ATF2 studies and preparation for ILC

Report A-RD10 and New Application

Thursday May 11, 2017

Outline

- Participants
- KEK*: host, organisation, installation, ATF2
- LAL*: IP-chamber, halo measurements
- LAPP*: GM sensors, Beam FeedForward based on GM
- Summary of 4 years of A-RD10
- Application for New project

Slides adapted from different participants

*principal contributor within FJPPL although collaborative work

Institute of High Energy Physics
Chinese Academy of Sciences

Recent participants over the past 4 years

FJPPL (TYL) application 2016-2017

Fiscal year April 1st 2016 – March 31st 2017

Please replace the red examples by the appropriate data in black

ID [1] : A_RD_10	Title: Nanometer stabilization studies at ATF2					
	French Group			**Japanese Group**		
	Name	**Title**	**Lab./Organis.[2]**	**Name**	**Title**	**Lab/Organis.[3]**
Leader	Andrea Jeremie	IRHC	LAPP/IN2P3	Nobuhiro Terunuma	Prof.	KEK
Members	Philip Bambade	DR1	LAL/IN2P3	Toshiaki Tauchi	A.Prof.	KEK
	Renjun Yang	PhD st.	LAL/IN2P3	Takashi Naito	A.Prof.	KEK
	Sandry Wallon	IR2	LA/IN2P3L	Kiyoshi Kubo	Prof.	KEK
	Frédéric Bogard	IE2	LAL/IN2P3	Shigeru Kuroda	A.Prof.	KEK
	Patrick Cornebise	IE2	LAL/IN2P3	Toshiyuki Okugi	A.Prof.	KEK
	Hayg Guler	CDD	LA/IN2P3L	Sakae Araki	Eng	KEK
	Viacheslav Kubytskyi	CDD	LAL/IN2P3	Hiroshi Yamaoka	Eng	KEK
	Laurent Brunetti	IR2	LAPP/IN2P3			

Presenter

Congratulations go to

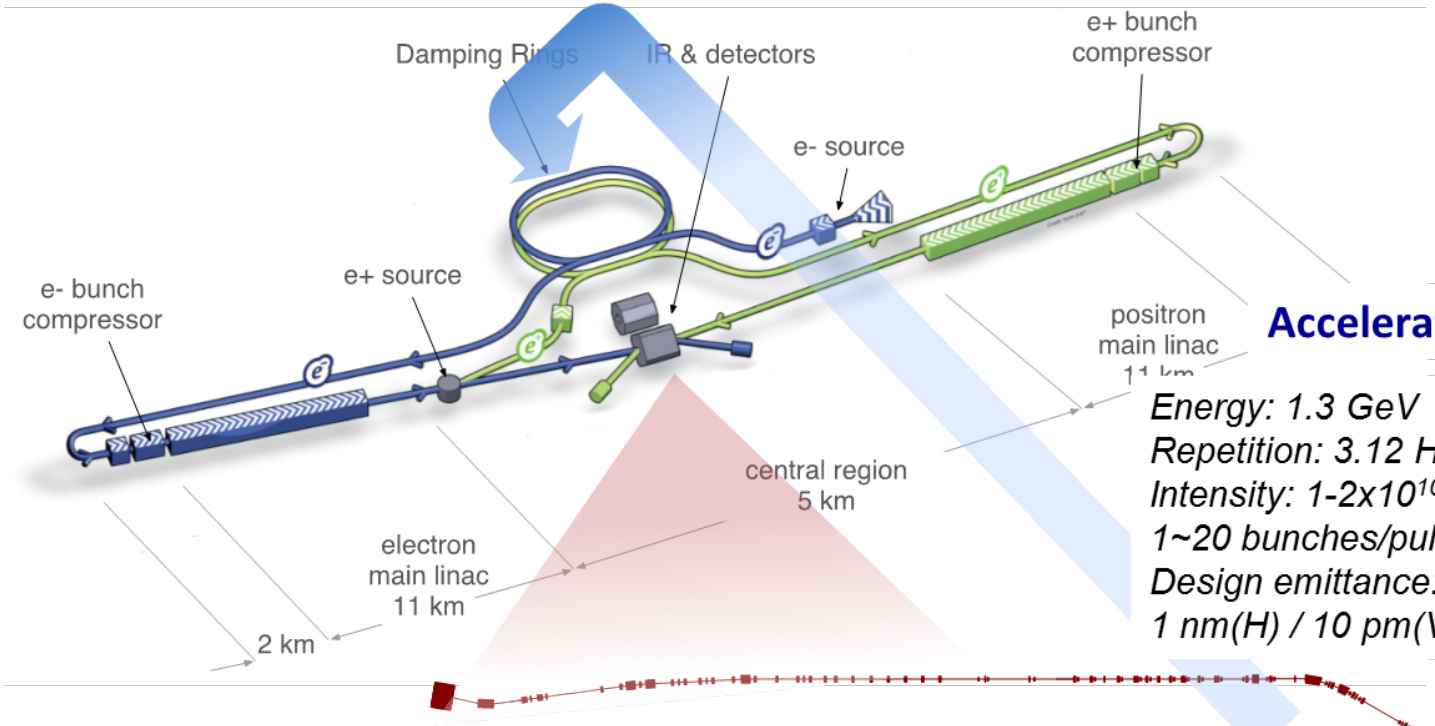
- Nobuhiro Terunuma (KEK): for receiving the Shuji Orito Prize 2017

For advanced results in the development of nanometer beam technology

Awarded for his work on the development of the nanometer beam required to achieve the ILC luminosity, and for his long contribution to the ATF/ATF2 program as a leader and a spokesperson of the collaboration.

- Shan Liu (LAL): Best Thesis Prize for Outstanding detector development work, awarded by the FCPPL in March 2015, in Strasbourg.

Nanometre scale beam handling at ATF/ATF2

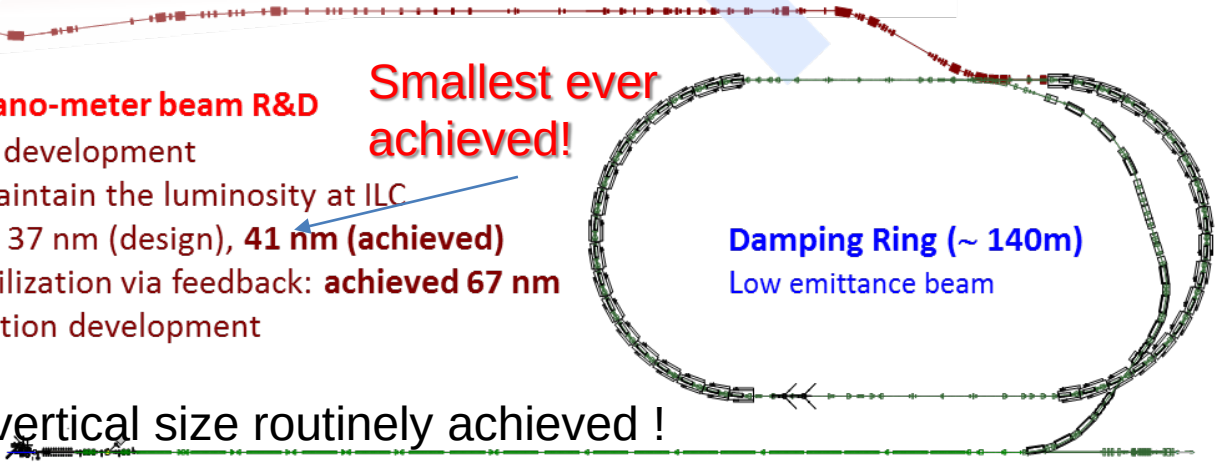


Accelerator Test Facility

Energy: 1.3 GeV
Repetition: 3.12 Hz
Intensity: 1-2x10^{10} 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), **41 nm (achieved)**
Goal 2: Beam stabilization via feedback: **achieved 67 nm**
Beam instrumentation development

Smallest ever achieved!

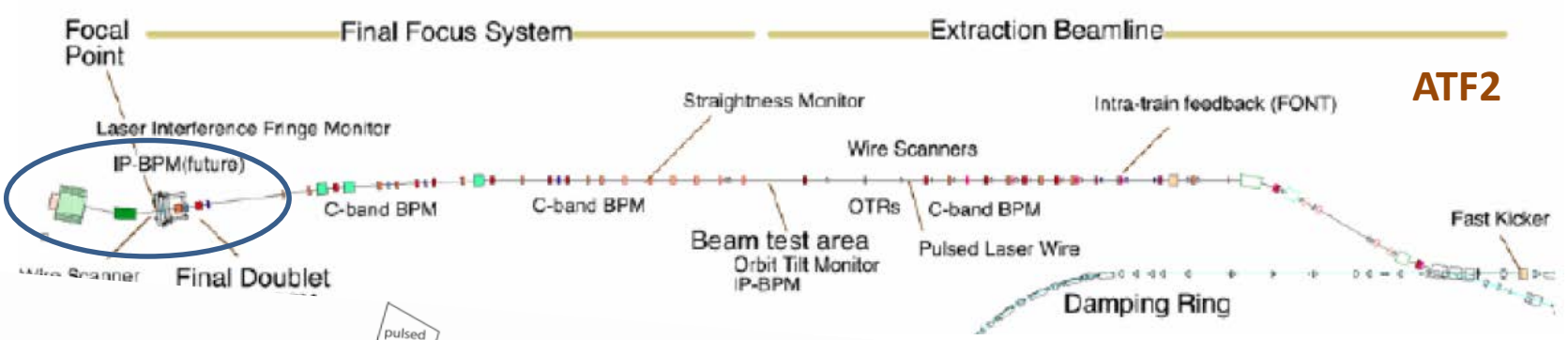


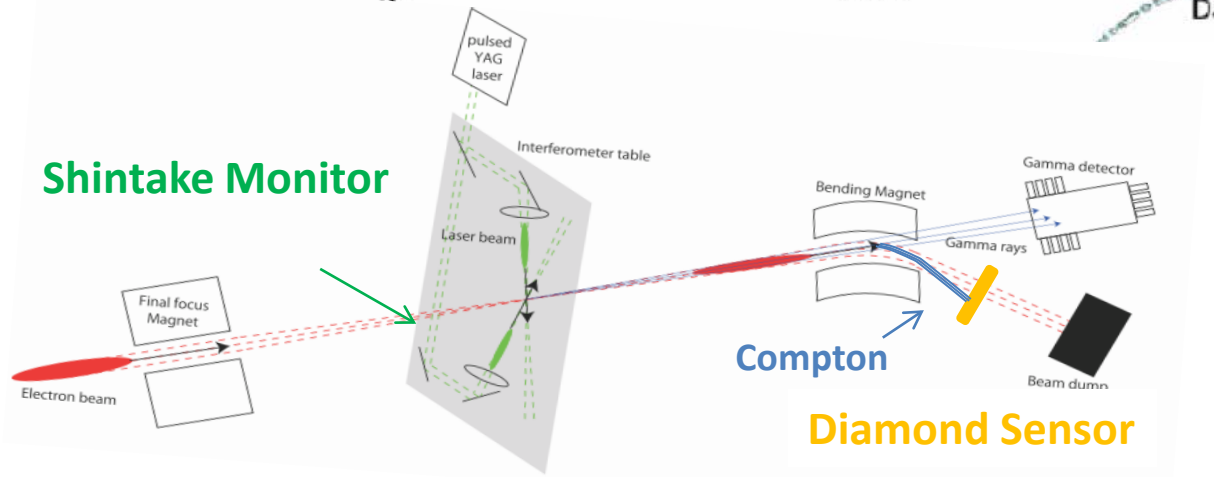
40-45 nm vertical size routinely achieved !

