E-JADE is a Marie Sklodowska-Curie Research and Innovation Staff Exchange (RISE) action, funded by the EU under Horizon2020

E-JADE Mid-Term Review

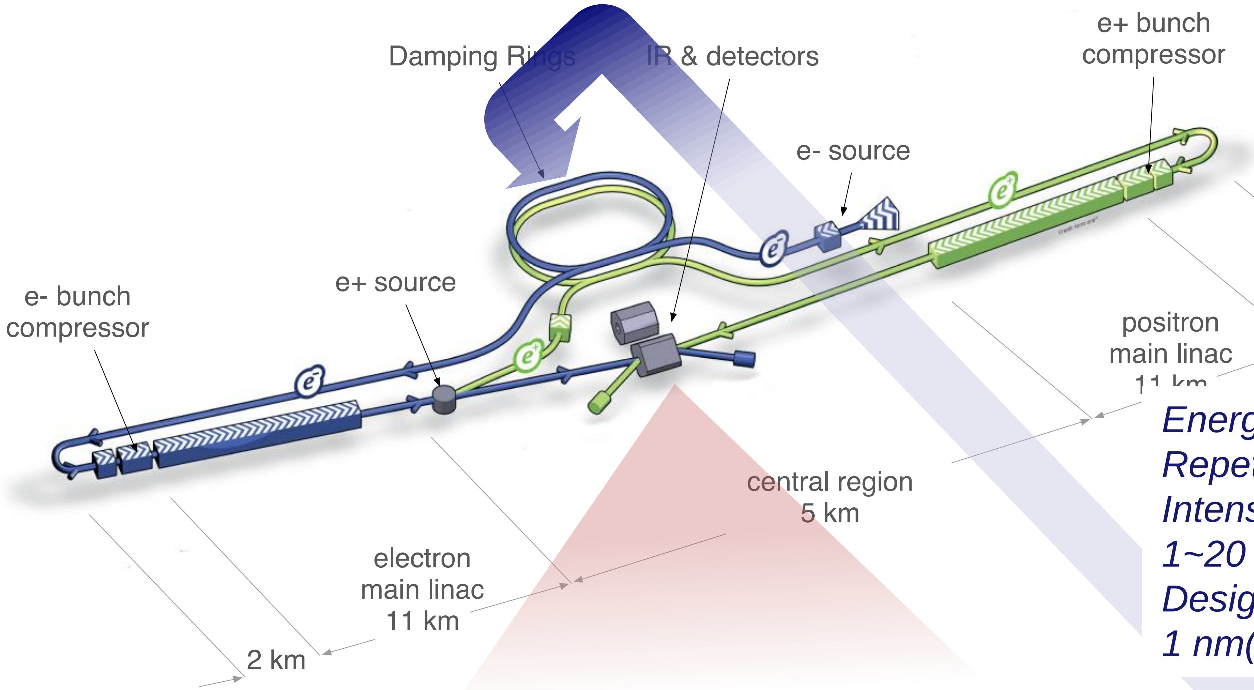
Nanometre scale beam handling at the ATF

ATF2 @ KEK (Japan)

Philip Bambade / WP2

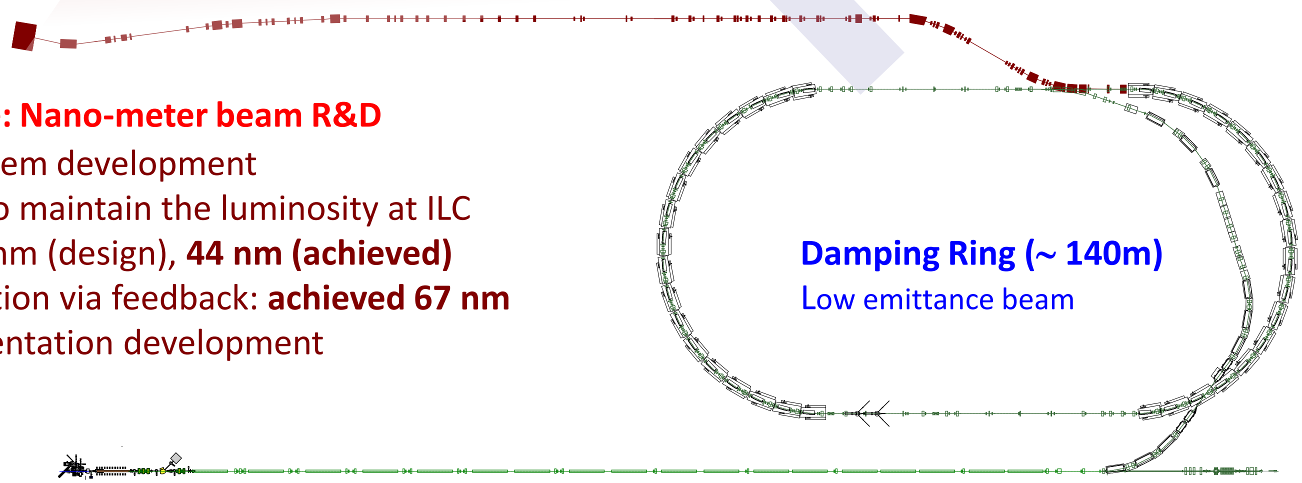
This project is funded by the European Union under Grant Agreement no. 645479

WP 2: ATF ↔ Linear Collider



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)

