^{-2}$ to 10^{-3} in 1 to 10ms
- Lumi monitoring for each bunch crossing: 2500 bunches, collision every 4 ns
- Measurement: radiative Bhabha scattering at zero photon angle
  - Large cross-section: ~0.2 barn
  - Proportional to L



- Technologies: set immediately outside beam pipe

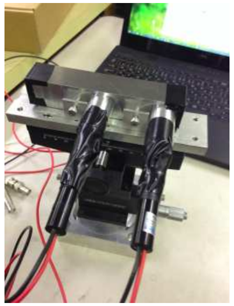
5 x 5 mm^2 diamond sensors

Cerenkov detector + scintillator

(Radiation hardness,

Fast charge collection)

ZDLM Group



LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

Plans for next years

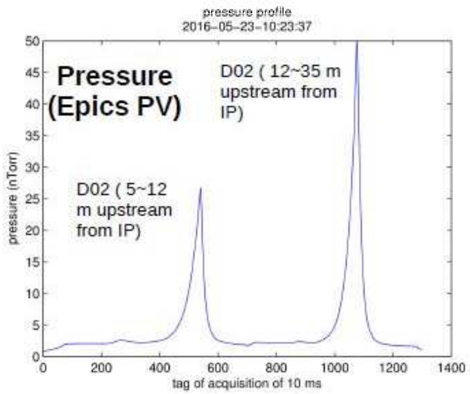
Initial setup (fall 2015)

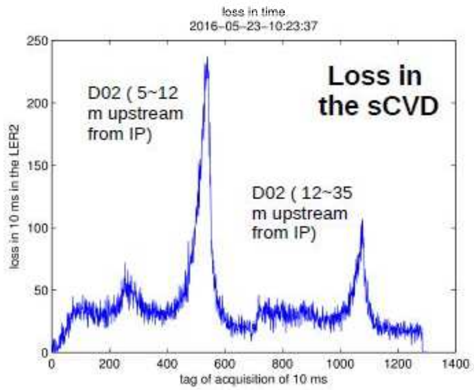
- Four 500 μm sensors, in LER/HER at 11/30 m resp.
- DAQ based on fast digital scope synchronized to RF
- Real-time processing with 5-6 latency for debugging and background investigation

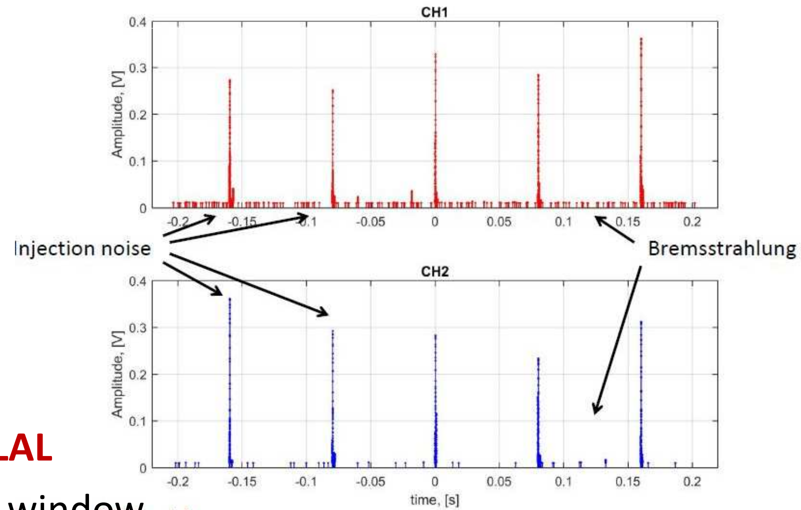
2016: Phase 1 tests (feb – june 2016) and analysis:

- Bremsstrahlung detection and measurements
- Initial background measurement analysis and beam loss mecanism studies (Brems, Coulomb, Touschek)
- Finalize DAQ for luminosity monitoring (+ feedback ?)

Signals from LER fast luminosity diamond sensors 01-03-16







2017 -2018

Dima El Khechen + Pang Chengguo, PhD LAL

- Mechanical integration % sensors for new LER vacuum window
- First data for luminosity monitoring & analysis
- Optimization in context of luminosity feedback
- System / parameter optimization for bunch-by-bunch monitoring at full 8 10^{35} $cm^{-2}s^{-1}$ luminosity (charge/current ampl., 500/140 μm sensor, thresholds…)

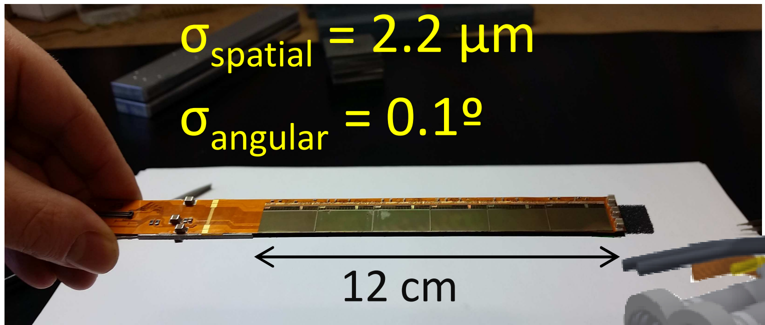
Measurement of SuperKEKB induced background with PLUME pixel detectors