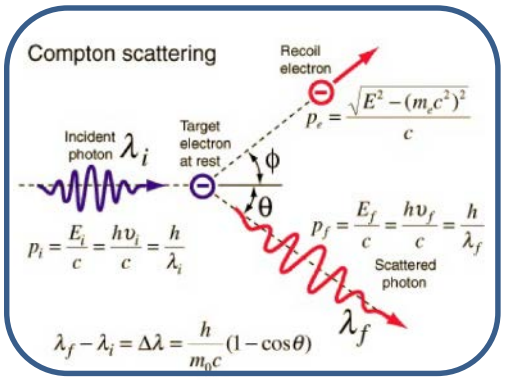
Beam Halo

Beam halo measurement

P.Bambade (LAL)







Motivations:

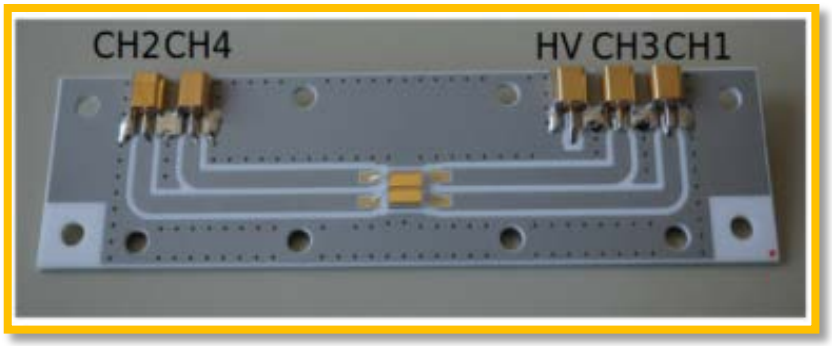
- ***Beam halo transverse distribution unknown → investigate halo model & propagation***
- ***Monitor beam halo to control backgrounds by means of collimation and tuning***
- ***Probe Compton recoil electron***

Diamond sensor scanners at ATF2 (+ PHIL)

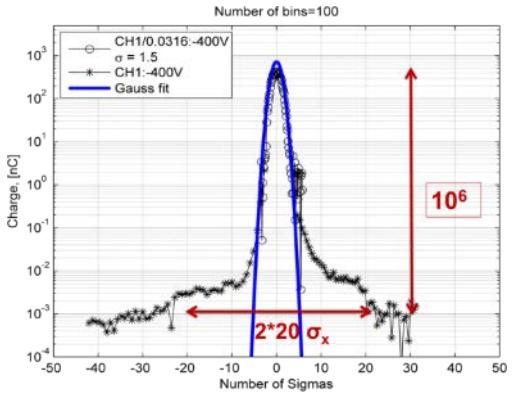
horizontal & vertical

1. Shan Liu 2012-2015
2. Renjun Yang 2015-2018
PhD @ LAL

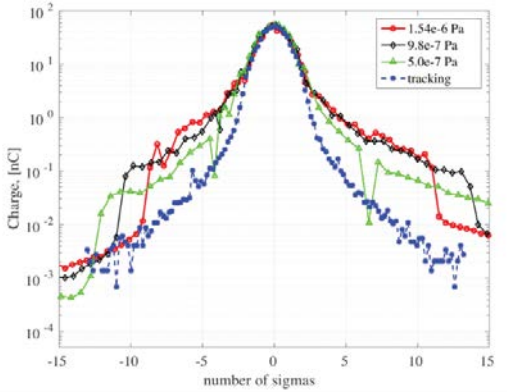
Measure the beam halo distribution with high dynamic range (~ 10^6)

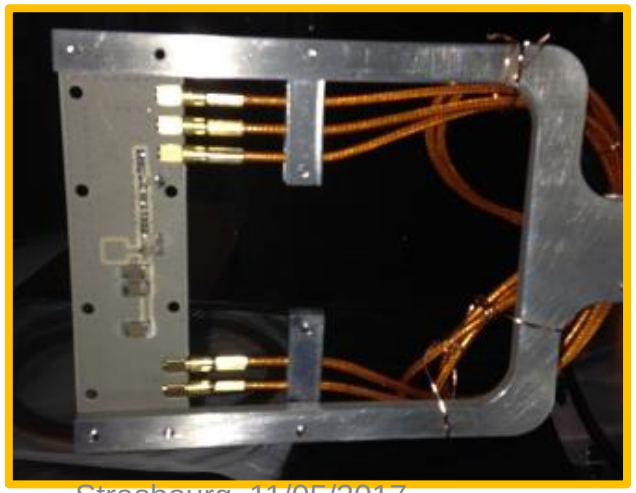


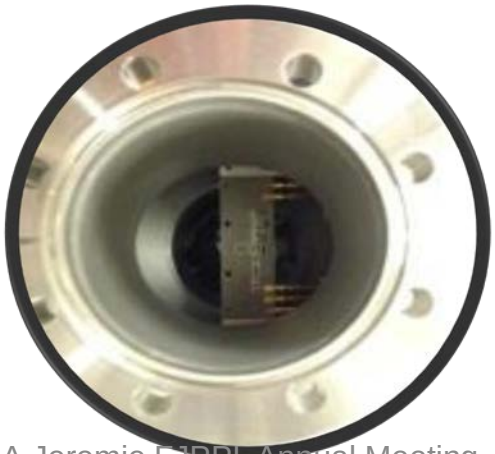
collaboration with CIVIDEC

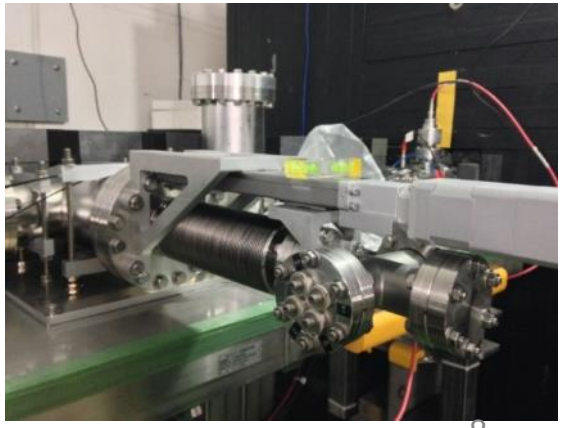


Dependence with ATF ring vacuum pressure





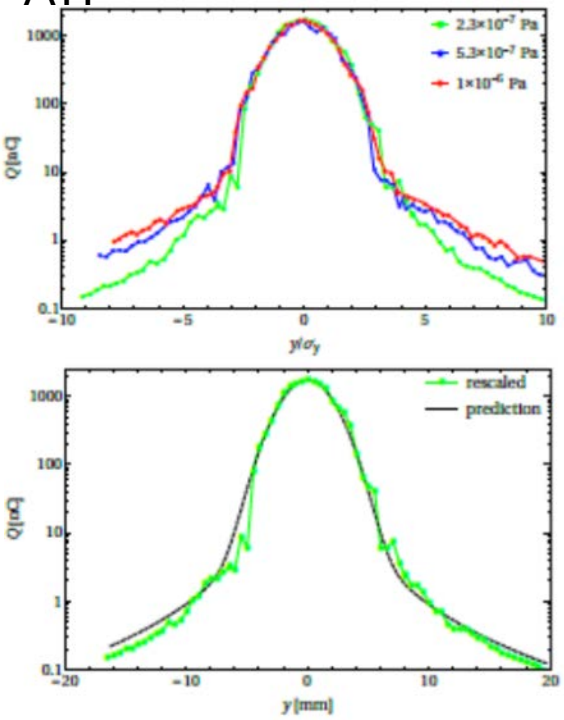




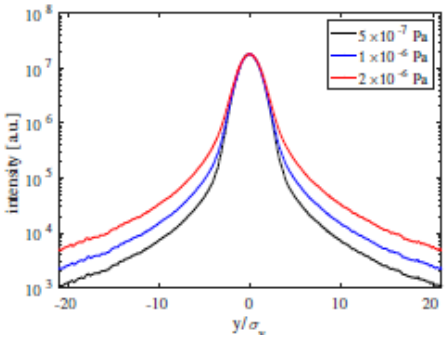
Experimental study of halo formation

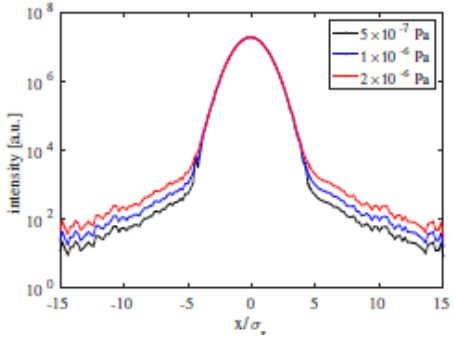
Vacuum dependence points to beam halo formation through BGS (Beam Gas Scattering)

Agreement between simulation and measurement => vertical halo is dominated by Beam Gas Scattering at ATF

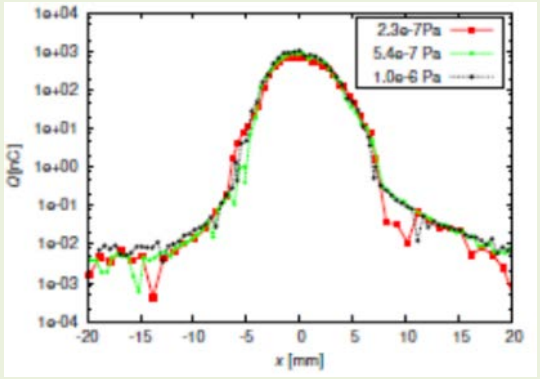


Simulation performed with SAD and benchmarked with vacuum lifetime





In horizontal direction, no significant vacuum dependence => other sources of halo: misalignment, wakefield, IBS…