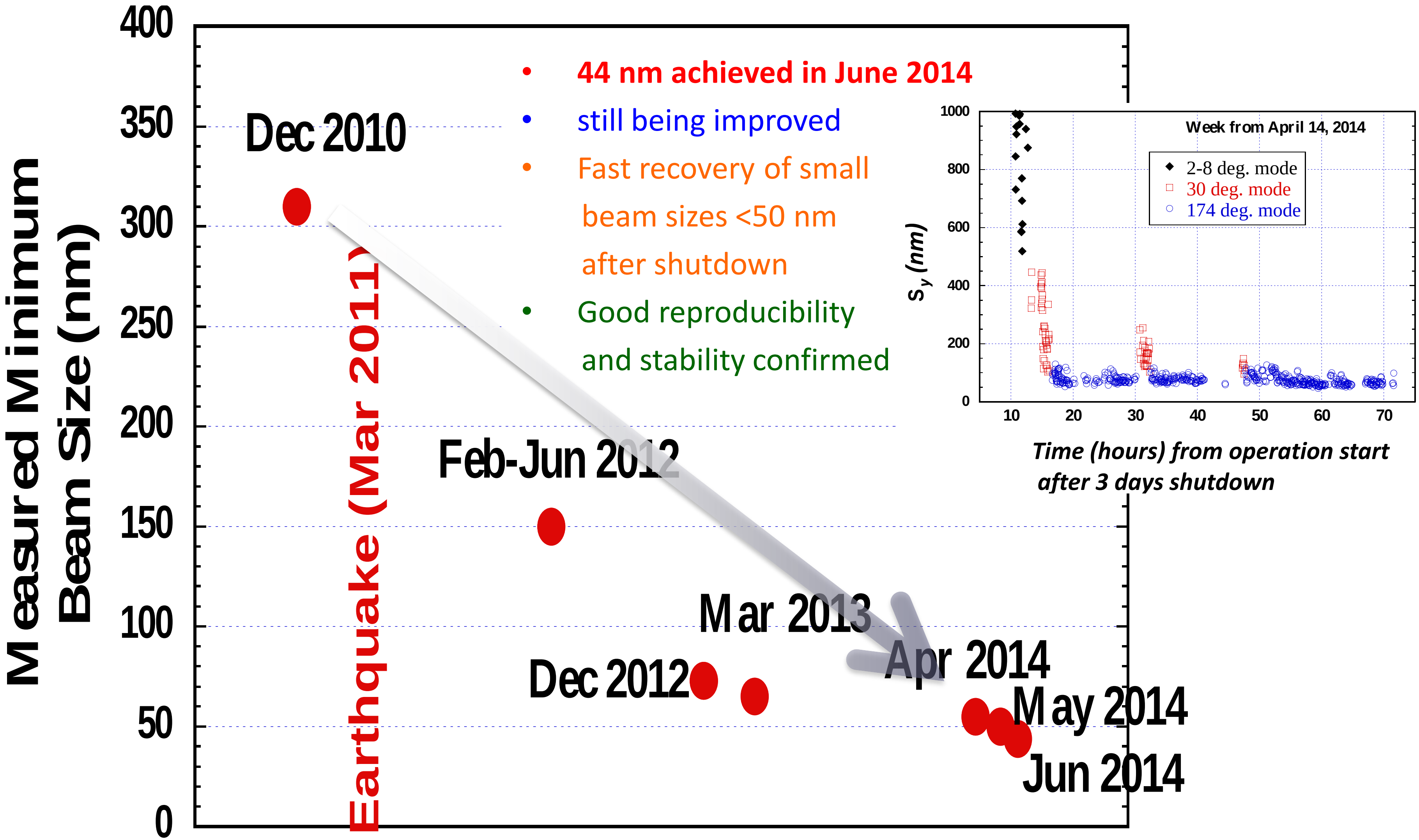


ATF2 beamline: Nano-meter beam R&D

Final focus system development
Technologies to maintain the luminosity at ILC
Beam size: 37 nm (design), **44 nm (achieved)**
Beam stabilization via feedback: **achieved 67 nm**
Beam instrumentation development

Damping Ring (~ 140m)
Low emittance beam

History of minimum beam size in ATF2



Presented by K.Kubo at IPAC2014

WP2: organization, objectives and tasks

Participant Short Name	CERN	CNRS	CSIC	KEK	RHUL	UoO	UoT
	R. Tomas	P. Bambade	A. Faus-Golfe	N. Terunuma	P. Karataev	P. Burrows	S. Komamiya
Person-months per Participant:	31	50	12	13	21	49	2

Objectives

1. Achievement and maintenance of nanometre scale beam size
2. Measurement and feedback to stabilise beam position at nanometre level
3. Development of advanced beam diagnostics instrumentation
4. Control of beam halo and background mitigation
5. Training of junior scientists and students in accelerator science

Task 2.1 **Beam Size Minimisation** (CERN, CNRS, KEK & UoT)

Task 2.2 **Wake Field** (CERN, CSIC, KEK & RHUL)

Task 2.3 **Ground Motion** (CERN, CNRS & KEK)

Task 2.4 **Halo Collimation and Backgrounds** (CNRS, CSIC, KEK & RHUL)

Task 2.5 **Beam Instrumentation and control** (CNRS, KEK, RHUL, UOXF & UoT)

Task 2.6 **Beam Position Feedback** (KEK & UOXF)

WP2: schedule and deliverables

- 2 deliverable reports submitted : **HaloCollBgds-1, Instr-1**
- 1 deliverable report under preparation : **GM-1**

→ OK

Month 12 HaloCollBgds-1: Report on halo measurement and control using diamond sensor and collimators

Month 12 Instr-1**:** Report on performance optimisation of installed high resolution beam position and size instrumentation

Month 24 Instr-2**:** Design report of optical transition/diffraction radiation combined measurement station including initial beam tests

Month 18 GM-1: Reports on synchronisation of GM and orbit measurements and on new GM sensor performance

Month 24 BeamSize-1: Report on performance of installed octupole magnet pairs in correcting 3rd order optical aberrations

Month 24 Wakefield-1**:** Report on wakefield simulation and measurements including mitigation plans and implications for the Linear Collider

Month 24 Feedback-1**:** Report on operation of collision point feedback system

Month 24 HaloCollBgds-2**:** Report on integrated simulation and evaluation of beam transport including beam instrumentation and charged particle backgrounds

Month 36 Wakefield-2**:** Report on wakefield free steering performance to mitigate wakefields

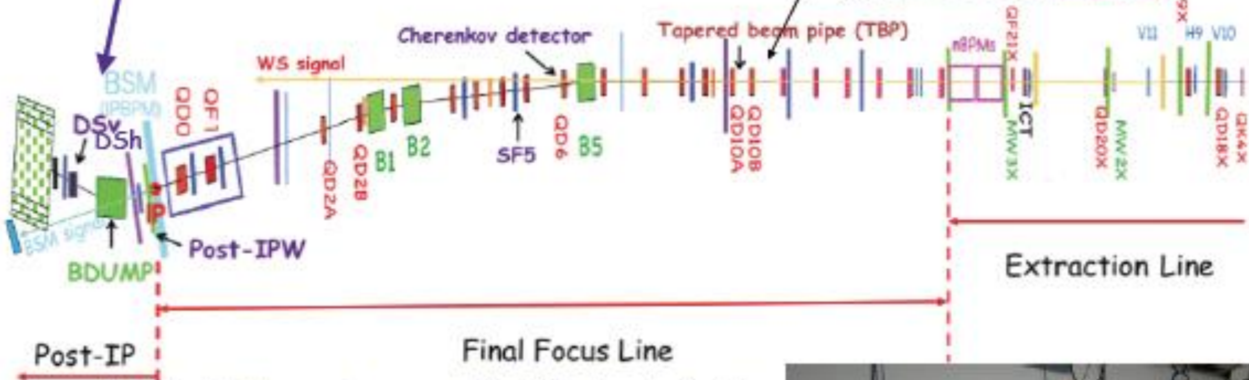
Month 36 GM-2**:** Final report on correlation between GM and orbit measurements and implications for GM based feed-forward

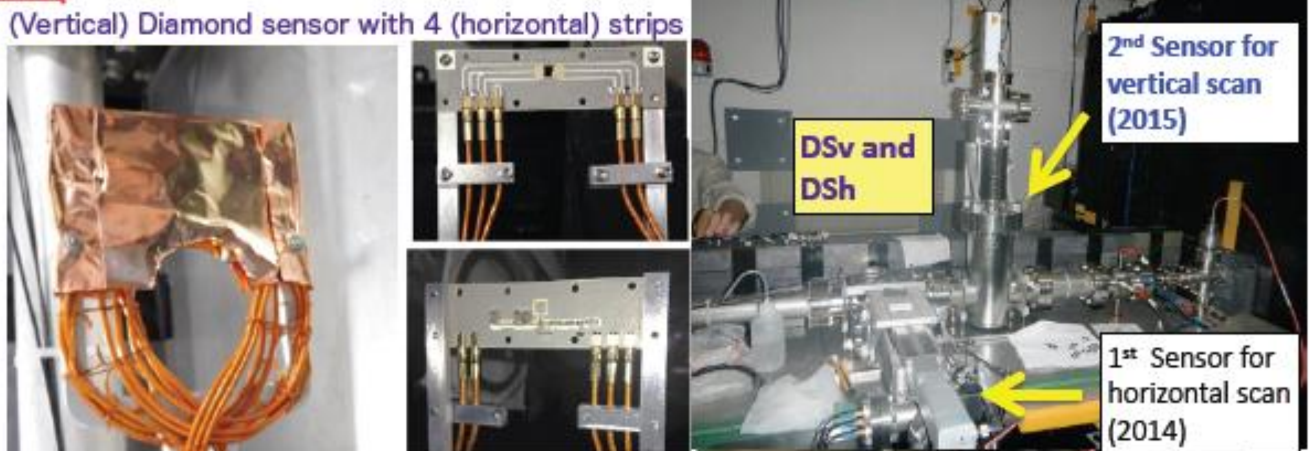
Month 48 Feedback-2**:** Final report on performance of interaction-point feedback system, and implications for its implementation in the Linear Collider