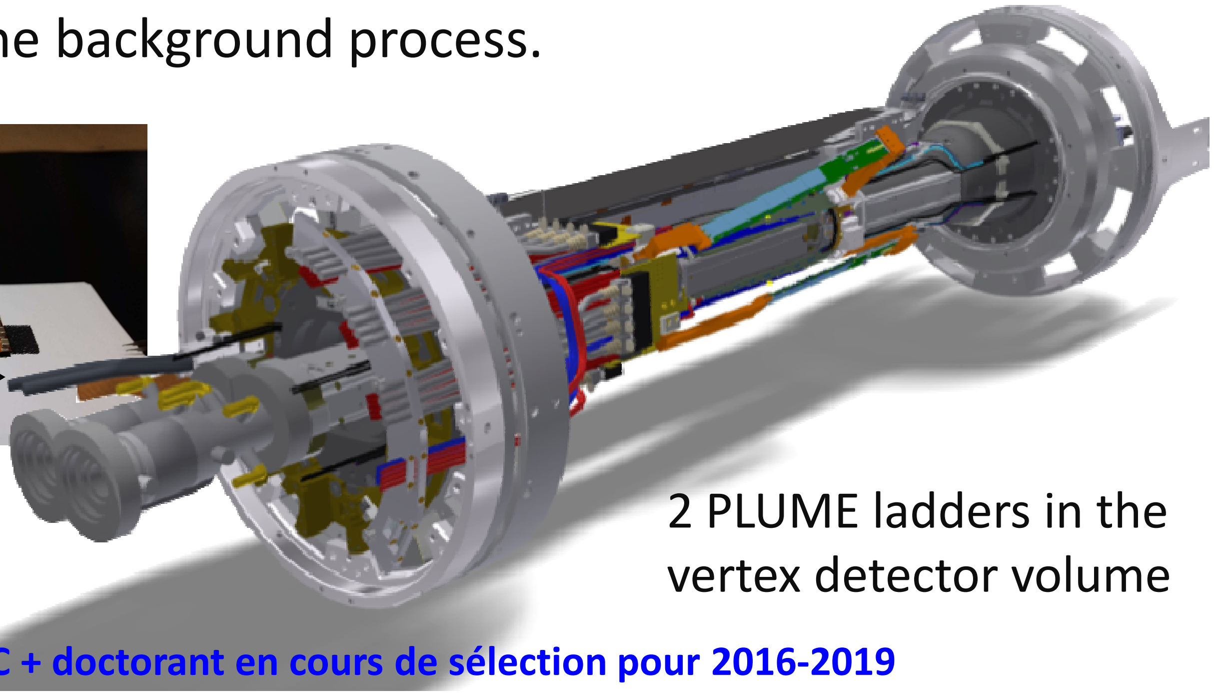
- BEAST II: **B**eam **E**xorcism for **A ST**able Belle **II** experiment
  - Commissioning of Belle II and SuperKEKB.
  - First collider with nano-beams, targeted lumi.: 8×10^{35} cm $^{-2}$ s $^{-1}$.
  - Phase 2 data taking: Nov. 2017 – April 2018, collider mode tuning.

- IPHC contribution to BEAST Phase 2:
  - First study of impact of nano-beam induced background in the vertex detector of Belle II:
    - On-line: hit rate, radiation level.
    - Off-line: identification of the background process: single beam (Touschek, beam gas, synchrotron), beam-beam (radiative Bhabha, 2-photons pair).
  - Validate simulation of nano-beam induced background: extrapolation of measurements done at 10^{34} cm $^{-2}$ s $^{-1}$ over 2 orders of magnitude.

Measurement of SuperKEKB induced background with PLUME pixel detectors

- PLUME detector:
  - Equipped with CMOS pixel (18×18 μm^2) sensors.
  - Ladder R&D for vertex detector @ILC (Bristol, DESY, IPHC).
  - Very light self supported device (for 2 measured points): 0.35 % X_0.
  - Double sided pixel layer: enhanced information
    - ➛ tracking possible with a single layer, also of MeV particles,
    - ➛ identification of the background process.





- Integration in a very constrained volume.

2 PLUME ladders in the vertex detector volume

Robert Maria, PhD IPHC + doctorant en cours de sélection pour 2016-2019

Broader view of LAL & IPHC contribution to SuperKEKB

- 1st goal @ LAL: fast luminosity measurement and beam loss diagnostics
  → contribute to commissioning & SuperKEKB feedback system
- 1st goal @ IPHC: beam background assessment in Belle 2 inner tracker volume
  → experimentation and modeling

Beam-beam physics in the context of first collider with nano-beam scheme

- backgrounds from low Pt process → critical for Belle-2 exp. conditions… FCC-ee,CEPC…
- special QED features of processes at vanishing Pt for nanometer beam sizes

- LAL ↔ IPHC collaboration → MIBEL ANR application in 2016
- Close collaboration with Belle 2 / BEAST and SuperKEKB communities at KEK

1. Couples naturally to a possible French contribution to Belle-II
2. LAL & IPHC groups jointly considering the physics program, starting in 2018
3. Potential IPHC interest in contributing to a future inner detector upgrade

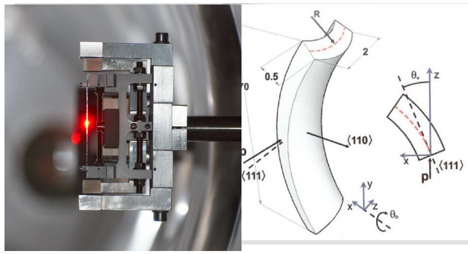
IN2P3 BEAST effort

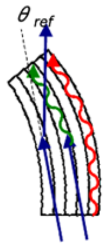
excellent preparation and strategy for future e^+e^- colliders, not only SuperKEKB/Belle 2

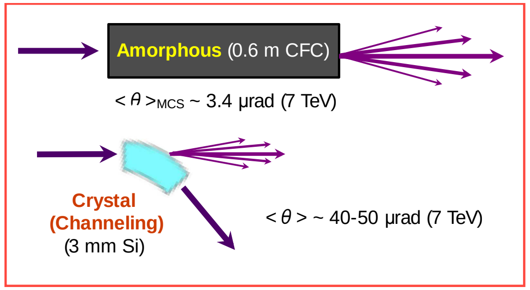
UA9

Investigate bent crystals as primary collimators in hadron colliders

- Bent crystals work as a "smart deflectors" on primary halo particles (W. Scandale 10.1103/PhysRevSTAB.11.063501)



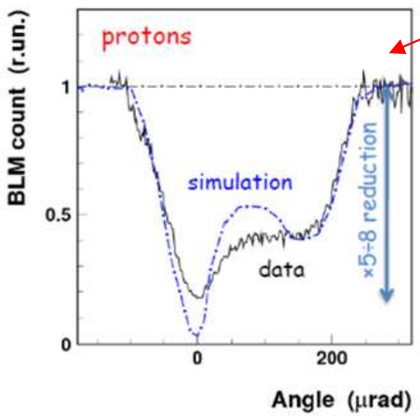




- If crystalline planes are correctly oriented, particles are subjected to a coherent interaction (channeling)

The UA9 Collaboration is investigating how to use bent crystals as primary collimators/deflectors:

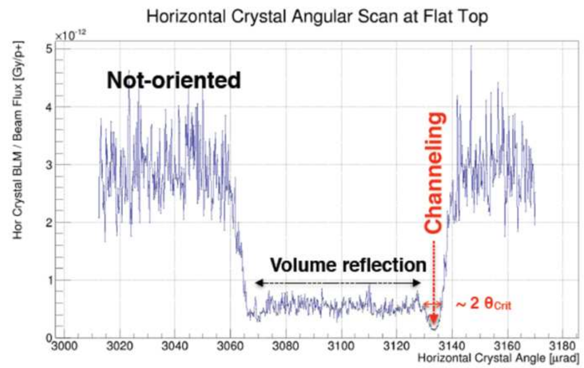
- operational and machine protection concerns are considered in cooperation with the Collimation Team
- 3 installations (since 2014): SPS North Area (H8), SPS (since 2008), LHC



Channeling observed for the first time with LHC beams in 2015

- Protons: 6.5 TeV
-
- Pb ions: 450 GeV

World Premiere !!