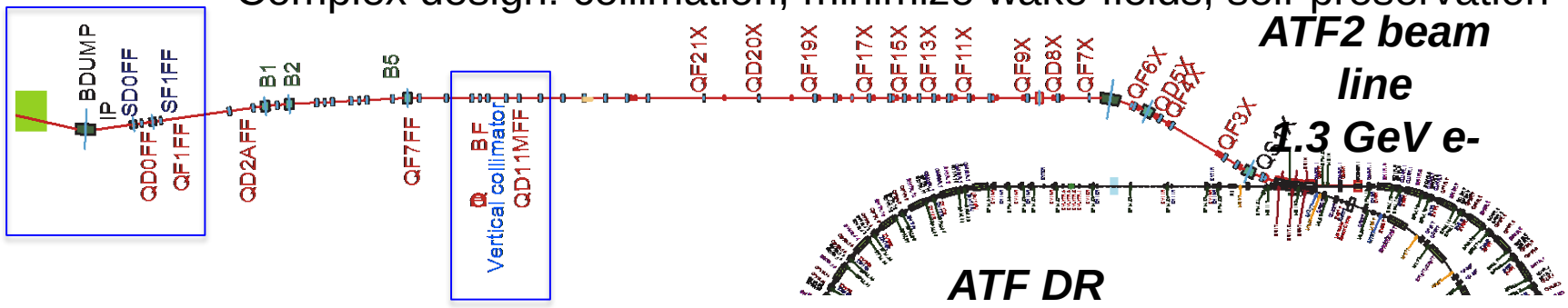


Beam halo formation well understood in vertical direction R.Yang

Retractable vertical collimation system

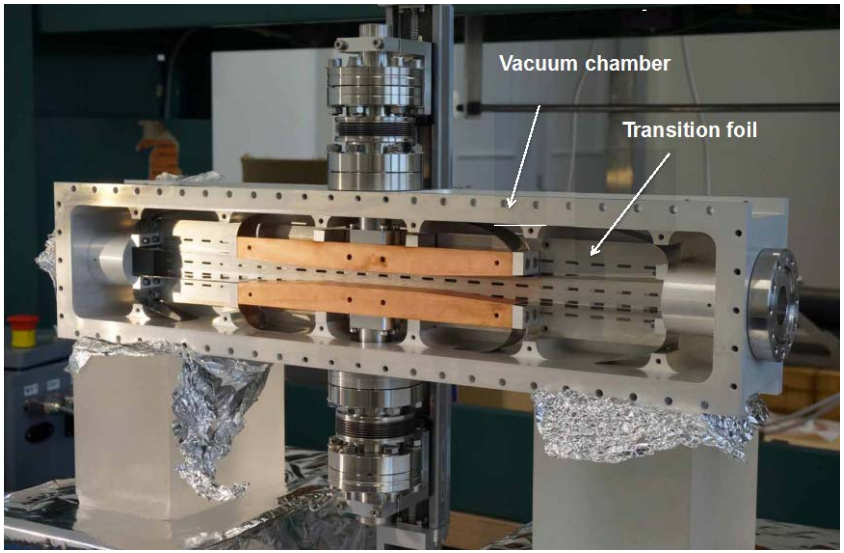
A vertical collimation system was installed in the ATF2 FFS in March 2016

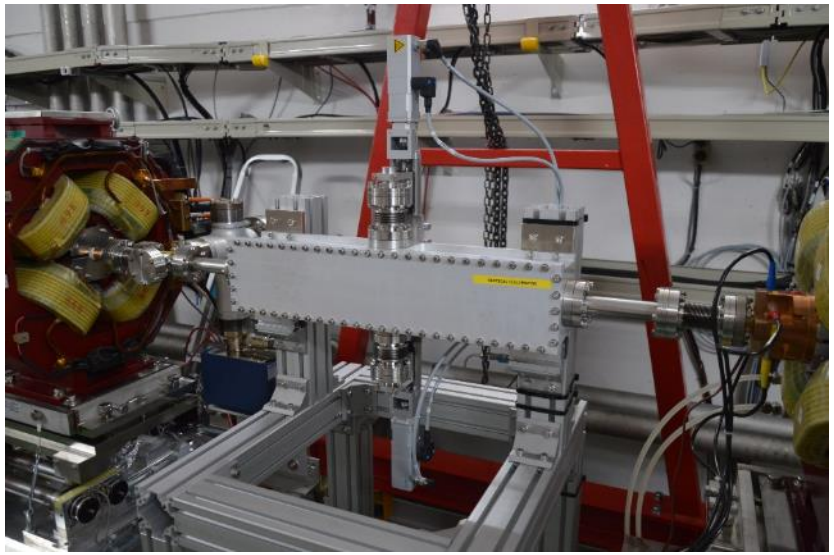
Complex design: collimation, minimize wake fields, self-preservation



- ✓ β^c_y=7126.51 m
- ✓ $\Delta\Phi_y$ BDUMP-C=3π and $\Delta\Phi_y$ DS-C=3π

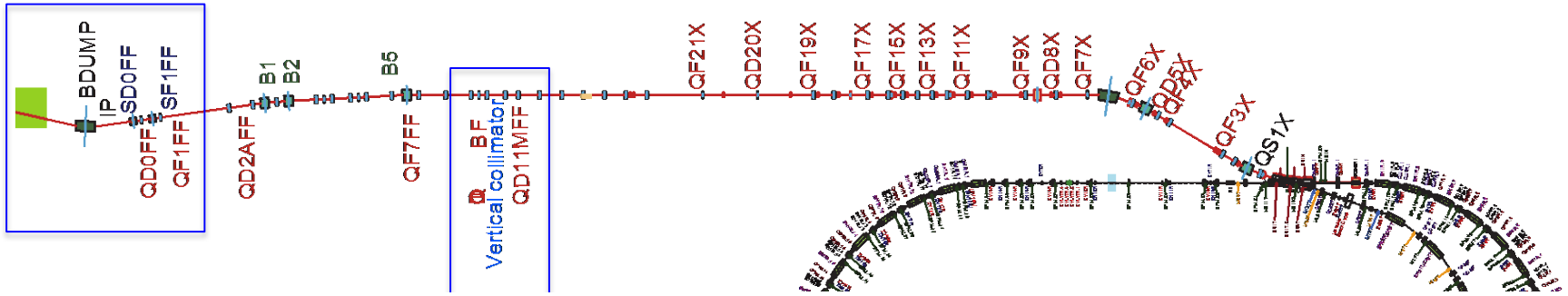
half aperture from 3-12mm (with mechanical stop) and 2-12 (without mechanical stop)



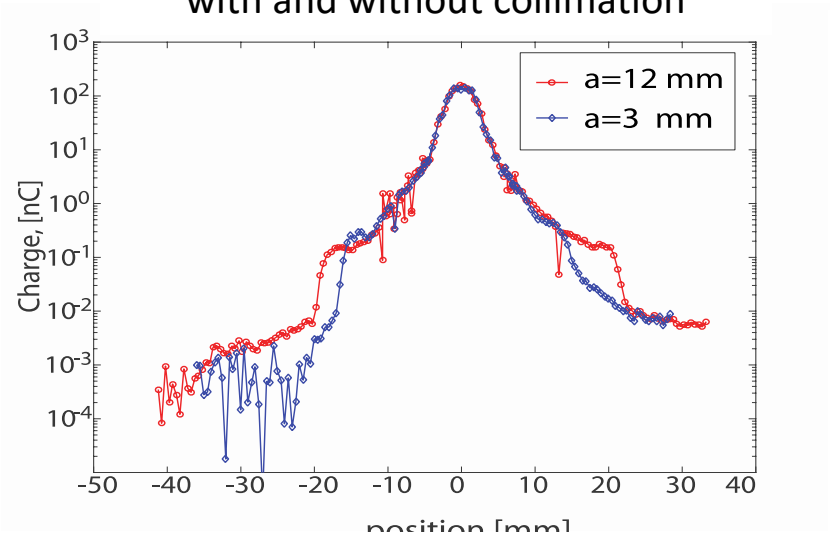


PhD @ LAL with IFIC: N.Fuster-Martinez

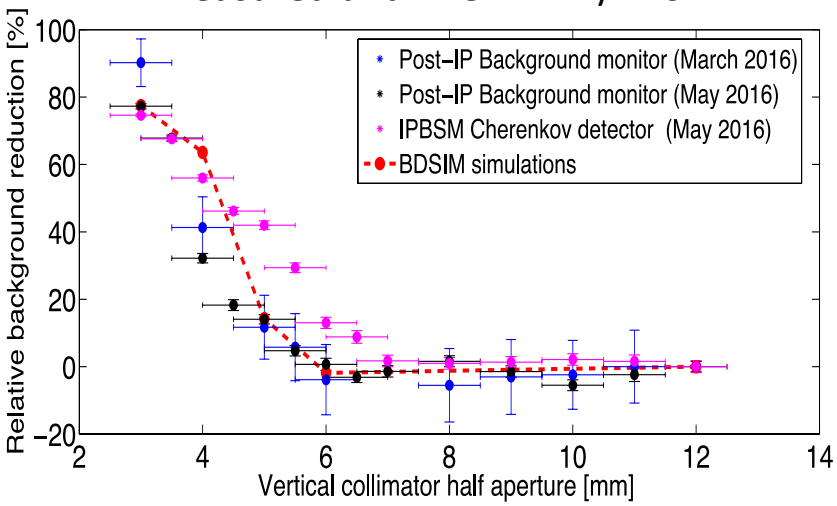
Measurements and simulations



Charge collected in Diamond Sensor with and without collimation



Background suppression factor measured and in GEANT4/BDSIM



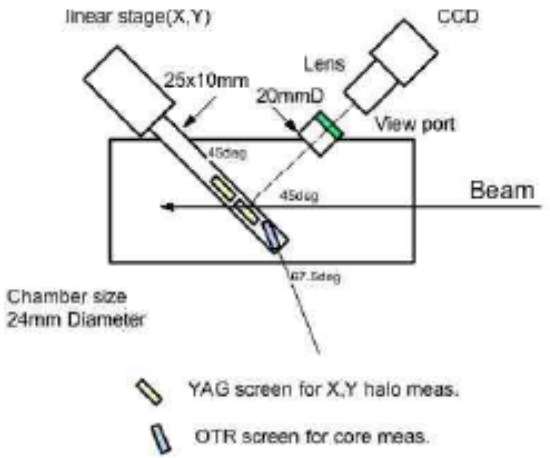
- Observe effect of beam collimation at post-IP
- Measurements compared with the relative reduction of background photons generated in Beam Dump by GEANT 4 (BDSIM): good agreement
- Post-IP background photons reduced when vertical collimation closed < 6 mm