Month 48 BeamSize-2**:** Final report on beam size minimisation in horizontal and vertical dimensions using optimised optics, and implications for the Linear Collider

WP2 deliverable : HaloCollBgds-1 (1)

Horizontal and Vertical Diamond Scanners (DSh, DSv) 1.5 m after BDUMP magnet. Installed + commissioned in Nov-Dec 2014 and May-June 2015, respectively.

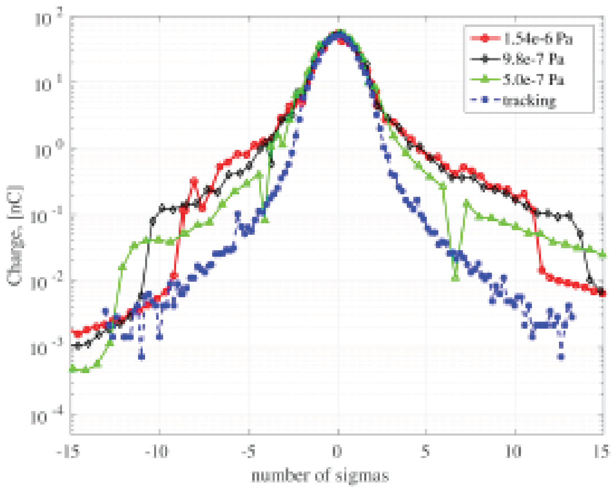


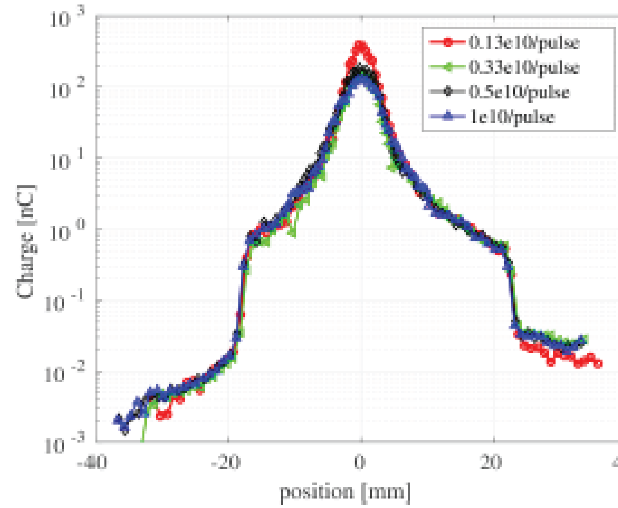


WP2 deliverable : HaloCollBgds-1 (2)

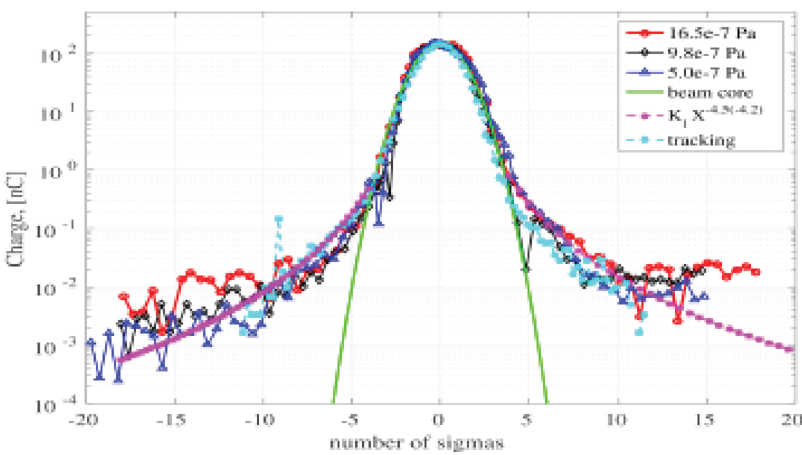
Measurements of Beam Halo

1. Vertical direction as a function of DR vacuum pressure and the beam intensity





2. Horizontal direction as a function of DR vacuum pressure



1. Vertical beam halo is mainly determined by elastic beam gas scattering in the damping ring(DR). The beam size increases with the beam intensity as expected from the intra-beam scattering.

2. Horizontal beam halo is dominated by the other source for less dependence on the DR vacuum pressure.

RJ. Yang, Poster for the IPAC 2016, 4 May 2016

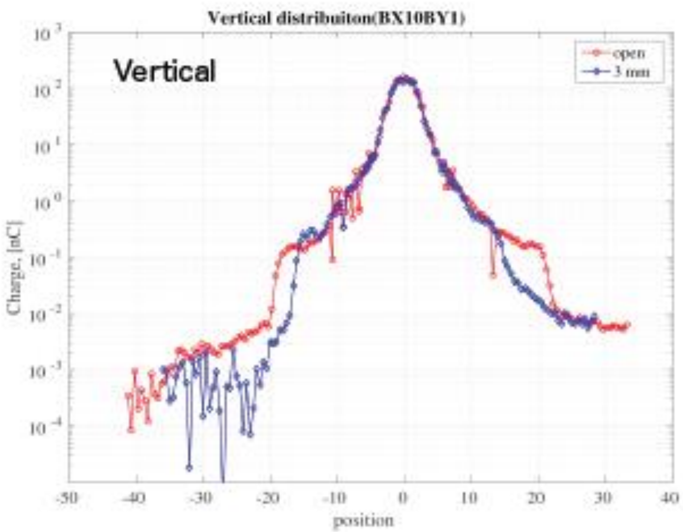
WP2 deliverable : HaloCollBgds-1 (3)

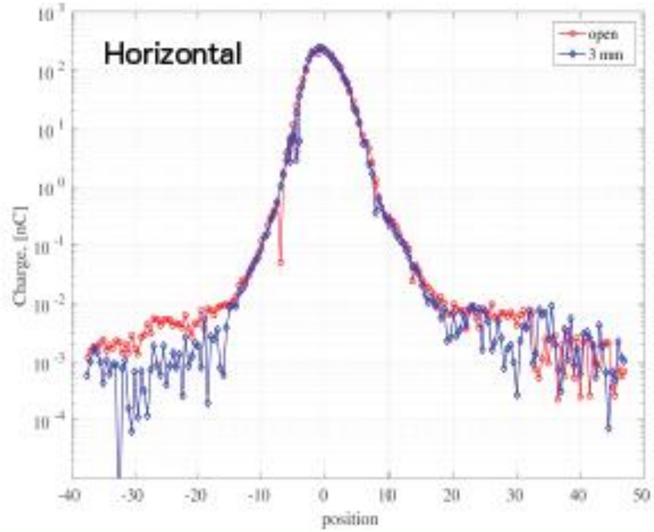
Beam cut by collimator

LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

IFIC CSIC

- Beam optics: bx10by1
  beam intensity: 0.3e10 /pulse
  damping ring vacuum: 5.07e-7 Pa
- Collimator setting: open (red line)and closed to 3 mm (blue line)