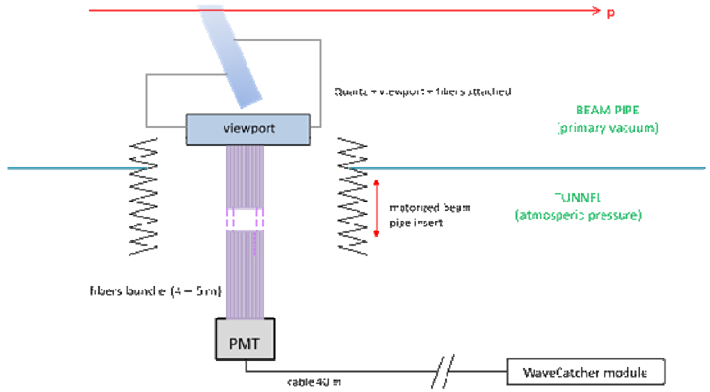


Losses recorded with BLM at goniometer position normalized to beam flux

Cherenkov Proton Flux measurement

Aim: development of a Cherenkov detection chain for the counting of the number of deflected protons of the SPS halo

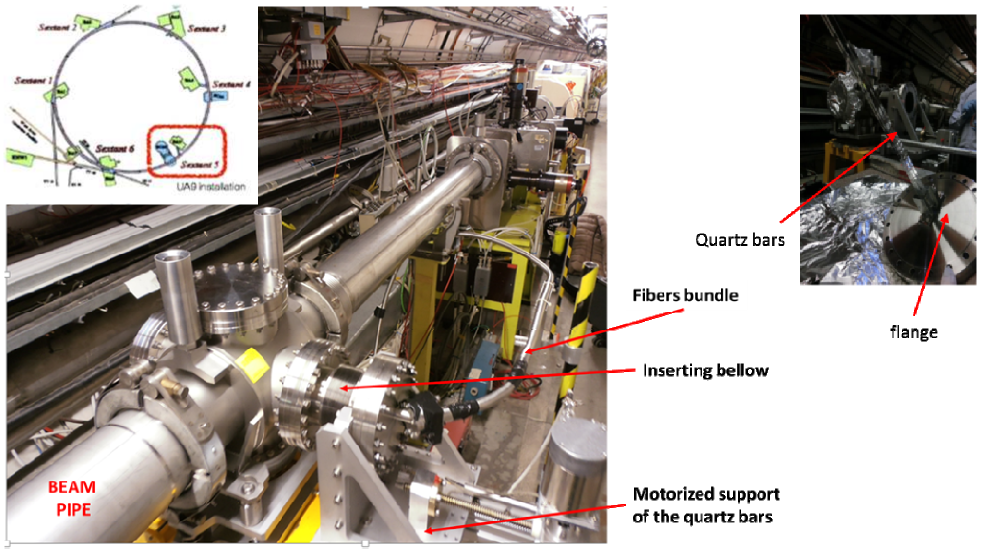
The CpFM concept



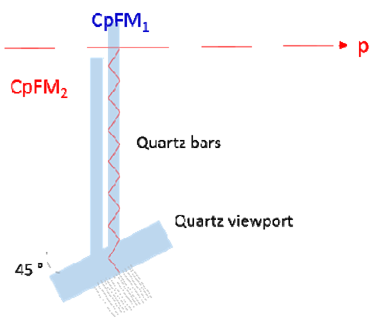
In vacuum detector to limit the increase of the impedance budget

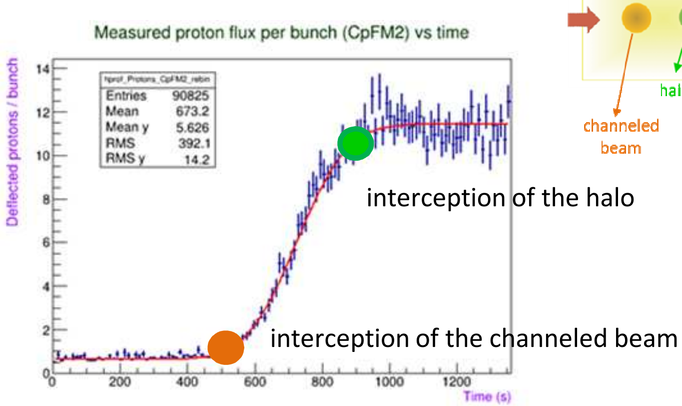
1.interception of the channeled beam (1 to 100 protons) by a quartz radiator (retractable finger)
2. emission of Cherenkov light readout by a rad-hard PMT
3. PMT amplified signal readout by the WaveCatcher module

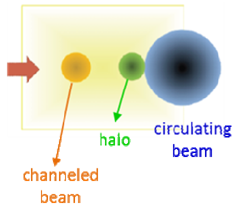
Installation of the CpFM inside the SPS beam pipe in 2015



4 x 24 h of data-taking time in 2015





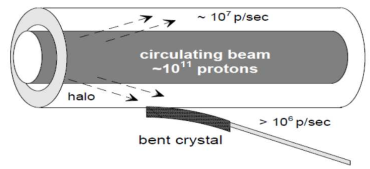


- CpFM works well
- Sensitivity to 1 incident proton

CpFM is the only calibrated detector in the UA9 experimental set up that measures the number of deflected particle with a precision of 15 %

CpFM for SPS slow extraction

Request from the CERN Accelerator Beam Transfer group to test the basic concepts of crystal-assisted extraction → **CpFM in TT20 to study the harmonic content of the extracted spill**. The detector should be robust enough for MDs and for standard high-intensity operation.