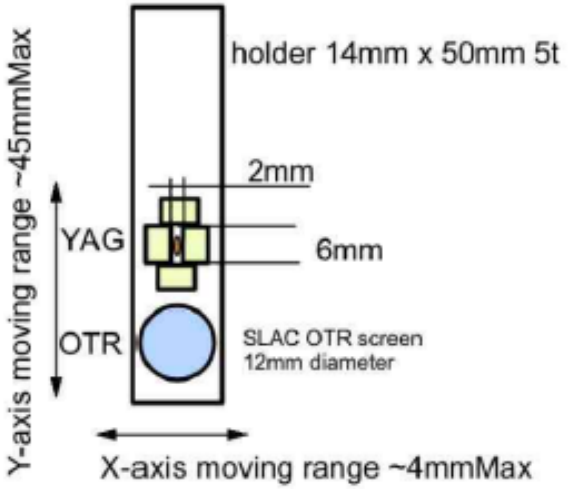
Upgrading of OTR/YAG screens monitor (LAL, KEK)

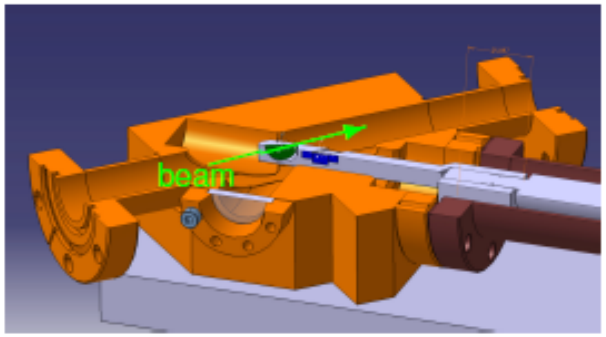
- Motivation: fast diagnostic of beam halo at dispersion free region
- Idea: 3 screens(2 YAG screens for halo and 1 OTR screens for beam core) are combined to realize high dynamic range 2D profile imaging

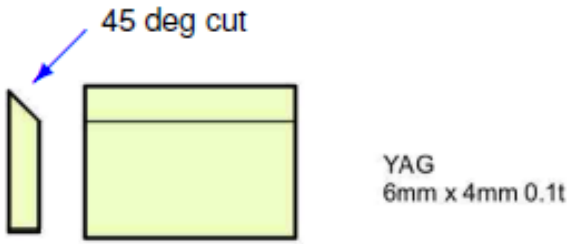
Add another halo measurement

- Could help understand horizontal measurements
- Upstream halo







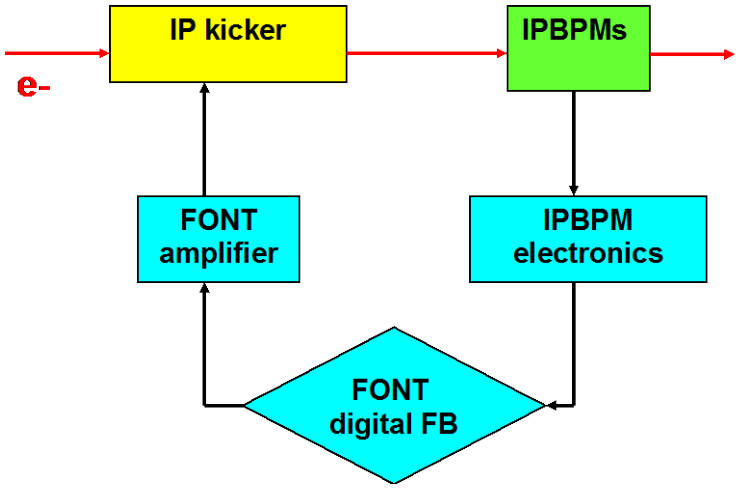


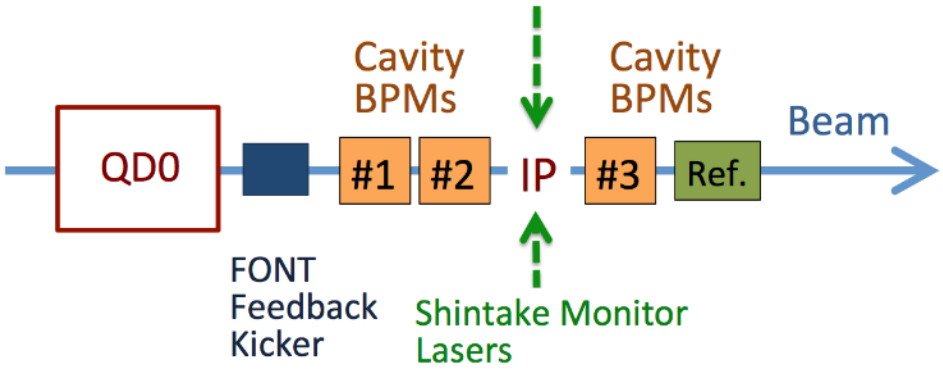
- Horizontal slices are cut by 45 deg to avoid edge effects (horizontal insert)

Renjun Yang (PhD LAL) + Sandry Wallon (LAL)

Nanometer stabilization at IP

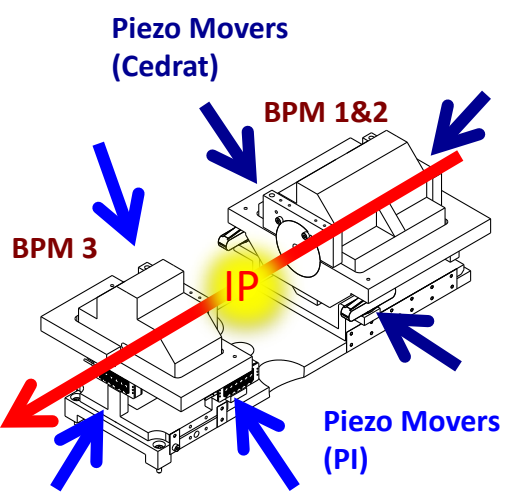
Nanometer stabilization at ATF2 IP

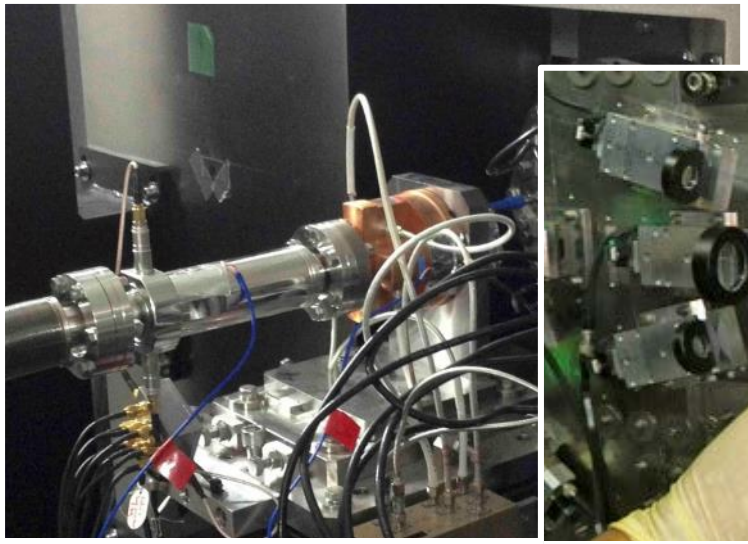




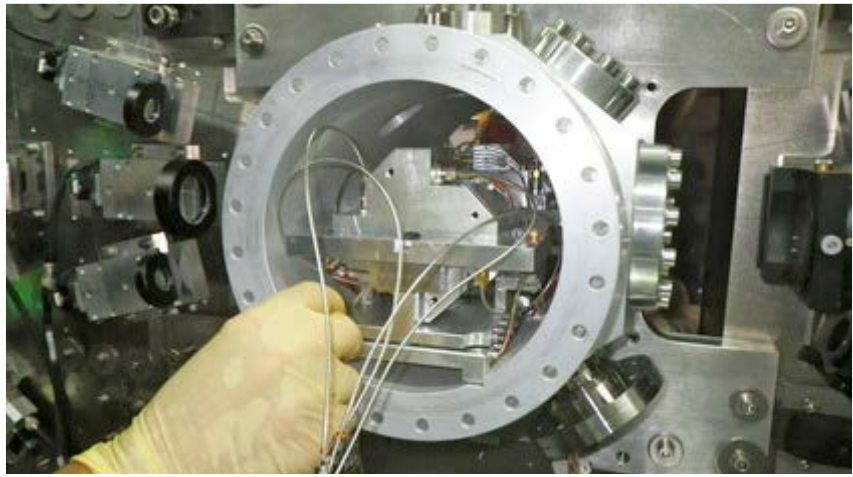
Best stabilization achieved ~ 60-70 nm

Goal 2 →1 – 10 nm





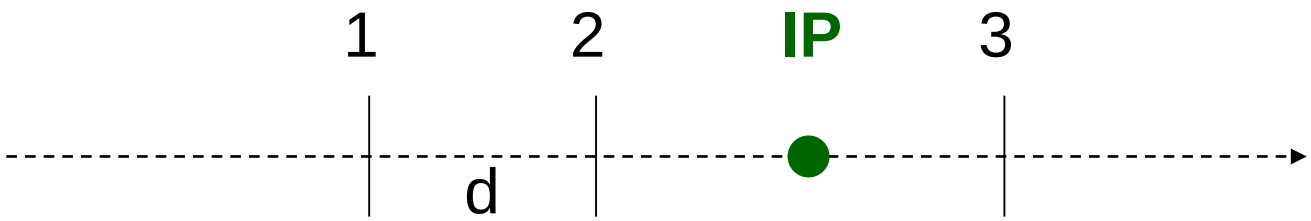
stripline feedback kicker



IP-BPM with mover in a vacuum chamber

Oscar Blanco
PhD @ LAL
2012-2015

Required precision on relative IP-BPM scale factors depends on beam parameters



d ~ 0.1 m
ε_y ~ 12 pm
σ_{jitter} / σ ~ 10%

$\theta_{IP} = (y_2 - y_1) / d$
$y_{IP} = 2\, y_2 - y_1$

ξ = calibration error of 1 relative to 2
→ $2\, y_2 - y_1 \sim y_{IP} + 2\, \xi\, \theta\, d$

1. **Determination of resolution**
2. **Feedback to IP or to 3rd IP-BPM**

β ~ 1 m (e.g. diagnostic section)

Residual ~ $2\, (\varepsilon / \beta)^{0.5}\, d\, (\sigma_{jitter} / \sigma)\, \xi \sim 10^{-7}\, \xi$ → $\xi \sim 10^{-2}$ for 1 nm error

$\beta \sim 10^{-4}$ m (interaction point : nominal optics)

Residual ~ $2\, (\varepsilon / \beta)^{0.5}\, d\, (\sigma_{jitter} / \sigma)\, \xi \sim 10^{-5}\, \xi$ → **$\xi \sim 10^{-4\,/\,-3}$ for 1 / 10 nm error**

Vertical movers calibration

(non-linear fit + slightly reduced stroke)