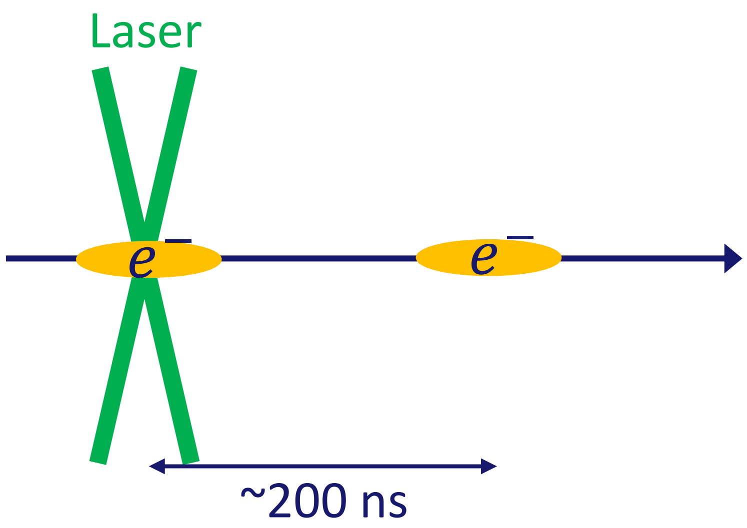


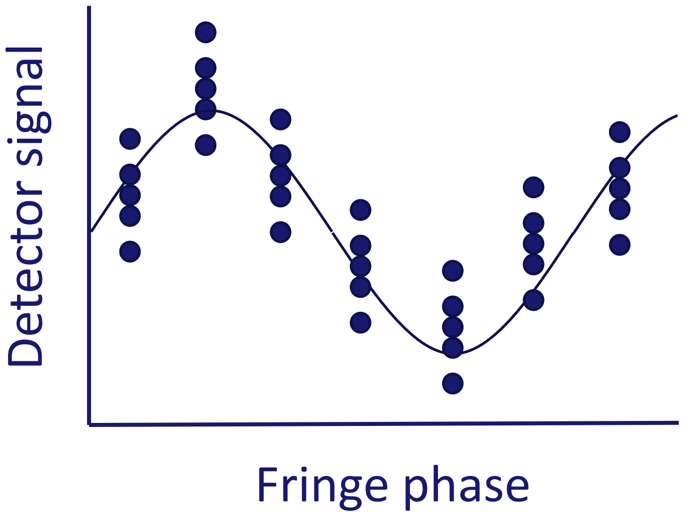
1) Vertically, symmetric cuts by vertical collimator are observed
2) In vertical plane, less residual halo beyond cut by collimator (fewer secondary particles when closing collimator)
3) Horizontally, less residual halo on low energy side when collimating vertically

RJ. Yang, presented at the ATF operation meeting, 1 April 2016

WP2 deliverable : Instr–1(1)

2nd bunch IPBSM measurement (Task 2.1)

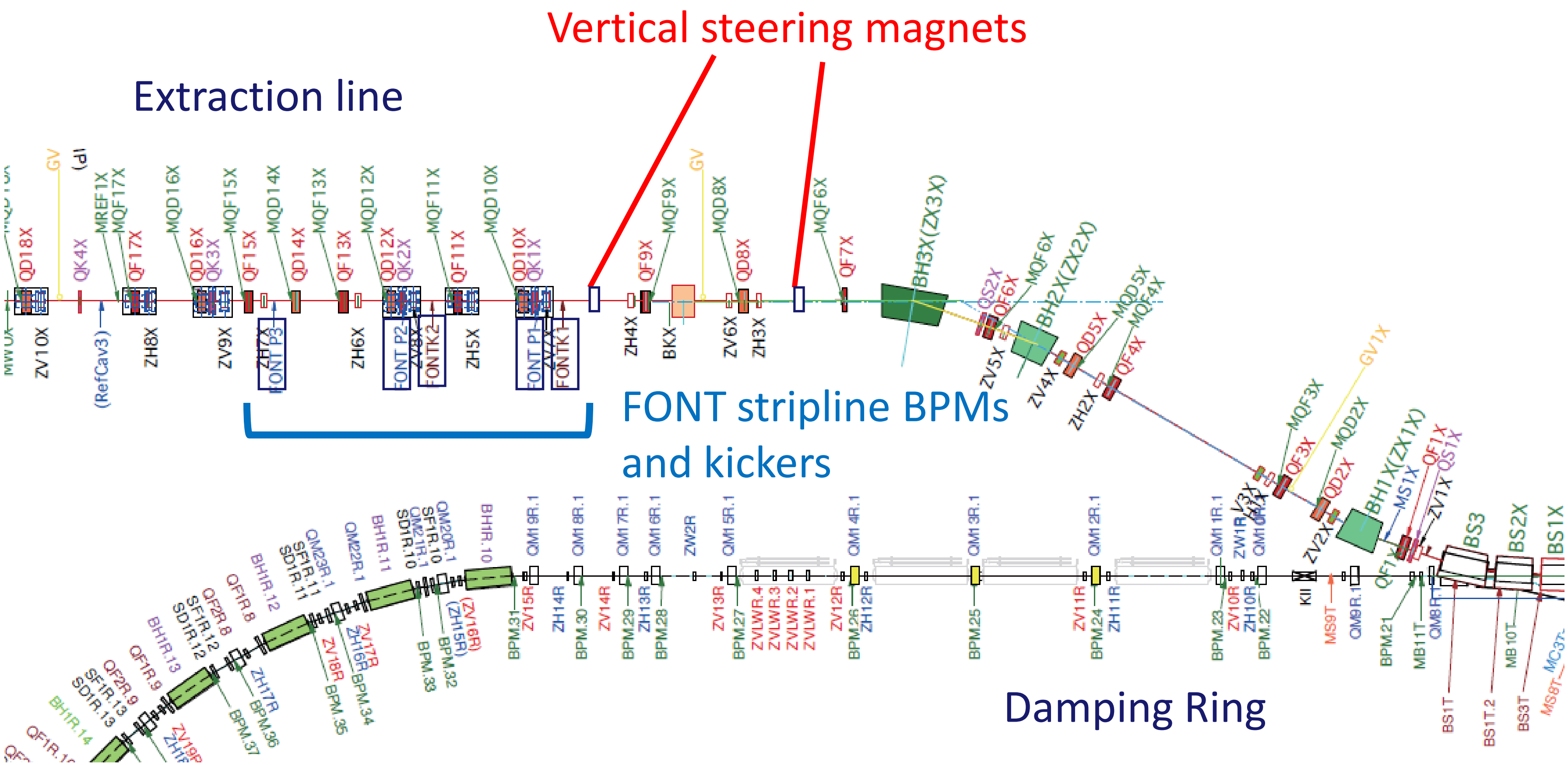




- Timing of the IPBSM laser is matched to 2nd bunch timing
- Beam size measurement is done by measuring 100-200 pulses
- It is not possible to measure the beam size of 1st&2nd bunch at the same time