CERN SL/95-88 (AP)

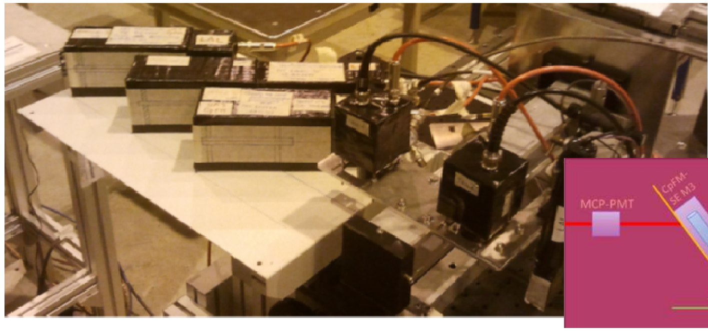
Development of a CpFM with :

⟹ high dynamic range

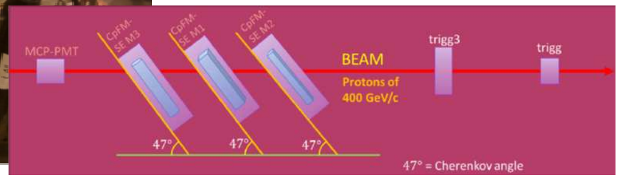
⟹ time response < 2ns

⟹ high sampling rate

⟹ large data buffering

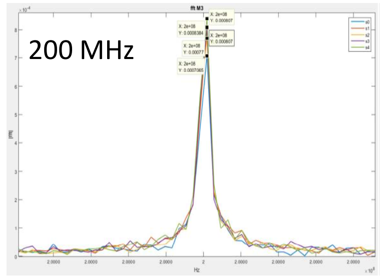


Beam Test in H8 (CERN)

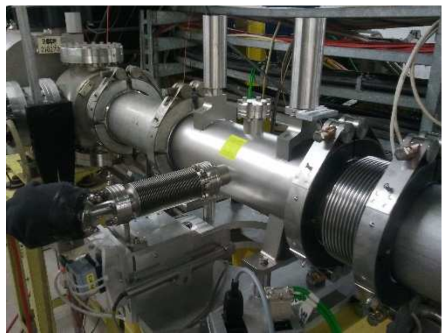


Analysis of the signal (FFT)

Harmonic contents of the spill : we observed the SPS revolution frequency of 43 kHz and its second harmonic (86 kHz) and the 200 MHz structure imposed by the SPS accelerating RF system ➡ CpFM-SE is able to detect the time-varying structure of the spilled beam



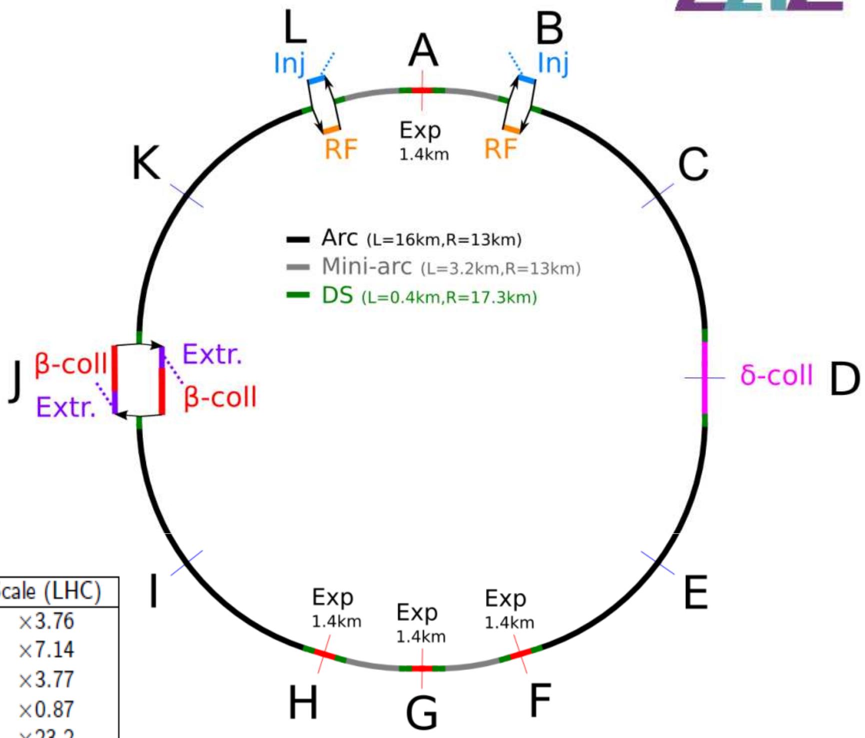
June 2015: insertion of the CpFM-SE in the SPS (TT20 section)



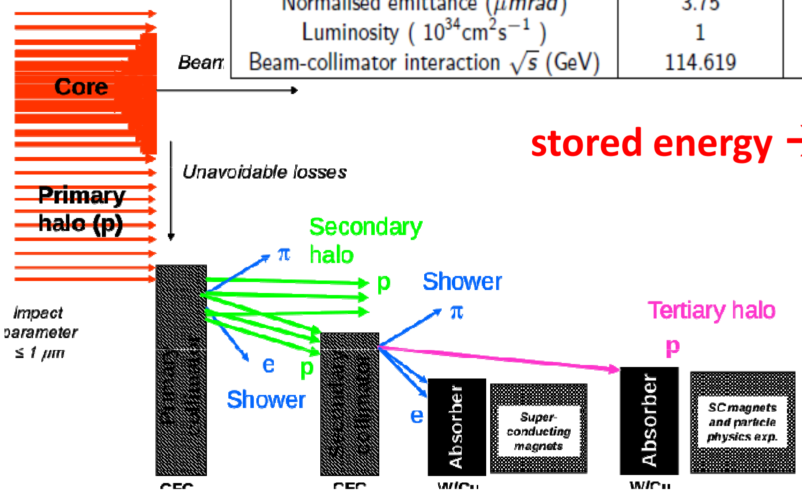
FCC-hh collimation section design and evaluation

The European Circular Energy-Frontier Collider Study (EuroCirCol) project has received funding from the European Union's Horizon 2020 research and innovation programme under grant No 654305. The information herein only reflects the views of its authors and the European Commission is not responsible for any use that may be made of the information.

1. Enhance collimation system simulation codes :
   MERLIN and Sixtrack
2. Initial scaling of LHC optical layouts for the betatron (with CERN) and energy (with CEA) collimation systems
3. Develop full ring beam pipe model
4. Loss maps with the nominal (V6) accelerator and collimation system layout
5. Evaluate betatron and energy collimation systems
   (cleaning efficiency ~ 10^{-7})



Parameter	LHC (V6.503)	HL-LHC	FCC (V6)	Scale (LHC)
Length (m)	26658	26658	100171	×3.76
Top beam energy (GeV)	7000	7000	50000	×7.14
Bunch count (25ns)	2808	2808	10600	×3.77
Bunch particle count (10^{11})	1.15	2.2	1	×0.87
Stored beam energy (GJ)	0.362	0.693	8.4	×23.2
Normalised emittance ($\mu mrad$)	3.75	2.5	2.2	×0.59
Luminosity ($10^{34}cm^2s^{-1}$)	1	5	5	×5
Beam-collimator interaction $\sqrt{s}$ (GeV)	114.619	114.619	306.315	×2.67