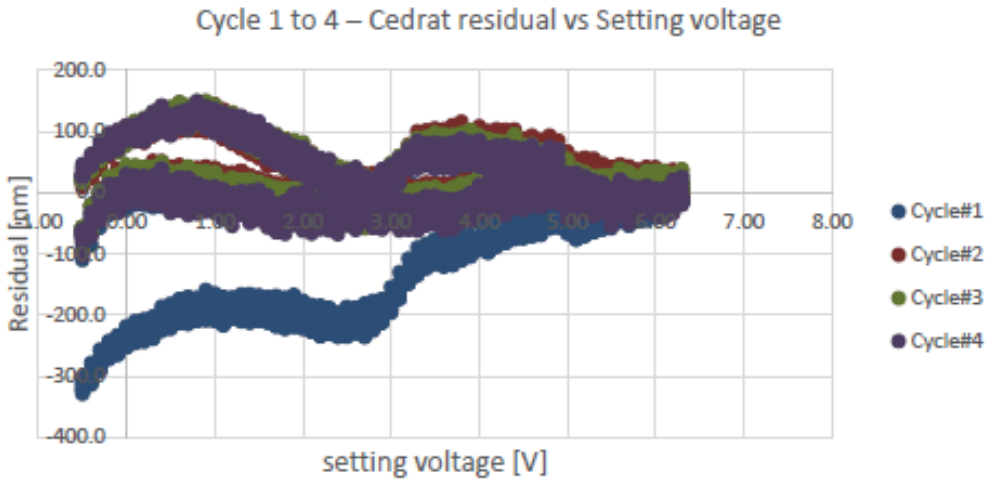
Residual from cubic polynomial fit

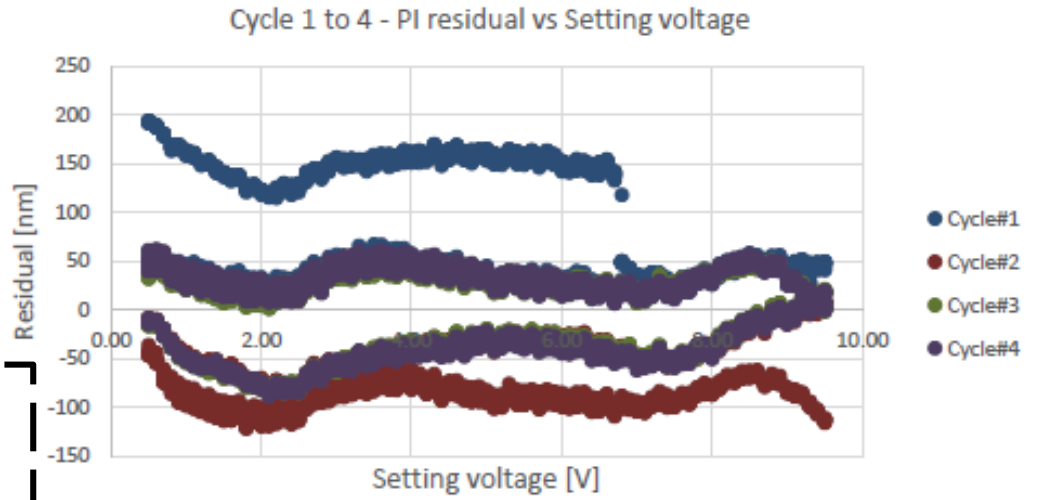
	Cedrat polynomial fit coeffs (-1 to 7 to -1V travel ; calculated without -1 to 0.4V and 6.4 to 7V data)			
	a [nm/V^3]	b [nm/V^2]	c [nm/V]	d [nm]
4 ups	9.63397	222.106	29013.5	29234.1
4 downs	6.52030	198.9	29255.2	29594.1

With cubic polynomial fit and reduced stroke (see in red), Cedrat and PI movers are almost in the same range of accuracy (roughly +100/-200 nm or +200/-100 nm)

	PI polynomial fit coeffs (0 to 10 to 0V travel ; calculated without 0 to 0.4V and 9.6 to 10V data)			
	a [nm/V^3]	b [nm/V^2]	c [nm/V]	d [nm]
4 ups	-1.63945	21.8446	-30055.1	-293.296
4 downs	-0.49394	-2.33170	-29919.0	-272.911

10^{-3} possible for PI & Cedrat with cubic calibration fit

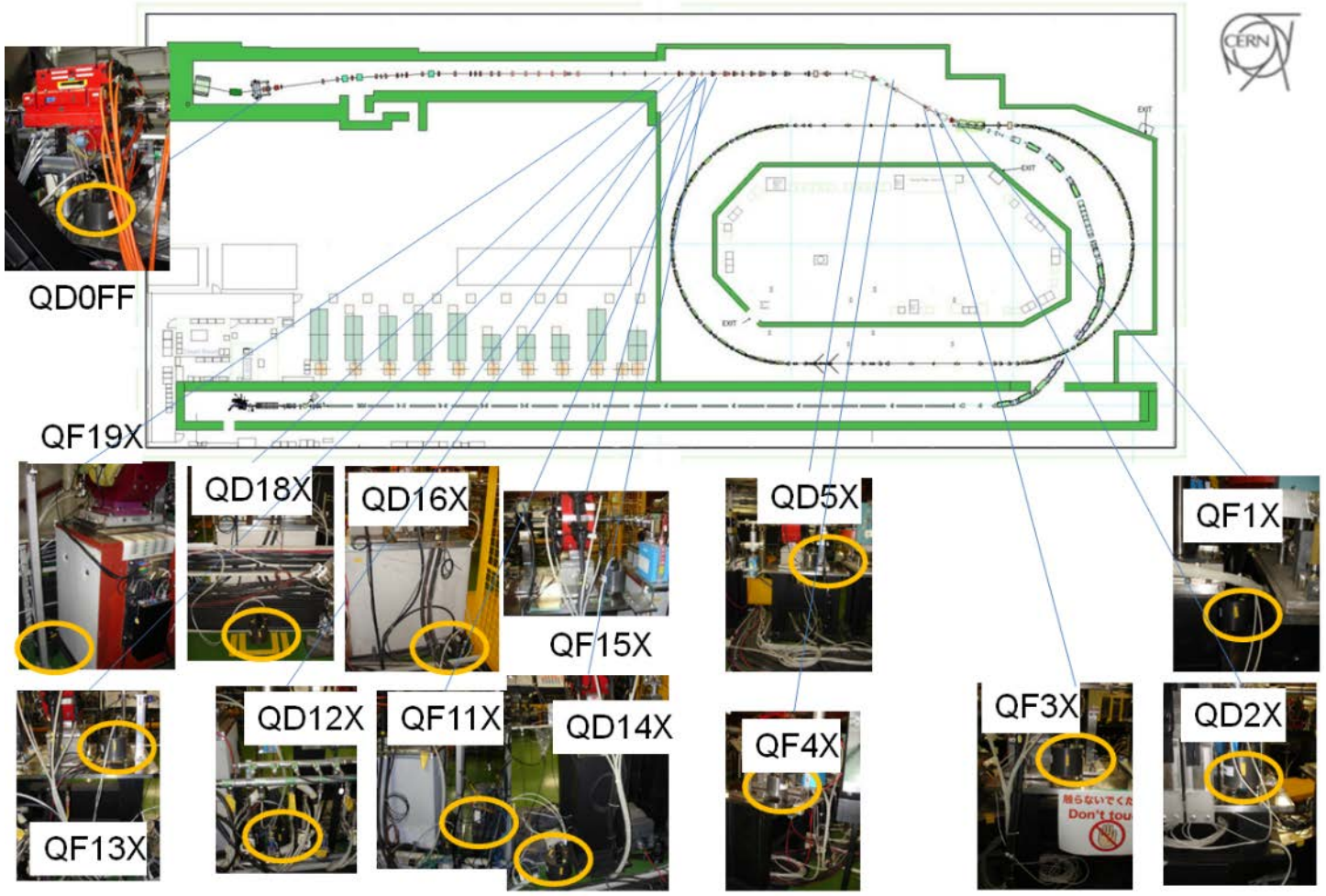




Sandry Wallon (LAL)

Ground Motion and GM based feedforward

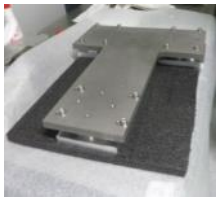
14 Guralp 6T sensors all along ATF2 for GM studies and GM feedforward



Guralp 6T: 0,5Hz-100Hz, two directions connected (vertical and horizontal can be placed parallel or perpendicular to beam direction), mainly in Extraction line, 2 sensors easily relocated

A.Jeremie (LAPP)

Vibration source identification and mitigation

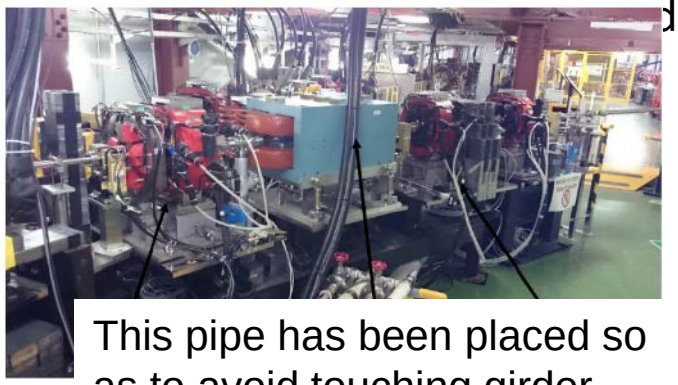


Rel. Displ. RMS @ 1Hz QF1FF vs tabletop	Initial support		New support
Horizontal	290 nm	÷~6	52 nm
Vertical	21 nm	÷~4	6 nm

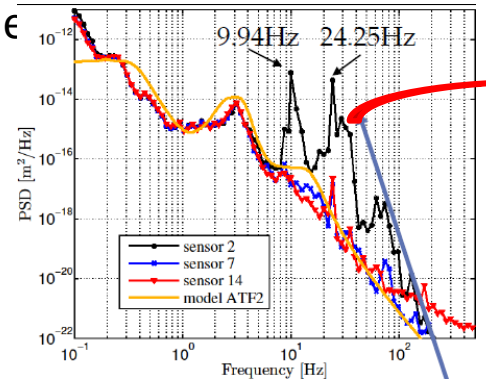
Success in vibration mitigation

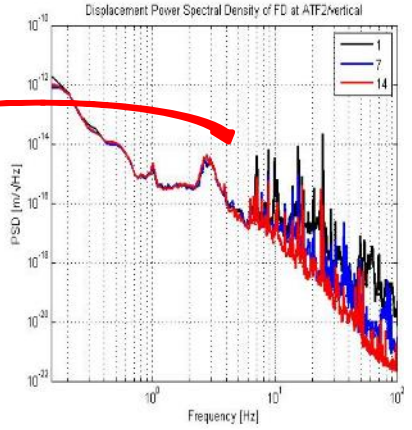
New Final Focus QF1FF magnet (better multipole behaviour) 3 times heavier => needed support study

- New support design, fabrication, installation in 2015



This pipe has been placed so as to avoid touching girder





RMS orbit jitter was reduced by a factor 1.4.