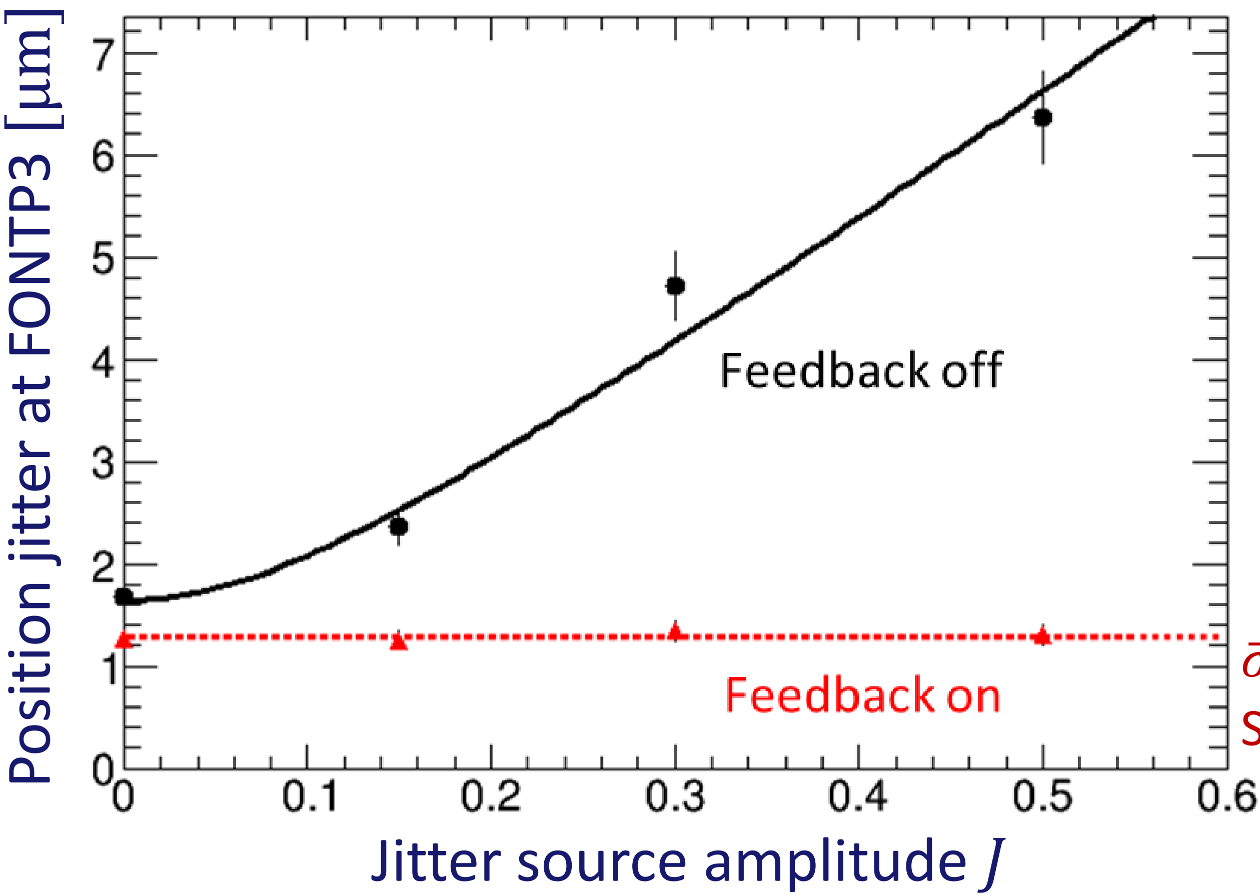
WP2 deliverable : Instr–1(1)

FONT upstream feedback (Task 2.6)



WP2 deliverable : Instr–1(3)

2nd bunch beam position measurement with/without FONT feedback
with respect to varying artificial input jitter



Bar $= jitter/\sqrt{2(100-1)}$

$$\sigma'_{\Delta y} = \sqrt{\sigma^2_{\Delta y,0} + \sigma^2_{\Delta y}}$$

$\sigma_{\Delta y}/J = 12.8\ \mu m$

$\sigma_{\Delta y,0} = 1.6\ \mu m$

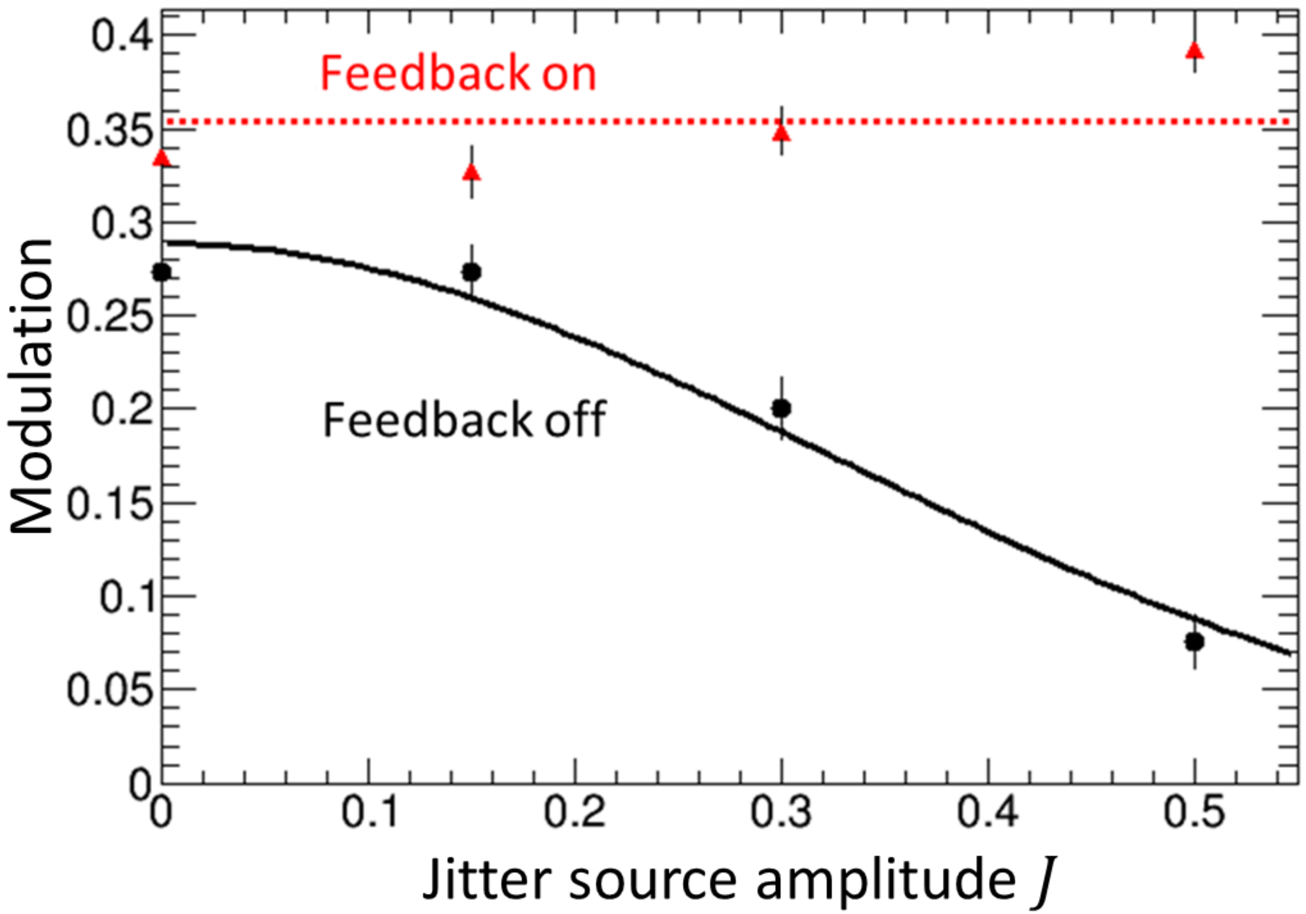
$\chi^2/N_{dof} = 4.0/2$

$\bar{\sigma}_{\Delta y} = 1.3\ \mu m$

Standard deviation = 0.04 μm

WP2 deliverable : Instr-1(4)