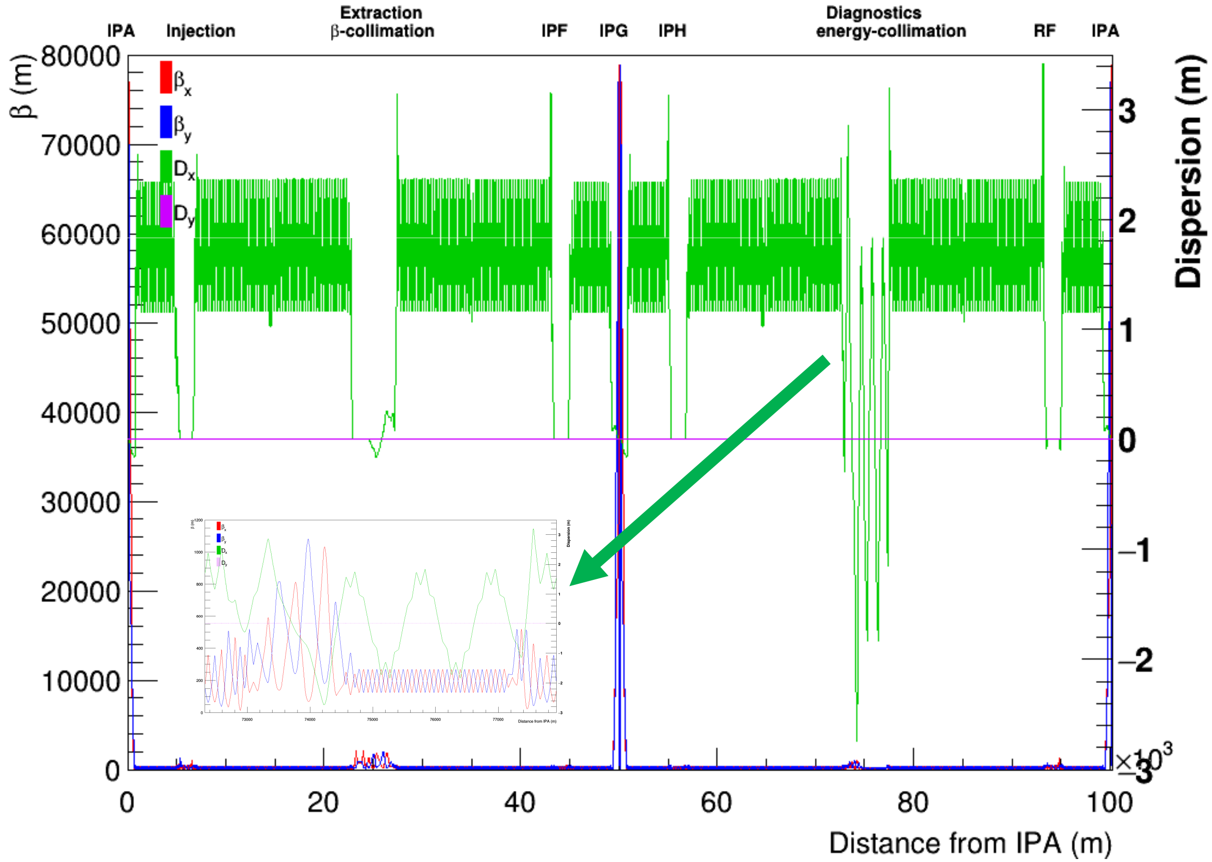


stored energy → 23 × LHC

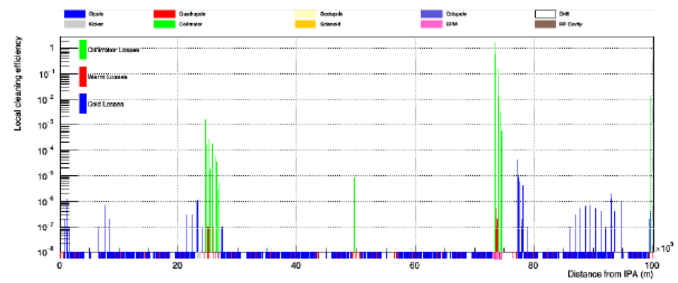
LHC collimators

FCC-hh collimation section design and evaluation

IPNO: Antoine Lachaize (CCD-IN2P3), Luc Perrot (+ J.-L. Biarrotte)
LAL: James Molson (CDD-EurCirCol), Angeles Faus-Golfe, Philip Bambade, Sophie Chancé
Main collaborators: M. Fiascaris & S. Redaelli (CERN), B. Dalena & A. Chancé (CEA)

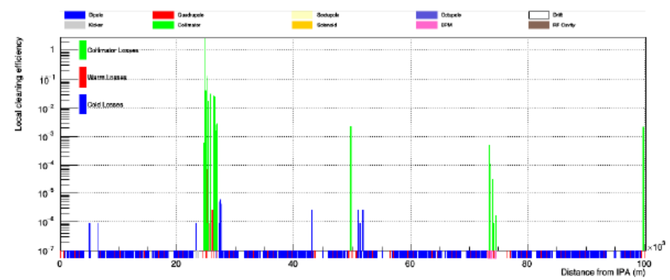


First baseline full optics FCC layout



First betatron & energy loss maps

- *non-orthogonal…*
- *IR losses…*



Argument for IN2P3 involvement & Assessment

- Limited contribution to central design & operation of accelerators (exception: FCC-hh collimation at LAL and IPNO)
- Significant contribution to collider R&D with strong innovation & research content (instrumentation, smart collimators, beam-beam background,…)
- Strong educational impact : many PhD and master students…
- Asset of IN2P3 engineering resources (electronics, mechanics,…)

IMPORTANCE

- Prepare IN2P3 teams to contribute to the next big facility in HEP (international bidding for design and R&D)
- Facilitate / lever IN2P3 participation to future HEP experiments

STRENGTHS

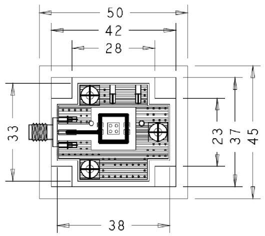
- Good international visibility and integration, teams are at the state of the art
- Chosen topics are generic while in context of specific projects $\rightarrow$ risk mitigation

