Status of ATF2 final focus prototype

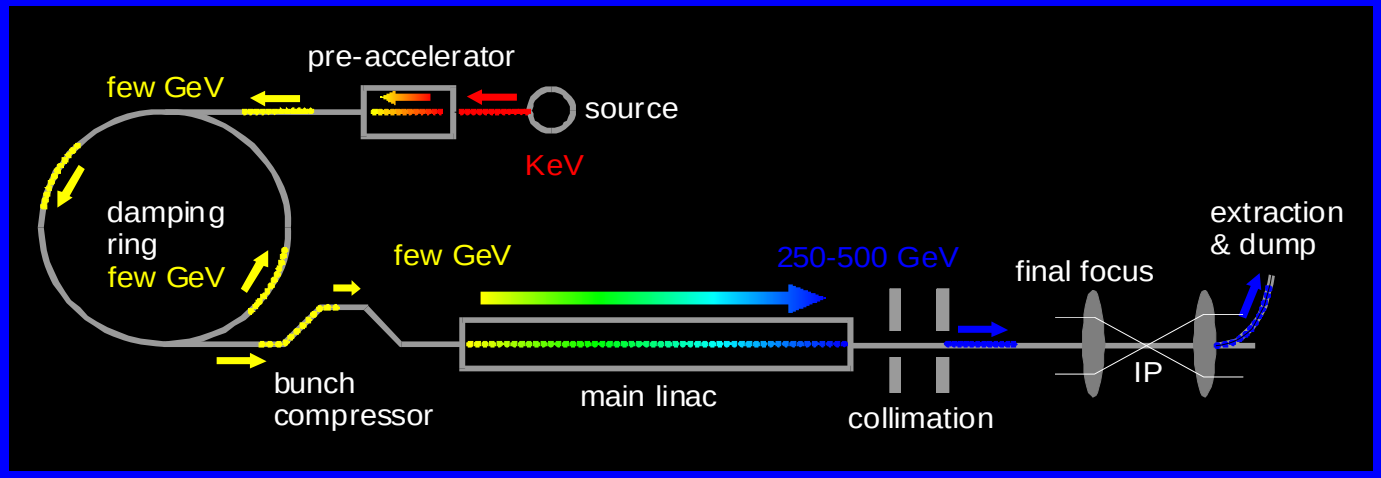
(emphasizing French involvement)

Philip Bambade
LAL-Orsay

with { Andrea Jérémie et al. (LAPP)
Marc Verderi & Hayg Guler (LLR)

ILC-GDE-France meeting
Orsay, 29 January 2008

LC needs nanometer-size beams



H_D = disruption enhancement
f = linac repetition rate
N_e = bunch population
n_b = bunches per train
σ = RMS bunch size
ε = emittance
η = power transfer efficiency

$$L \sim \frac{n_b N_e^2 f}{4\pi\sigma_x\sigma_y} H_D$$

$$\sigma^2 = \varepsilon_n \beta / \gamma$$

set $\sigma_z = \beta_y$

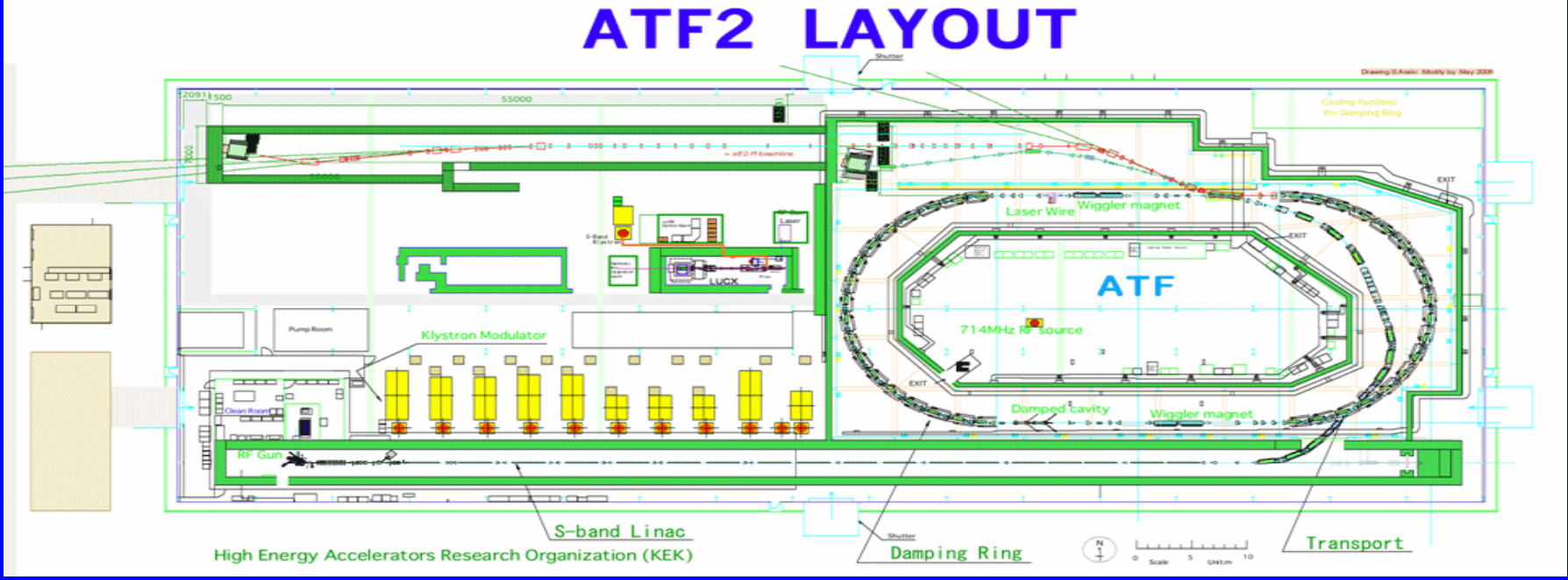
$$L \sim \eta \frac{P_{\text{electrical}}}{E_{CM}} \sqrt{\frac{\delta_E}{\varepsilon_{n,y}}} H_D$$