2nd bunch beam size measurement with/without FONT feedback
with respect to varying artificial input jitter



Bar = fit error

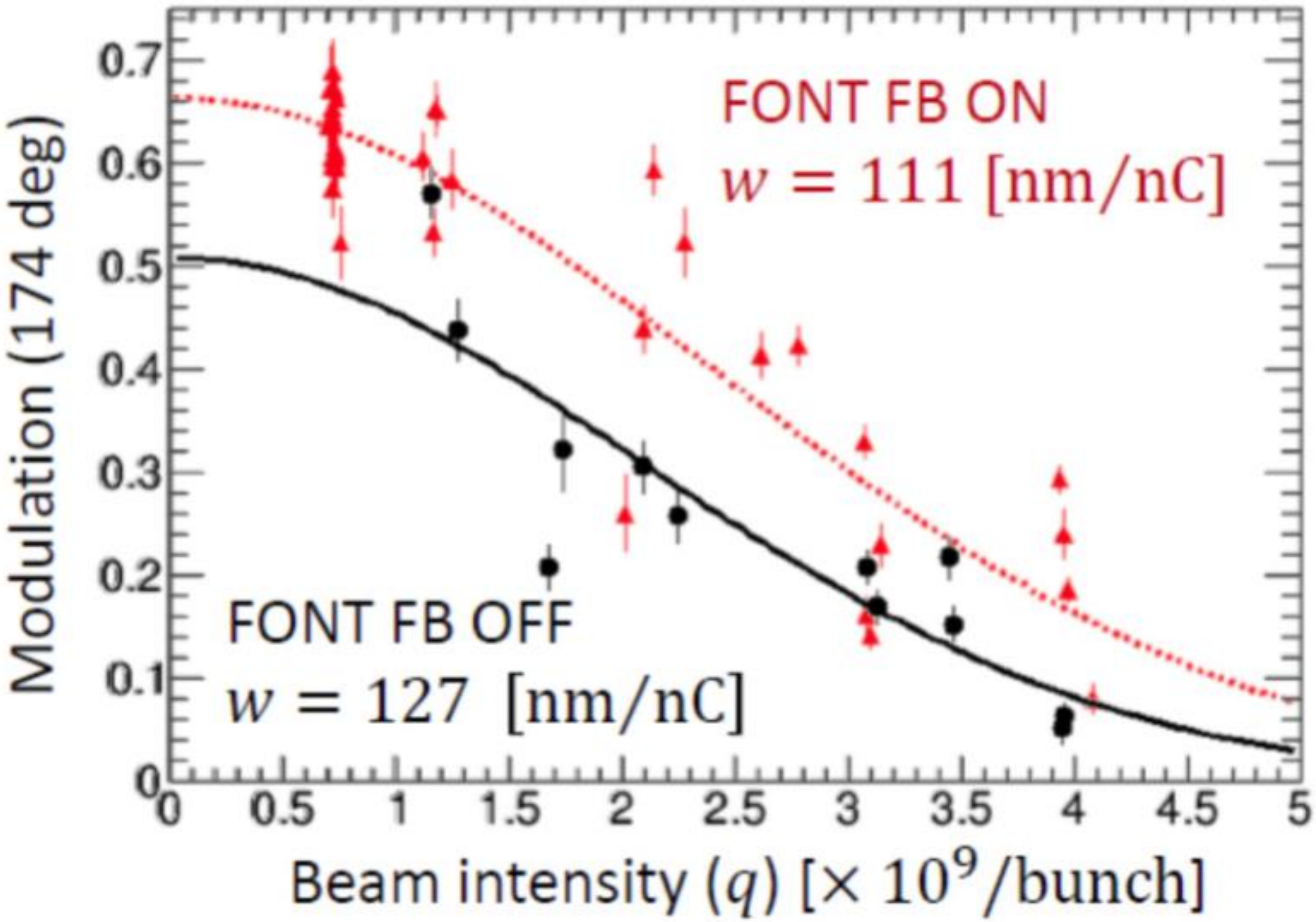
Standard deviation= 0.03

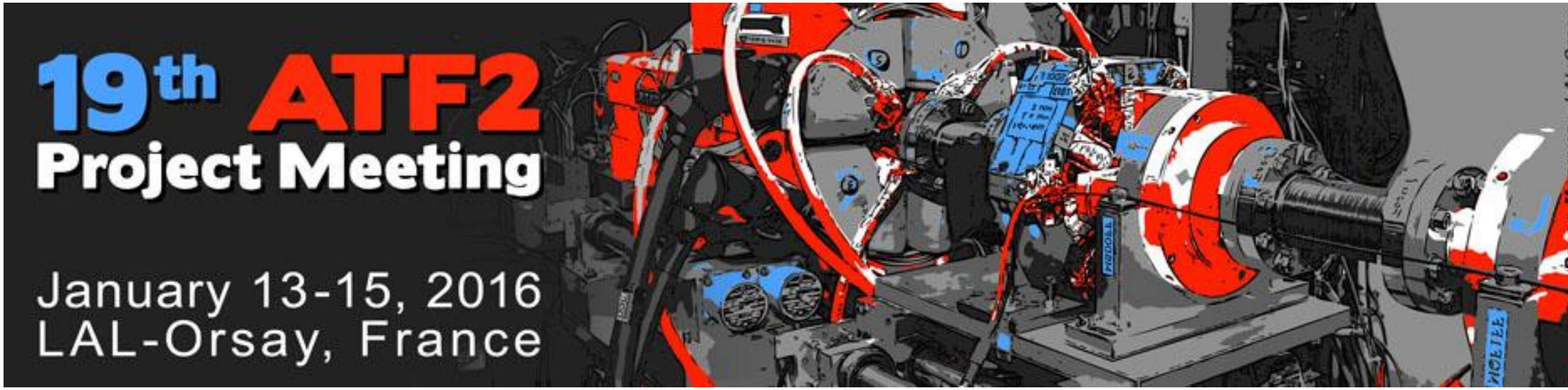
$M = M_0 \exp(-2k_y^2 \sigma_{\Delta y}^2)$
$\sigma_{\Delta y}/J = 131$ nm
$\chi^2/N_{dof} = 3.4/2$

(k_y ~IPBSM laser wavelength)