WEAKNESSES

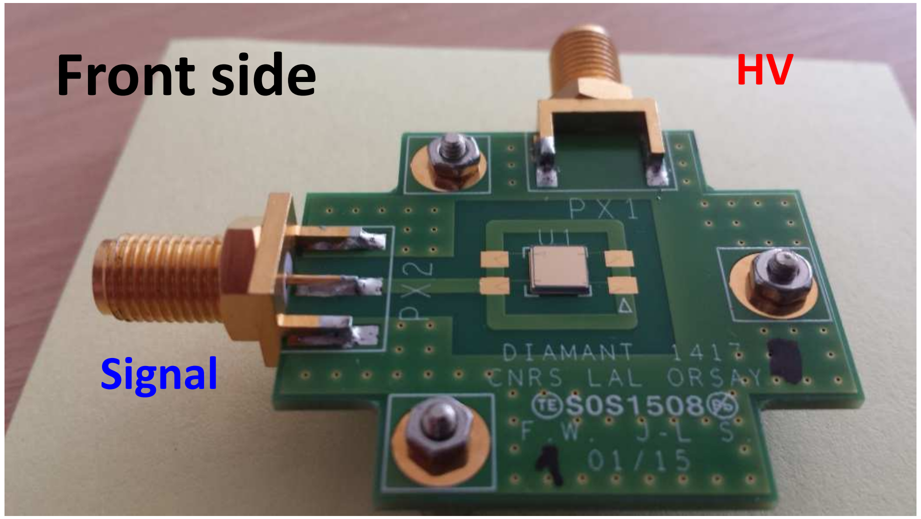
- Balance diversity $\leftrightarrow$ fragmentation $\rightarrow$ better articulation/coordination ?
- Too small teams ! Funding for human resources $\rightarrow$ postdocs and PhD students