- Linac repetition rate ***f*** << ring frequency ⇒ need tiny IP size **σ**
- Beam-beam mutual focusing → beamstrahlung, disruption…

focus

1. RF technology (gradient, efficient power transfer)
2. Beam phase-space control & stability → emittance ε

ATF2 final focus test @ KEK



Goal A : nanometer beam size
- obtain $\sigma_y \sim 35$ nm at focal point
- reproduce reliably σ_y and maintain in time

1. Expert training on real system
2. Instrumentation for nano-beams
3. Accelerator RD & operation by multi-partner collaboration

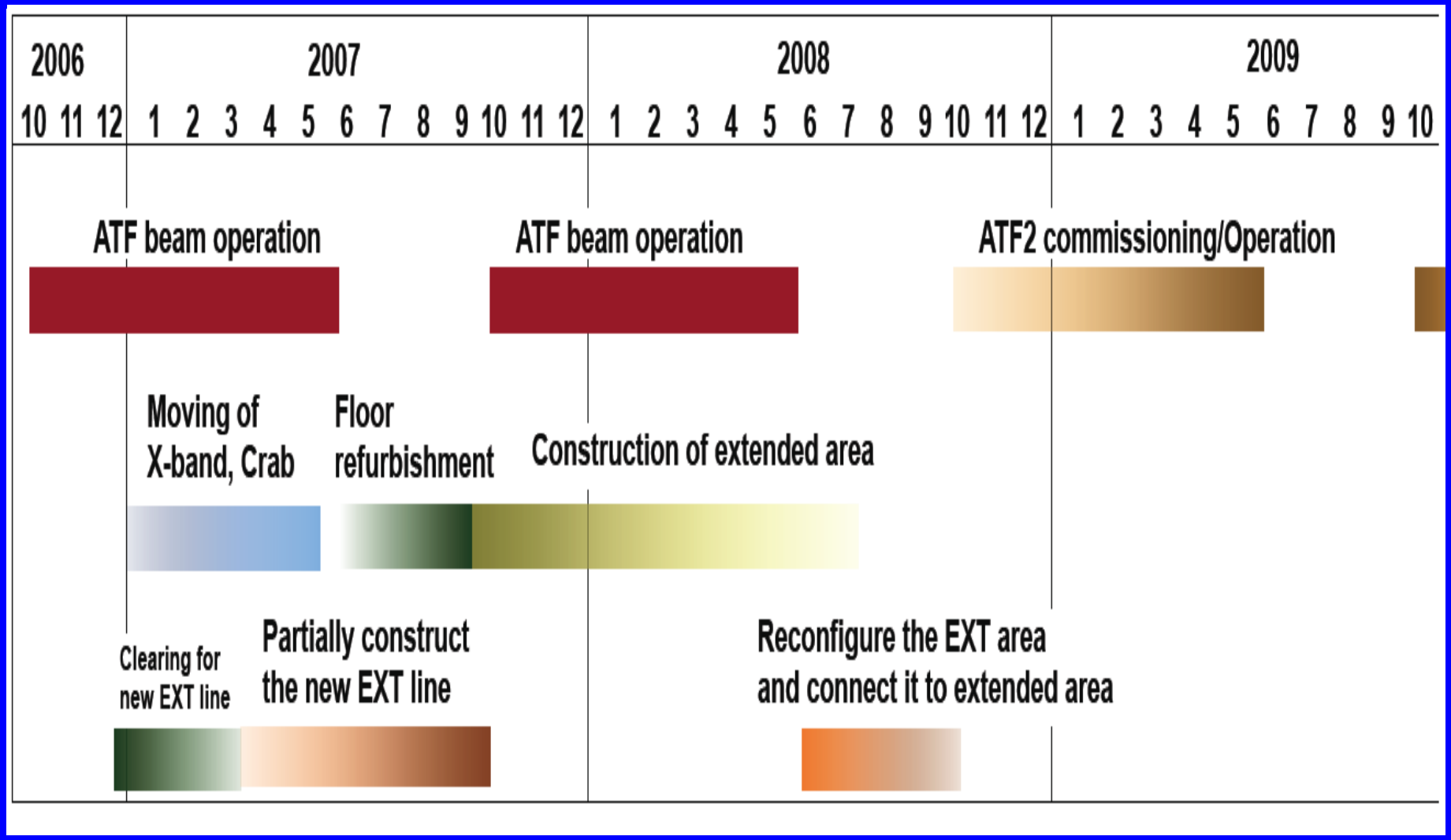
Goal B : trajectory stabilisation
- 1-2 nm at focal point
- intra-train feedback (ILC-like trains)