WP2 : Recent progress

2nd bunch beam size measurement with/without FONT feedback
in the presence of natural beam jitter





https://agenda.linearcollider.org/event/6939/

⇒ E-JADE WP2 annual workshop

Wednesday 13
- Status of beamline alignment, hardware and software at ATF
- 19th Technical Board & System Group Coordinator Session

Thursday 14
- Status of beam tuning for 37nm beam (Goal-1)
- Beam size tuning at the nominal beam intensity, wakefield issues

Friday 15
- IP beam stabilization at nanometer level (Goal-2)
- Future Plans

Participants

on-going or recent ATF2 graduate student

remote participant

* speaker

- ** ARAKI Sakae, KEK Japan*
- * BAMBADE Philip CNRS LAL IN2P3 France
- BERGAMASCHI Michele CERN Switzerland
- * BETT Douglas CERN Switzerland
- * BLASKOVIC KRALIEVIC, Neven Oxford University U.K
- * BROMWICH Talitha University of Oxford U.K
- BURROWS Philip Oxford University U.K
- FAUS-GOLFE Angeles IFIC - LAL Spain
- * FUSTER Nuria IFIC Spain
- ** JANG, Si-Won KNU Korea*
- ** JEREMIE, Andrea CNRS LAPP IN2P3 France*
- ** KANO, Yuya University of Tokyo Japan*
- * KIEFFER Robert CERN Switzerland
- ** KUBO, Kiyoshi, KEK Japan*
- ** NAITO Takashi, KEK Japan*
- ** OKUGI, Toshiyuki KEK Japan*
- * PATECKI Marcin CERN Switzerland
- * PLASSARD Fabien CERN Switzerland
- SCHUETZ Anne DESY Germany
- * TAUCHI Toshiaki KEK Japan
- * TERUNUMA Nobuhiro KEK Japan
- *TOMAS Rogelio CERN Switzerland*
- * WALLON Sandry CNRS LAL IN2P3 France
- WHITE Glen SLAC USA
- YAMAMOTO Akira KEK & CERN Japan
- YANG Renjun CNRS LAL IN2P3 France

WP2 : Secondment report

	CERN		CEA		CNRS		CSIC		DESY		RHUL		UOXF		TOTAL _days	Target / Actual
Beneficiaries	KEK	UoT	KEK	UoT	KEK	UoT	KEK	UoT	KEK	UoT	KEK	UoT	KEK	UoT		
WP1	6	6	0	0	0	0	0	0	0	0	0	0	0	0	12	1,3%
WP2	90	0	0	0	159	0	33	0	0	0	199	0	120	0	601	12,3%
WP3	0	0	0	0	66	0	0	0	187	89	0	0	0	5	347	10,7%
WP4	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0,1%
WP5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,0%
Subtotal	*96*	*8*	*0*	*0*	*225*	*0*	*33*	*0*	*187*	*89*	*199*	*0*	*120*	*5*	962	
TOTAL days	104		0		225		33		276		199		125			
Target / Actual	3%		0%		13%		8%		12%		29%		7%			

Total in contract = 163 months → have used 12.3 % so far, less than ~ 30% expected…

Explanations :

- slow start
- about 50% less ATF beam time in 2015, limited by electricity cost → **11 / 21-23 weeks**
- eligibility criteria lack clarity and are interpreted non uniformly…

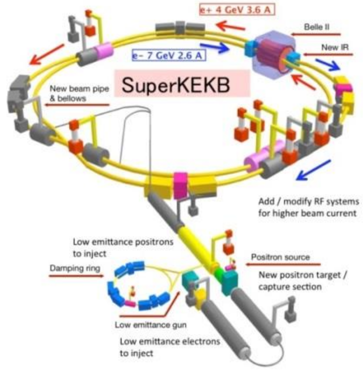
Mitigation :

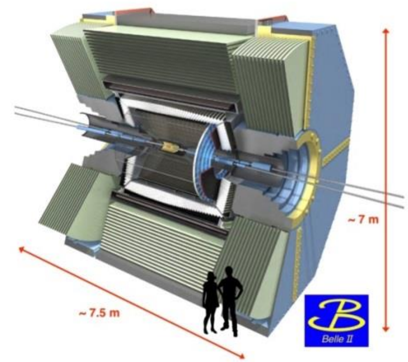
- extend scope to include research on “nanobeams” at SuperKEKB → **next slides**
- secure sufficient budget for ATF beam time in 2017-2018 ?
- clarify eligibility criteria ? → **for discussion**

WP2 : Extension of scope (1)

- Luminosity tuning & optimization
- Beam halo/loss modeling & monitoring

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

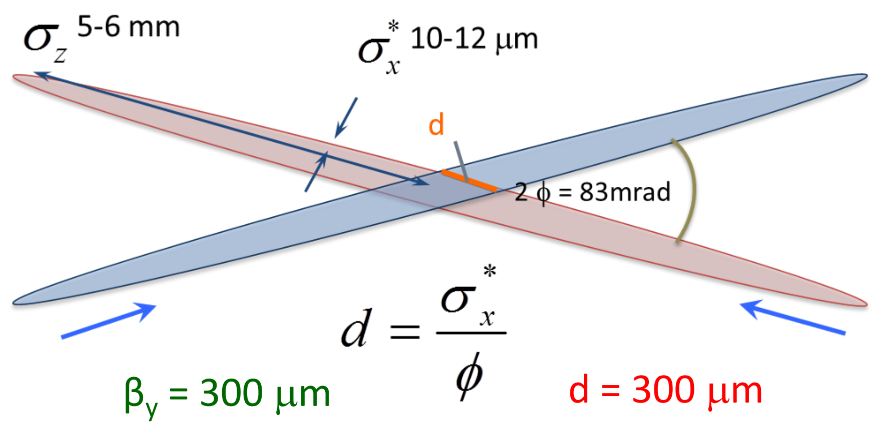




parameters		KEKB		SuperKEKB		units
		LER	HER	LER	HER	
Beam energy	E_b	3.5	8	4	7.007	GeV
Half crossing angle	φ	11		41.5		mrad
# of Bunches	N	1584		2500		
Horizontal emittance	ε_x	18	24	3.2	4.6	nm
Emittance ratio	κ	0.88	0.66	0.27	0.25	%
Beta functions at IP	β_x^*/β_y^*	1200/5.9		32/0.27	25/0.30	mm
Beam 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}**		$cm^{-2}s^{-1}$

→ **Lumi × 40**

Tests of optical tuning methods and luminosity optimization techniques at SuperKEKB



SuperKEKB uses novel "nanobeam" scheme

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

WP2 : Extension of scope (2)

Task 2.7 (new): Tests of optical tuning methods and luminosity optimization techniques at SuperKEKB

ATF2 & Linear Colliders $\leftrightarrow$ SuperKEKB

- Instrumentation for beam loss monitoring*
- Beam halo modeling*
- Optimization of collimation*
- Ground motion measurements, modeling and mitigation techniques
- Feedback to stabilize the transverse positions of the beams at the IP*
- Optical tuning to minimize the vertical beam size the IP

***active European contribution (additional resources)**

1. Fits well into steps defined to achieve overall WP2 goals $\rightarrow$ cross-fertilization
2. E-JADE covers the successive SuperKEKB commissioning phases
3. SuperKEKB = high priority KEK project $\rightarrow$ some WP2 scientists already contribute