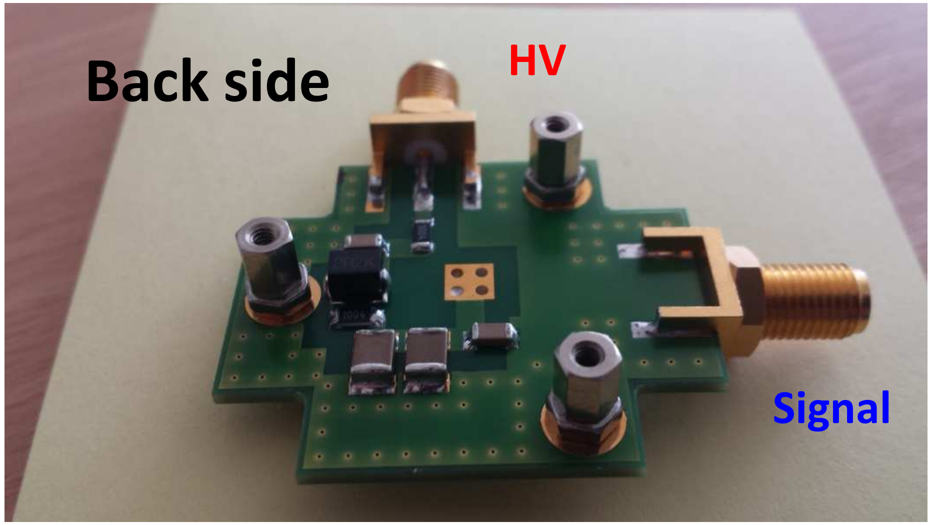
Extra slides

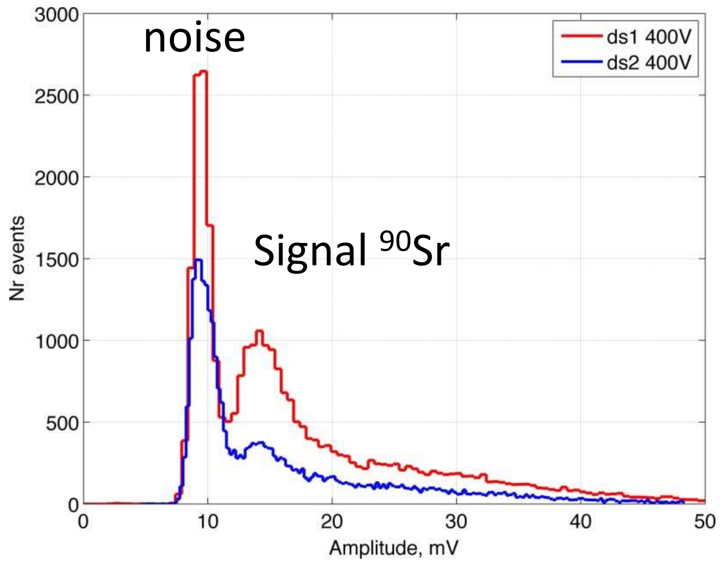
Diamond sensor prepared at LAL

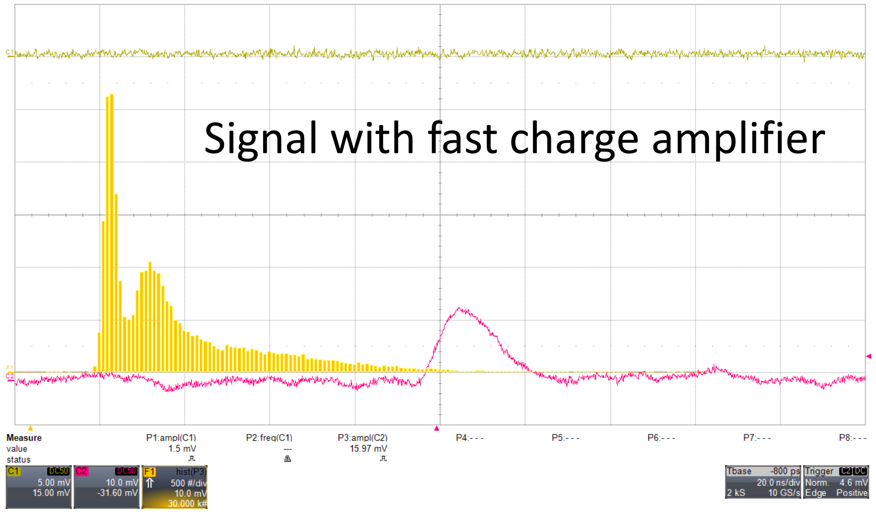


500µm sCVD diamond from E6 with Ti/Pt/Au metallization from GSI



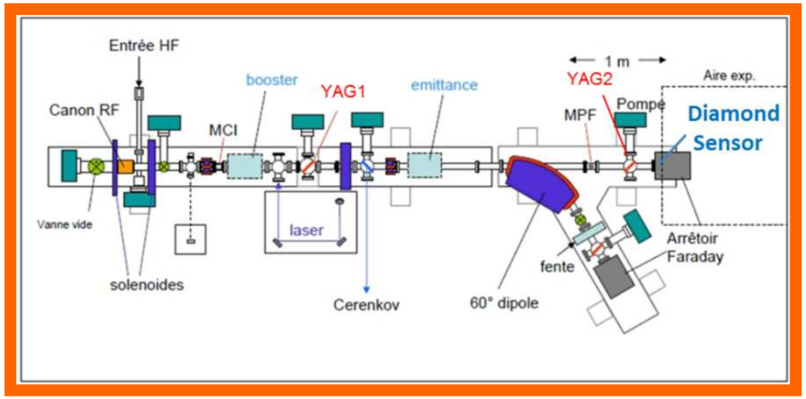


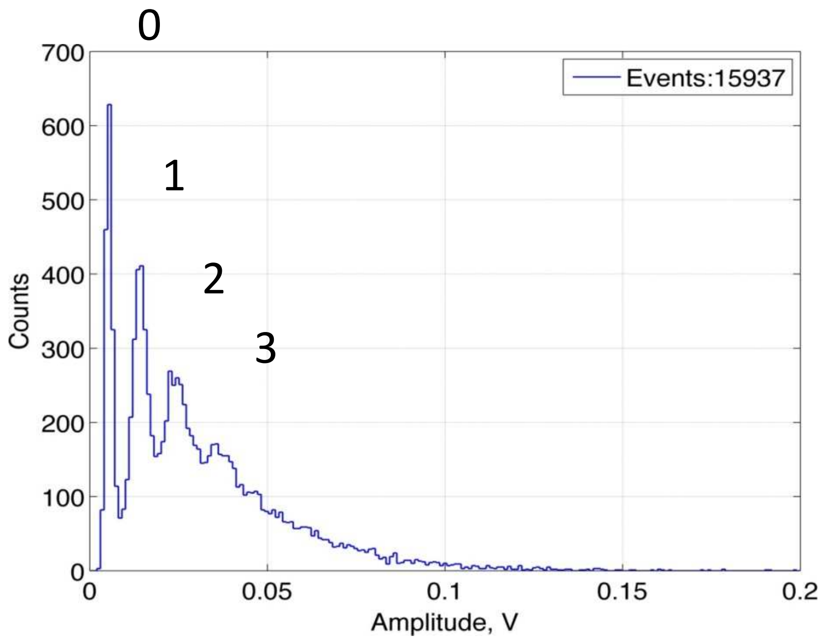


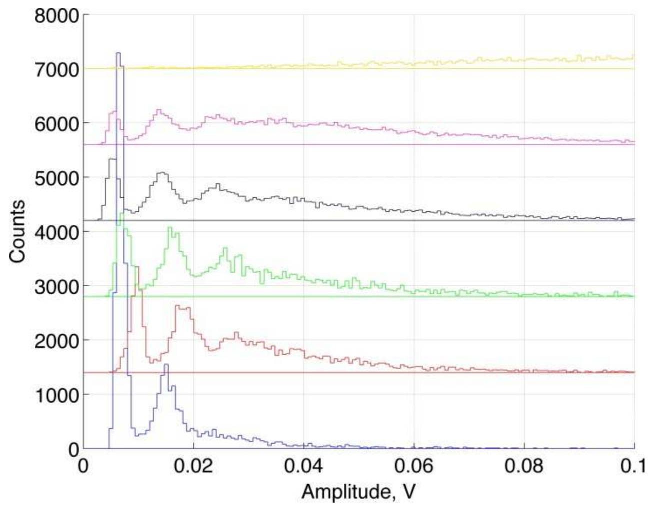


Diamond sensor → single electron control in LEETECH @ PHIL

10^9 3.5 MeV e-/bunch





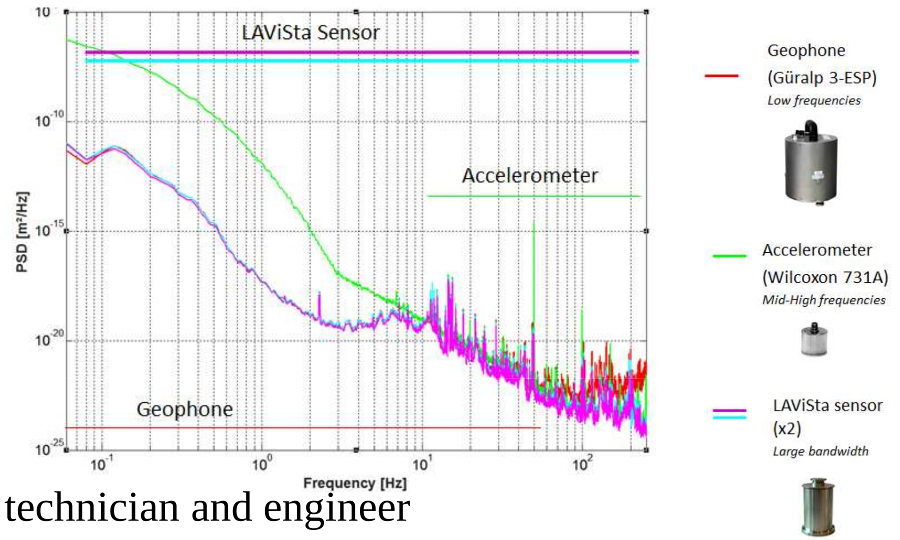


← different collimator settings

➢ *CLIC R&D* LAViSta – Beam Vibration control at the interaction point

- **Development of a vibration sensor:**
  - Promising results (similar to the best commercial sensors on a larger bandwidth)
  - **French patent (FR 13 59336), PCT extension in progress**
  - Optimized version in test (measurement in vertical or horizontal) for measurements and for active control
  - Triaxial version in progress
  - Outreach with the SATT of Grenoble (Linksium)

Developed prototypes



- **Project overview:**
  - Resources: 0,1 FTE physicist / 2,3 FTE technician and engineer
  - Budget (2016): IN2P3 (35 Keuros), General council (40 Keuros), FJPPL (1,5 Keuros), E-JADE
  - Collaboration: CLIC, ATF2, (SuperB)
  - Partnership: SYMME (University of Savoie)
  - Conferences of particles physics (PAC09, IWLC10, IPAC10, PAC11, IPAC11, LCWS11, LCWS12, ECFA13, LCWS13, LINAC14…) and engineering (Mecatronics10, ICINCO11…)
  - Co-authors of publications (CLIC with CERN, ATF2 with CERN, KEK and LAL, SuperB with INFN and SLAC), CDRs and TDRs,
  - Students / trainees (mainly from the University of Savoy) and involved in the PACMAN innovative doctoral program
  - Relevant knowledge in vibration analysis and control: lab Platform and various expertises (IRSN, IN2P3 labs, CTA collaboration…)

LAPP contribution to CTF3 instrumentation (2006-2014)