Step by step: vibration source identification and mitigation

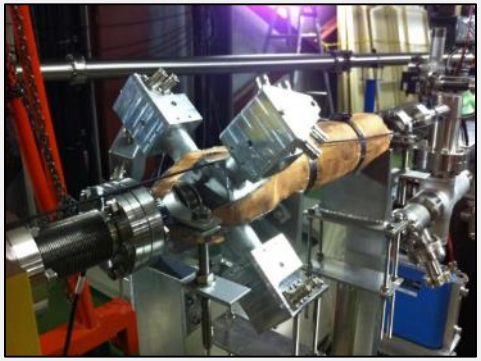
Similar concept to orbit feedback but uses **seismometers** instead of BPMs to drive the correction.

- Cheaper than active stabilization systems.
- Correct frequencies out of limits of orbit feedback.

Feed-forward setup

seismometers (mounted on quads)

stripline kicker "K2"



kicker amplifier

FONT5 board

drive pulse

trigger

drive signal

feed-forward correction value

CompactRIO (processor)

trigger

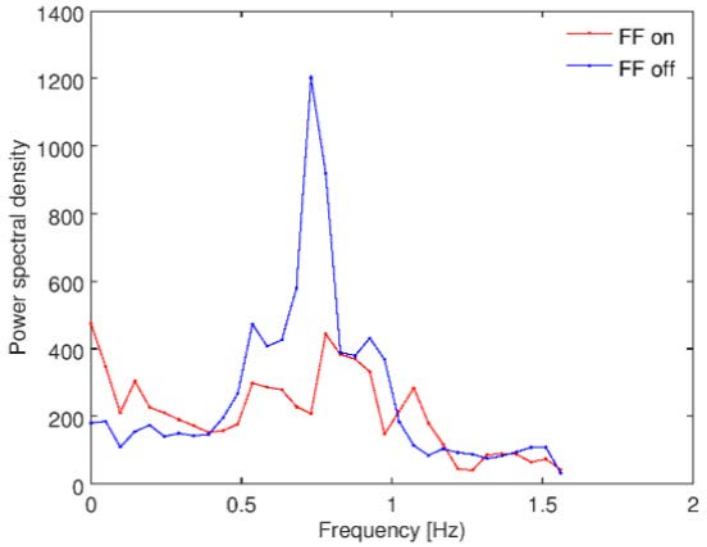
velocity signals

Feed-forward performance

Achieved first experimental demonstration of ground motion feed-forward technique.

Using a single seismometer and a single stripline kicker, consistently able to achieve a

15-20% reduction in beam jitter.



Dominant contribution to beam jitter comes from a ~24 Hz oscillation in the QD2X region believed to be due to cooling water pipes.

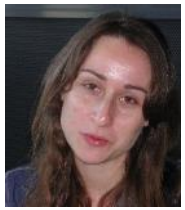
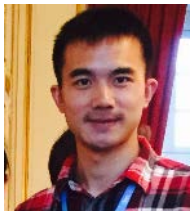
Publications in 2016

- *In vacuum diamond sensor scanner for beam halo measurements in the beam line at the KEK Accelerator Test Facility*, by S. Liu et al.: Nucl.Instrum.Meth. A832 (2016) 231-242
- *Commissioning and First Performance Studies of a Single Vertical Beam Halo Collimation System at ATF2* , by N. Fuster-Martinez et al.: THPOR030.PDF, presented at the 7th International Particle Accelerator Conference (IPAC 2016), Busan, South Korea, 9-13 May 2016
- *The Development of C-Band Cavity Beam Position Monitor with a Position Resolution of Nano Meter*, by S.-W. Jang et al.: THOAA02.PDF, presented at the 7th International Particle Accelerator Conference (IPAC 2016), Busan, South Korea, 9-13 May 2016
- *Modeling and Experimental Studies of Beam Halo at ATF2* , by R. Yang et al.: MOPMB008.PDF, presented at the 7th International Particle Accelerator Conference (IPAC 2016), Busan, South Korea, 9-13 May 2016
- *Ground Motion Compensation using Feed-forward Control at ATF2*, by D. Bett, et al., WEPOR005, in Proc. 7th International Particle Accelerator Conference (IPAC'16), Busan, Korea, 9-13 May 2016

- And 15 more common publications since 2013.

- Renjun Yang, PhD student of the LAL group on the ATF2 project was seconded to KEK for one month in October-November 2016, supported by the TYL-FJPPL Student or Early Stage Researcher Secondment Programme



PhDs during the 4 years of the FJPPL project:

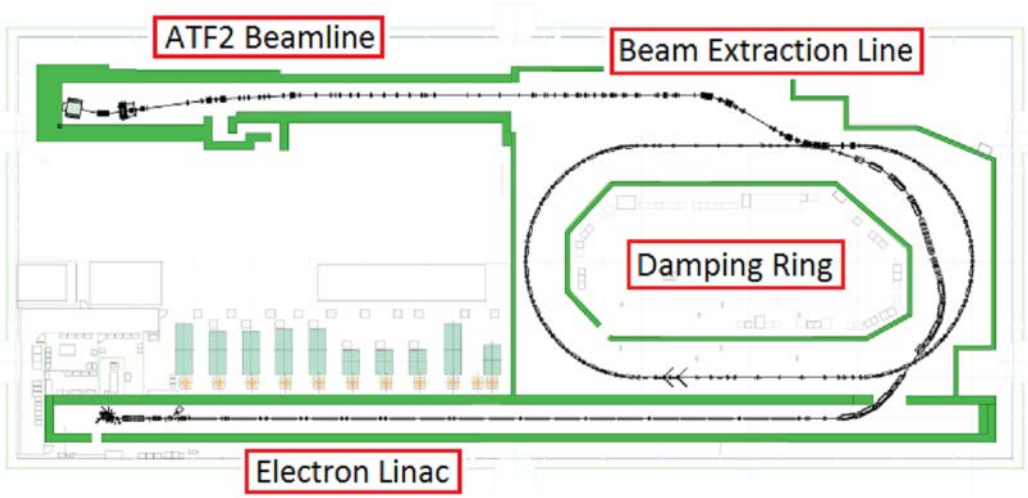
- Oscar BLANCO, CERN-LAL (2015), CLIC and ATF2
- Shan LIU, LAL (2015), ATF2
- Nuria FUSTER-MARTINEZ (2017), ATF2
- Renjun YANG, LAL (2018), ATF2

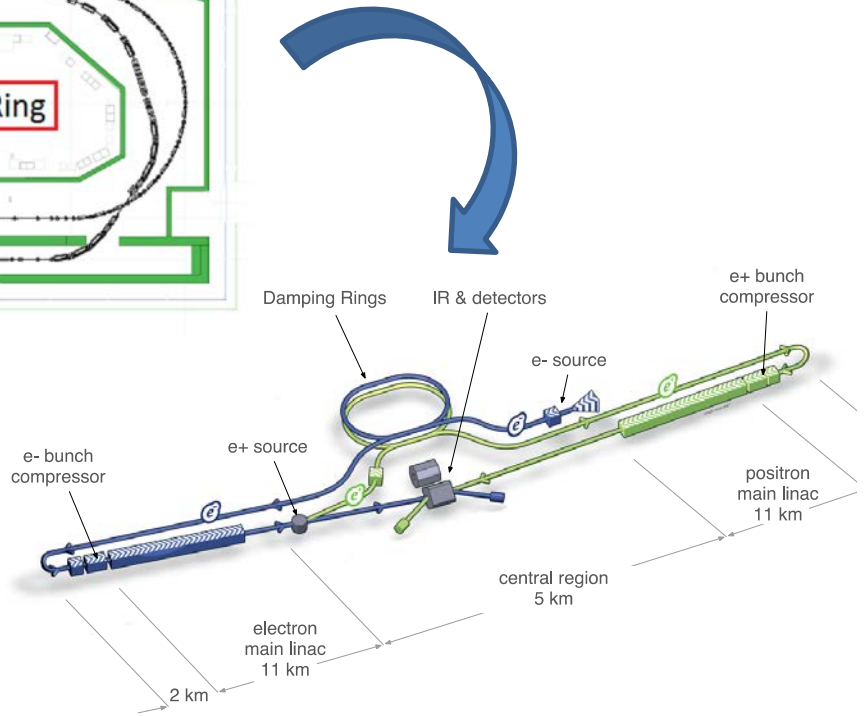
- KEK colleagues are very active with public relations and open days

Very important to train future generations!

- ATF2 is achieving it's goals and continuing improvement:
  - Goal 1: 37 nm beam size (41 nm achieved), demonstrated chromaticity design => routinely 40-50nm size beam
  - Goal 2: ~nm stability ongoing work
- FJPPL/ ATF2 collaboration has also reached following goals:
  - Intra-train beam position feedback performance increased
  - Ground motion feed-forward demonstrated
  - Collimation system installed, cause of vertical halo understood
- Successful collaboration
- … but new tasks to tackle

Application for new project

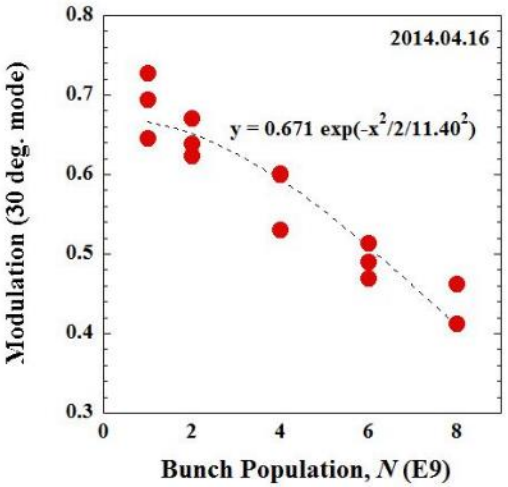




Look to the future of accelerators
⇒ Application

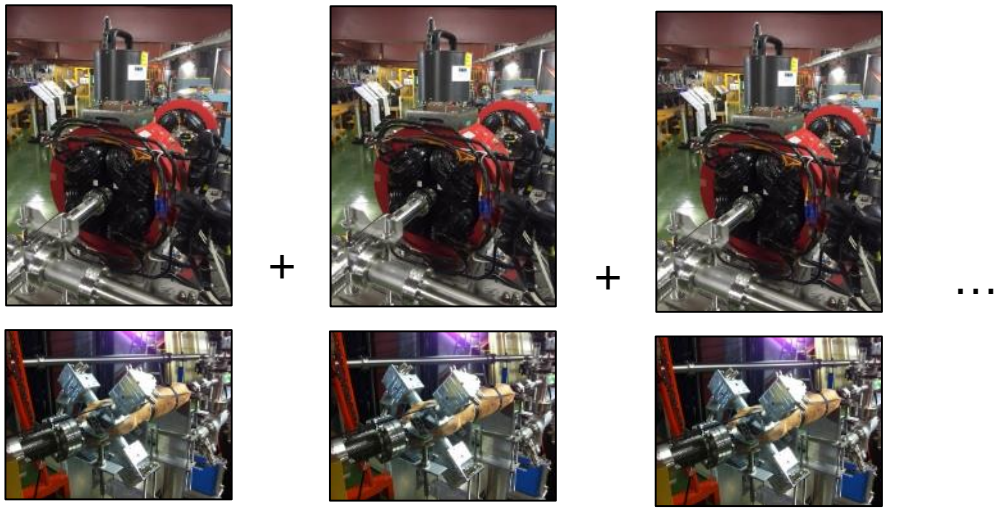
ATF2 studies and preparations for ILC

Intensity dependence of beam size (only 2-3mn)