WP2: Conclusions and prospects

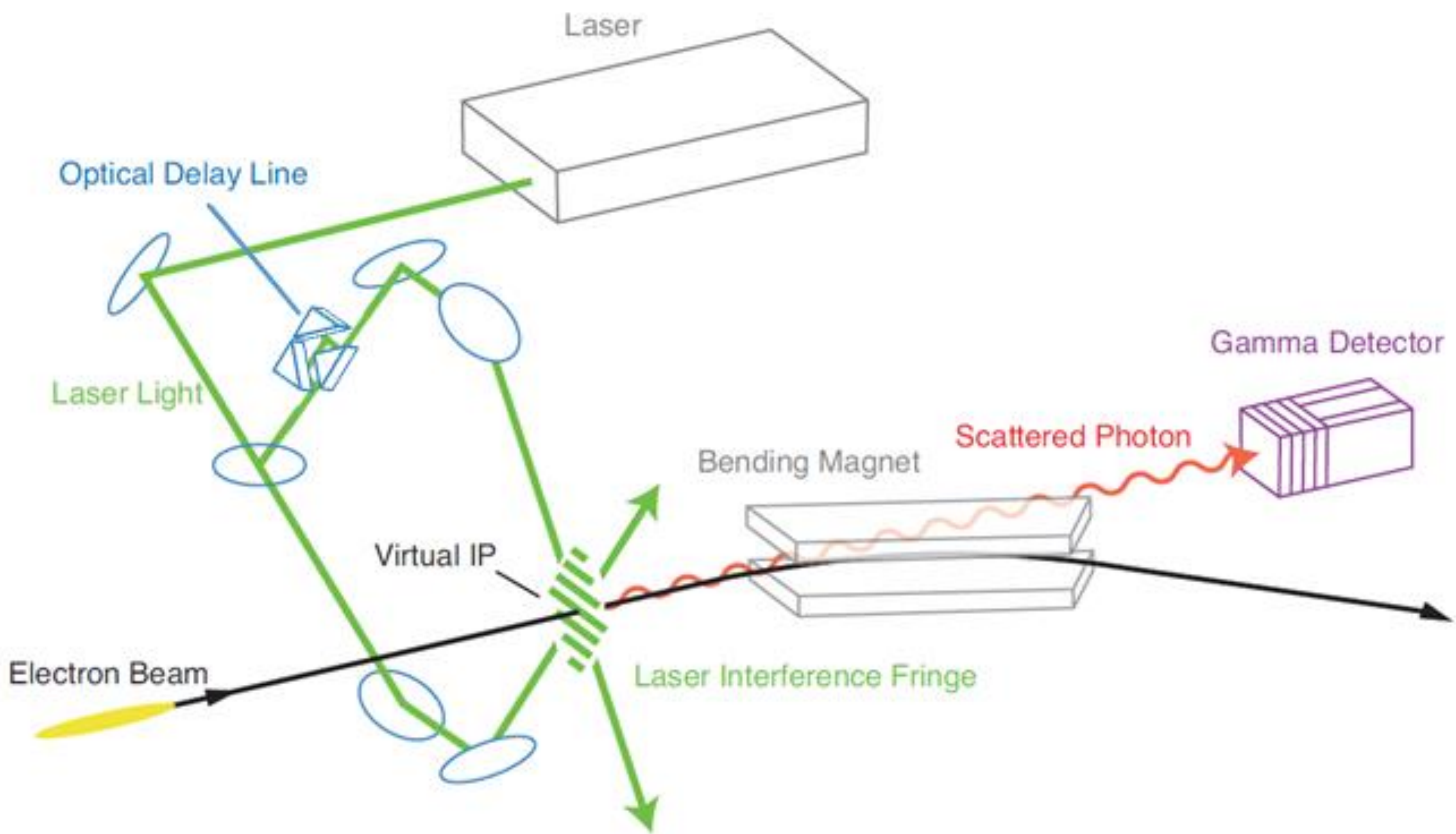
- Nanobeam handling techniques are a crucial aspect of future linear colliders such as ILC and CLIC
- Also of utmost importance for circular e+e– colliders (e.g. SuperKEKB, and CEPC / FCC-ee in the future)
- ATF @ KEK (Japan) is unique in the world for R&D on nanobeam technologies
- **E-JADE/WP2** takes full advantage of ATF to develop technical / scientific knowhow and train the **next generation of accelerator experts**
- ATF dedicated session tomorrow → Audiencia Reina

→ major contribution to the development of human resources and skills in Europe, at the state of the art in the field of accelerator science

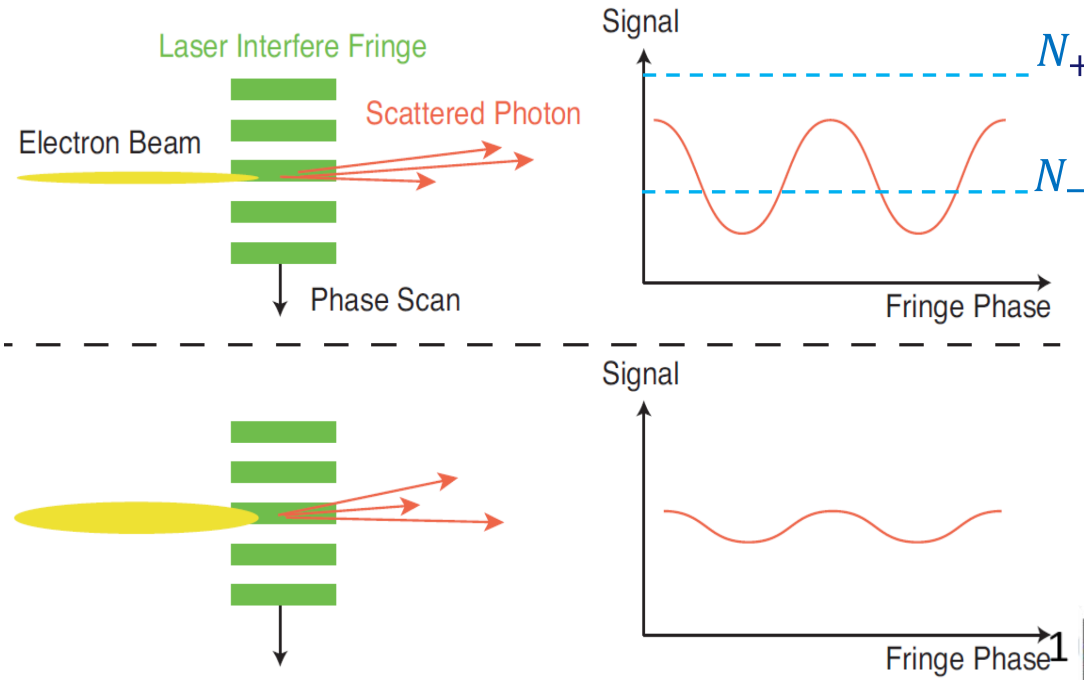
- Deliverables in 2016 → **1 in June 2016** + **5 in December 2016**
- Delay with secondments → expect to catch up
  1. **allocated beam time ILC agenda in Japan**
  2. **clarification of eligibility criteria**
  3. **extension of scope to include SuperKEKB nanobeams (priority project at KEK)**

EXTRA SLIDES

Scheme of Interaction Point Beam Size Monitor



Concept of IPBSM



Small beam size ⇒ large M

Large beam size ⇒ small M

Modulation depth $M = \frac{N_+ - N_-}{N_+ + N_-}$