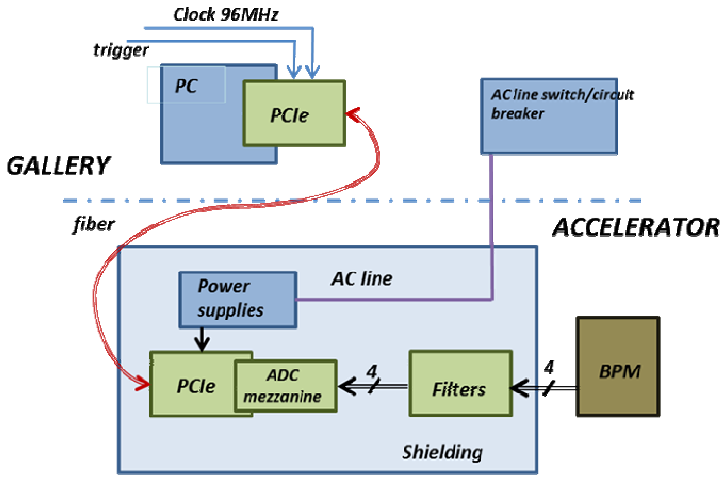
Préamplification BPMs, chassis d'acquisition local.

- ***Première version:*** ***2006-2009,***

Acquisition des **50 BPMs** inductifs de CTF3.
12 châssis, budget total ***~150K€***.
Lecture des faisceaux de 2008 et 2009,
¼ du coût standard.

- ***Deuxième version: 2010-2014.*** Collaboration avec CERN-CO.

Acquisition BPM stripline & lien optique unique synchrone et déterministe.
Budget ***~10k€/an.***
Actuellement acquisition faisceau.



→ Moyenne de 2,2 FTE.
→ R&D électronique valorisée sur ATLAS ITK. Gain ~1 an.

The 11th International workshop **POSIPOL** will be held in **Orsay** and hosted by **LAL**.

This workshop is mainly focused on the e+ sources and is addressed to the community working on the e+e- collider projects and on development of sources for industrial and medical applications.

Summary of positron source R&D

- Extensive R&D, studies and tests are ongoing => extended collaborations between many laboratories all around the world.
- A strong collaboration on positron source for the future collider are set up between LAL, IPNL, CERN, KEK and IHEP.
- Several PhD and undergraduate students have been trained in the positron source group of LAL (2 PhD, several L3, M1/M2 students).
- The work is constantly presented at different workshops and the conferences (CLIC workshop, POSIPOL, LCWS, Channeling, IPAC etc.). The relevant results are continually published (NIM B).
- Financial support: LAL, FCPPL, FJPPL, E-JADE.
- Human Resources: partially involved R.Chehab, I. Chaikovska and H. Guler. Reduced manpower over the last years.
- Continuously requested and a strong expertise of the LAL-Orsay e+ group together with a well-established collaboration with KEK make the increase of the number of people involved in the e+ source studies indispensable.

Luminosity Monitoring for Belle-II/SuperKEKB

LAL

Philip Bambade – *researcher*
Dima El Kechen – *PhD stud. (end 2016)*
Didier Jehanno – *elec. Eng., DAQ*
Viacheslav Kubytskyi – *Post-doc*
Cécile Rimbault – *researcher*
Yann Peinaud – *Mech Eng*
Pang Chengguo – *PhD stud. (start 2016)*

KEK

Yoshihiro Funakoshi – SuperKEKB
Ken-Ichi Kanazawa – SuperKEKB/vacuum pipe
Yukiyoshi Ohnishi – SuperKEKB/beam loss MC
Yusuke Suetsugu – SuperKEK/vacuum pipe
Mika Masuzawa – SuperKEKB
Toshiyuki Oki
Takashi Kawamoto
Masako Iwasaki
Sadaharu Uehara – Belle-II/ZDLM
Hiroyuki Nakayama – Belle-II/BEAST

Related collaborations: **IPHC-Strasbourg** (I. Ripp-Baudot et al.): Beam backgrounds in Belle-II
Funding: IN2P3 (~ 30k), H2020/Rise/JENNIFER (~ 75k in 4 yrs), LIA FJPPL(TYL) (~ 4k), P2IO (1/2 Phd Thesis), CSC (PhD thesis from oct. 2016)

Broader view of LAL contribution

- 1st goal: fast luminosity → contribution to commissioning, SuperKEKB feedback system
- Beam-beam physics in the context of first collider with nano-beam scheme:
  - backgrounds from low Pt process → critical for Belle-2 exp. conditions… FCC-ee,CEPC…
  - special QED features of processes at vanishing Pt for nanometer beam sizes

Couples naturally to a possible French contribution to Belle-II

May also team up with IPHC group to look at the physics program, starting in 2018

Measurement of SuperKEKB induced background with PLUME pixel detectors

- Collaborations and applications to grants:
  - Supported by IdEx 2015 – Université de Strasbourg: Exploratory project
  - Collab. with KEK: FJPPL project since 2014
  - Collab. with KEK and LAL (P. Bambade, C. Rimbault): MIBEL project submitted to ANR 2016 (evaluation on-going)
  - On-going application to a PhD grant: 2016-2019

- Prospects beyond 2018: hoping to contribute to the Belle II experiment

  ➛ BEAST is an excellent preparation

  - Plan for joint physics analysis with LAL group, starting in 2018
  - Potential interest for a future detector upgrade at high luminosity

Robert Maria, PhD IPHC + doctorant en cours de sélection pour 2016-2019

UA9

CpFM program for 2016 → 2018:

✓ SPS data analysis: measurement of the collimation efficiency and to support studies of the diffusion dynamics in cooperation with CERN accelerator physicists
✓ Upgrade of the CpFM-SPS: improved quartz bars and fibers bundle, monitoring of the PMT response
✓ CpFM-SE operation: commissionning of the new readout electronics (high-speed digitizer card)
✓ CpFM for LHC: design of the detection chain, rad-hard tests

Budget:

- 2013 : 30 k€ from LAL (R&D studies)
- 2014 : 20 k€ from IN2P3
- 2015 : 25 k€ from IN2P3, 8 k€ from LAL
- 2016 : 36 k€ from IN2P3

Manpower:

39 m.months (LAL team)/year from 2013 to 2016

Internships: 2 M2 students (3 months each), 1 PHD Thesis (LAL – Kiev University) starting 1st September 2016

Publications, conference talks & posters:

- 13th Topical Seminar on Innovative Particle and Radiation Detectors (2013): V. Puill
- IEEE NSS 2013: L. Burmistrov
- NDIP 2014 : L. Burmistrov
- 13th Pisa Meeting on Advanced Detectors 2015 : W. Scandale
- Observation of channeling for 6500GeV/cprotons in the crystal assisted collimation setup for LHC, Physics Letter B