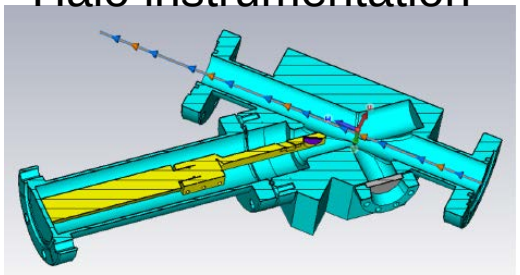
Inversely α to beam size

Studies show effect of Wakefields that are larger than expected



GM

Halo instrumentation



FJPPL (TYL) application 2016-2017

Fiscal year April 1st 2016 – March 31st 2017

Please replace the red examples by the appropriate data in black

ID [1] : A_RD_10	Title: ATF2 studies and preparations for ILC

	French Group			Japanese Group		
	Name	Title	Lab./Organis.[2]	Name	Title	Lab/Organis.[3]
Leader	Angeles Faus-Golfe	IR1	LAL/IN2P3	Kiyoshi Kubo	Prof.	KEK
Members	Philip Bambade	DR1	LAL/IN2P3	Toshiaki Tauchi	A.Prof.	KEK
	Renjun Yang	PhD st.	LAL/IN2P3	Takashi Naito	A.Prof.	KEK
	Sandry Wallon	IR2	LA/IN2P3L	Nobuhiro Terunuma	Prof.	KEK
	Frédéric Bogard	IE2	LAL/IN2P3	Shigeru Kuroda	A.Prof.	KEK
	Patrick Cornebise	IE2	LAL/IN2P3	Toshiyuki Okugi	A.Prof.	KEK
	Andrea Jeremie	IRHC	LAPP/IN2P3	Sakae Araki	Eng	KEK
	Laurent Brunetti	IR2	LAPP/IN2P3	Yu Morikawa	Eng	KEK

Funding Request from France

Description	€/unit	Nb of units	Total (€)	Requested to[4]:
LAPP travel to KEK and FJPPL events: meetings and measurements with sensors		2 travels	5000	IN2P3
LAL travel to KEK and FJPPL events (beam tests, meetings, installation)		4 travels	10000	IN2P3
LAL YAG/OTR vacuum chamber transport to KEK		1 transport	1500	IN2P3
Total			18500	

Funding Request from KEK

Description	k¥/Unit	Nb of units	Total (k¥)	Requested to:
Travel	150	3 travel	450	KEK
Visit to France	20/day	27.5 days	550	
Total			1000	

KEK: host of the ATF2 project

- Understanding intensity dependence of beam size
- Goal 2, nanometer beam position stabilization at IP

LAPP: ground motion effect on beam

- parameter optimization of the GM feedforward contributing to beam jitter mitigation
- enlarge the scope of the feedforward with a larger number of correctors along the beamline to prepare for ILC
- Vibration source identification all along the ATF2 line

LAL: nanometre beam measurement, control and design studies

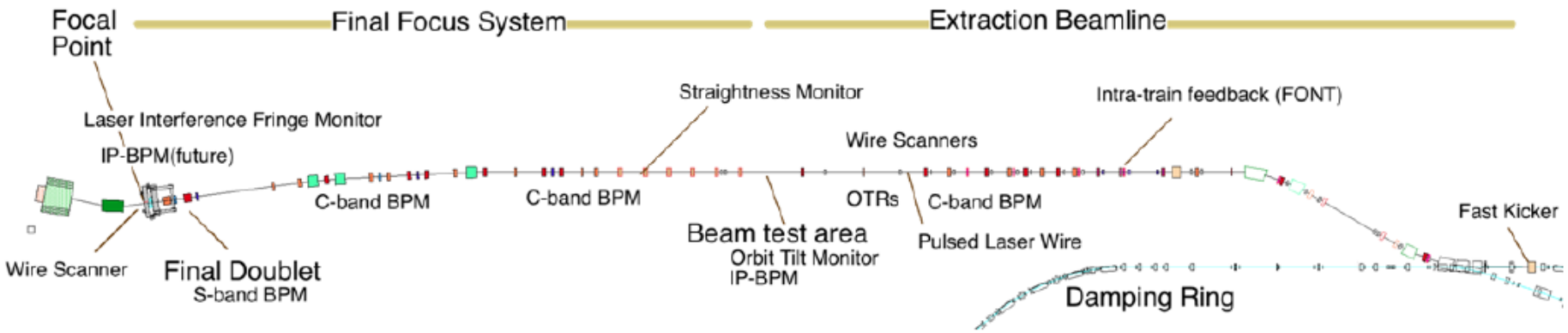
- careful study of the ATF2 beam halo, upgrade a YAG-based beam halo monitor, new vacuum chamber taking into account wakefield issues
- Continued support for piezo-movers and mechanics for the nanometer level beam stabilization project, modified version of two IP-BPMs
- LAL joining a new KEK-based study group charged with re-optimizing ILC IP/BDS/DR parameters for a staged ILC project starting with at 250 GeV centre-of-mass energy.

- Key members contribute to ILC European Action Plan as part of the E-JADE H2020 contract

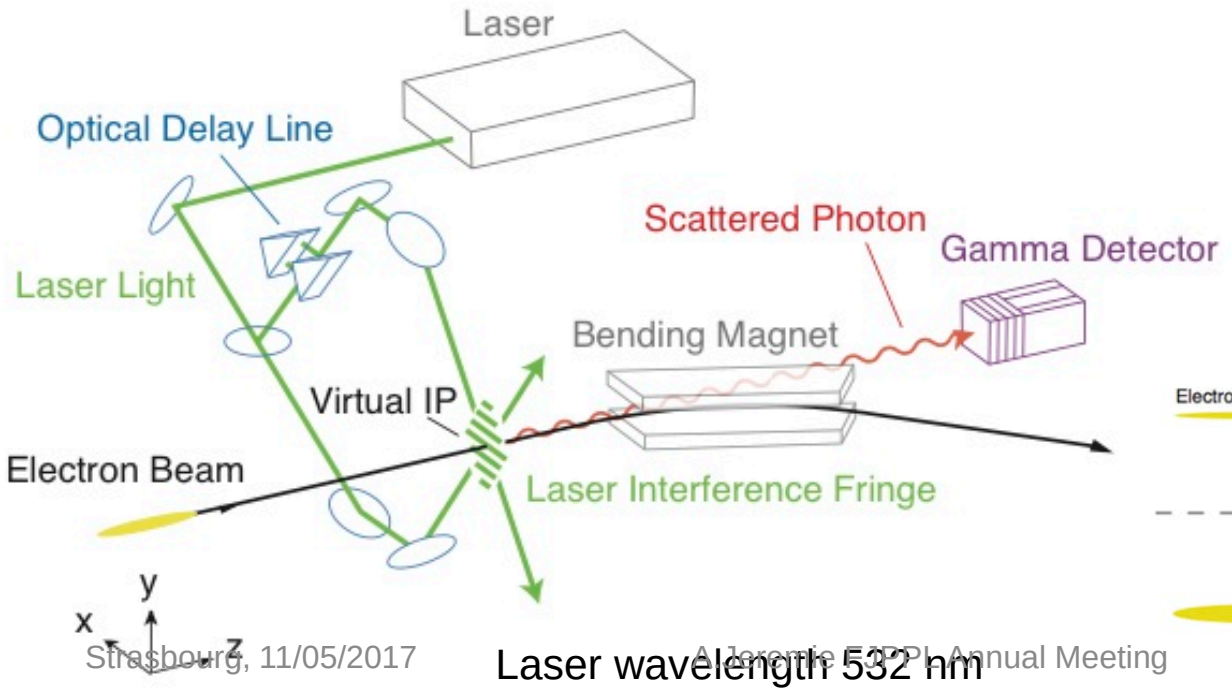
Several presentations at IPAC2017; training of students

backup

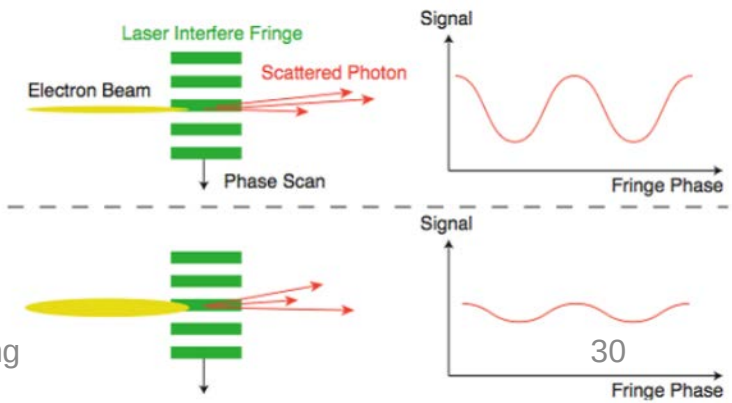
Measuring nanometre beams at ATF2



Goal 1 → 40-45 nm vertical size routinely achieved !



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



Laser wavelength 532 nm

Recent results of ATF2

ATF2: Final focus Test beamline

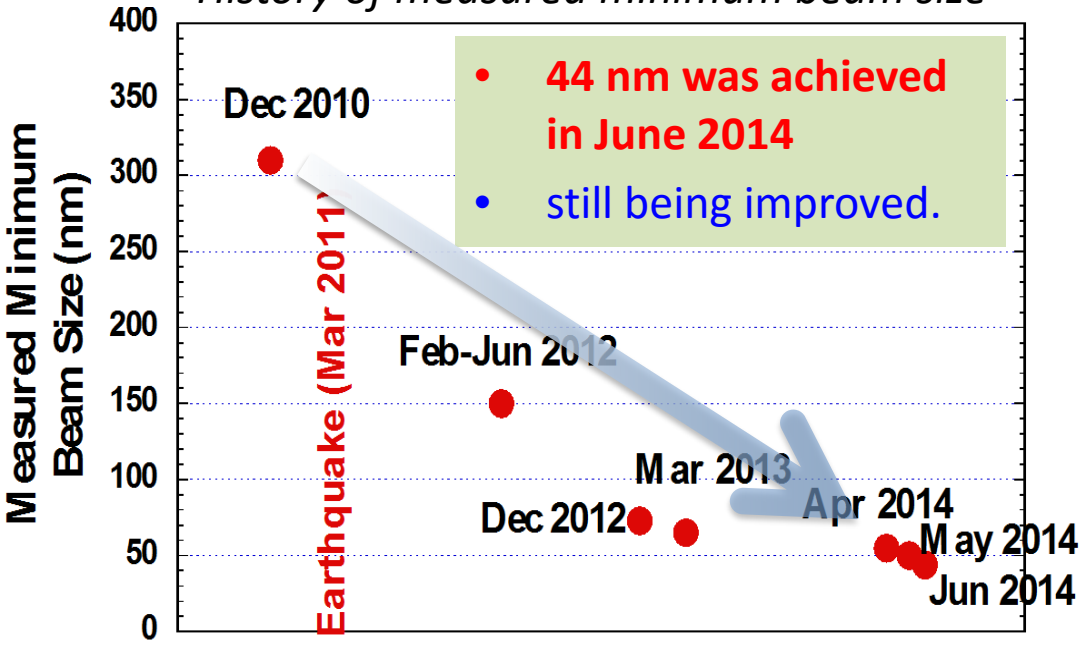
Goal-1: Develop final focus system for ILC

→ **37 nm vertical beam size at IP**

Goal-2: Develop beam position stabilization in a few nm

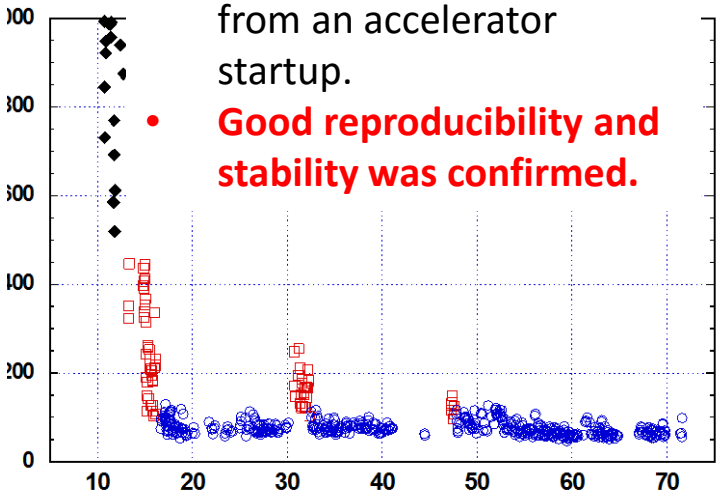
→ contributed by TYL-FJPPL and FKPPL programs.

History of measured minimum beam size



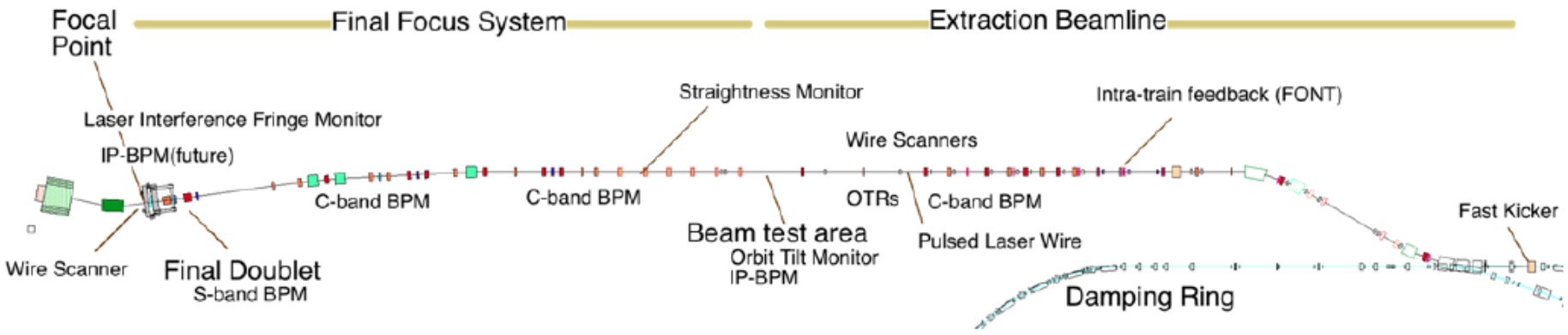
Presented by K.Kubo at IPAC2014

- Small beam size (<50 nm) was recovered in a day from an accelerator startup.
- **Good reproducibility and stability was confirmed.**

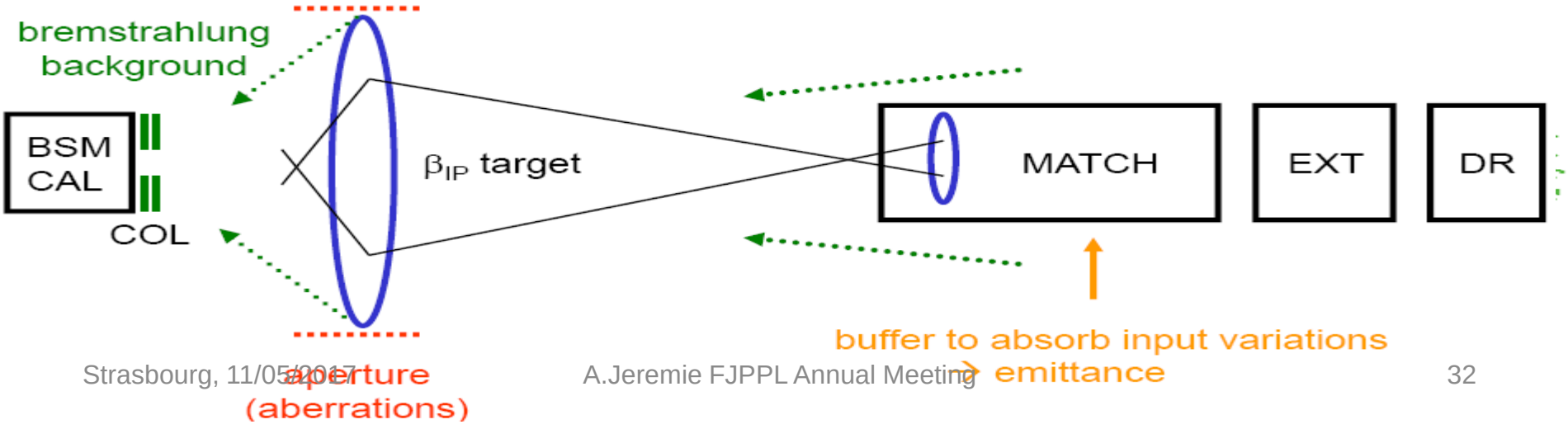


Time (hours) from operation start after 3 days shutdown

Producing nanometre beams at ATF2



2nd order telescope	Match optics into FF	DR extraction
fine tuning of local errors	*buffer section for input errors*	*setup, stability*

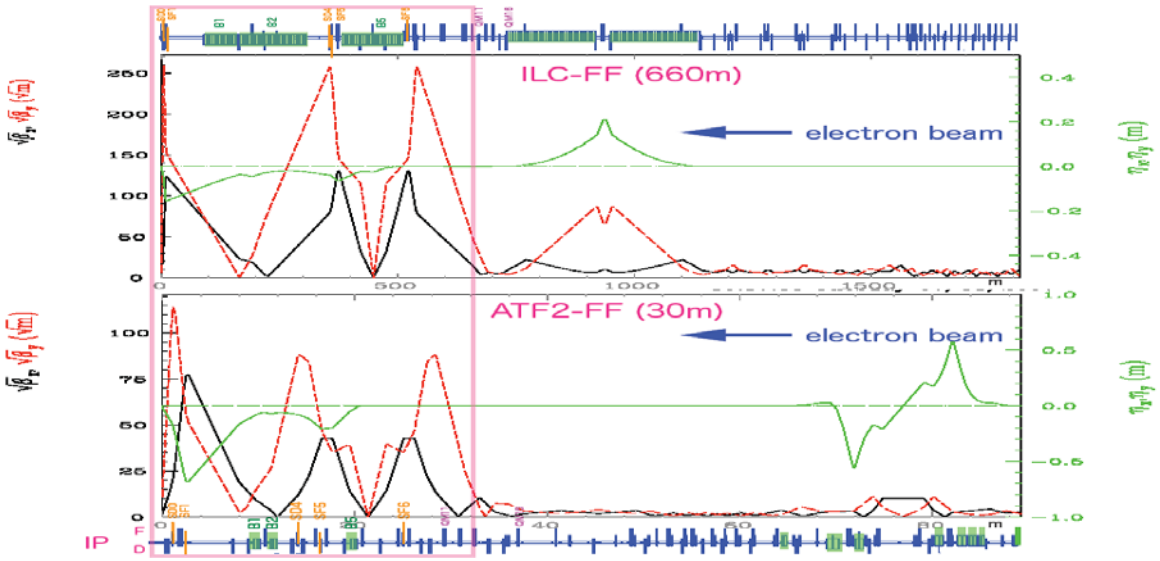


ATF2 = scaled ILC FFS

FFTB ➔ ATF2

local chromaticity correction

- ✓ ***superior***
- ✓ ***more compact***



Parameters	ATF2	ILC	CLIC	SuperKEKB
Beam Energy [GeV]	1.3	250	1500	4-7
L* [m]	1	3.5 - 4.5	3.5	0.47-1.3
$\gamma\varepsilon_{x/y}$ [m.rad]	$5\ 10^{-6}$ / $3\ 10^{-8}$	10^{-5} / $4\ 10^{-8}$	$6.6\ 10^{-7}$ / $2\ 10^{-8}$	~ $3\ 10^{-5}$ / ~ $1\ 10^{-7}$
IP $\beta_{x/y}$ [mm]	4 / 0.1	21 / 0.4	6.9 / 0.07	25-32 / 0.27-0.41
IP η' [rad]	0.14	0.0094	0.00144	
δ_E [%]	~ 0.1	~ 0.1	~ 0.3	0.065
Chromaticity ~ β* / L*	**~ 10^4**	**~ 10^4**	**~ $5\ 10^4$**	**$1.7\text{-}3.2\ 10^3$**
Number of bunches	1-3	~ 3000	312	2500
Bunch population	1-2 10^{10}	2 10^{10}	3.7 10^9	
IP σ_y [nm]	37	5.7	0.7	59