- 2008 end construction & installation
- october 2008 first beams
- 2009 commissioning

COST : ~ 3 + 1 M$ $\rightarrow$ Asia, EU, US

ATF2 Construction Schedule

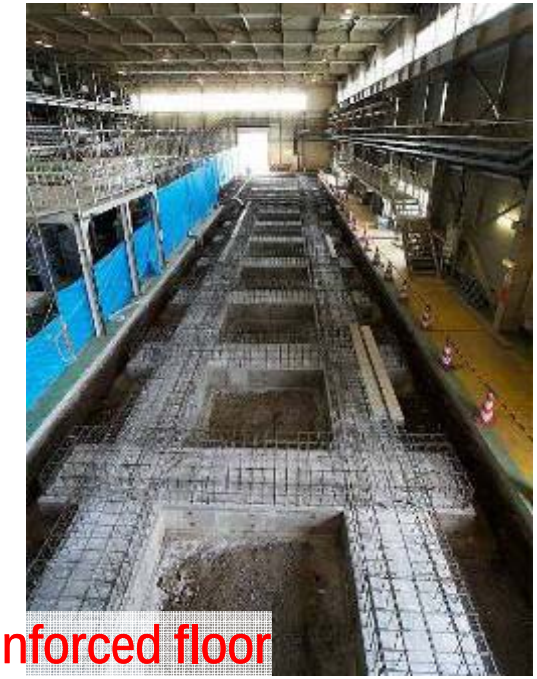
Not changed since December 2006



ATF2 construction

Assembly hall before construction

Assembly hall emptied for construction



Construction of reinforced floor

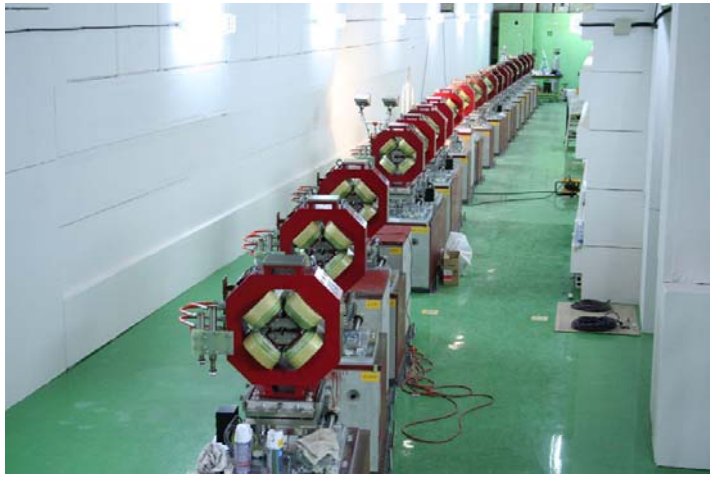
Construction of shielding

Photos: Nobu Toge

R. Sugahara (KEK)

Pictures of installation

4. The last magnet is going to the destination



5. Installation is finished

10 - 20 Dec. 2007 19 concrete base blocks were installed

7 - 9 Jan. 2008 22 movers and 19 quad-systems were installed

3 dipoles and 3 sextupoles not yet…

LAPP: Mechanical support & stability of FD
Characterisation & impact in beam operation
A.Jérémie, G.Gaillard, N.Geffroy
B.Bolzon → continues as ANR post-doc

LLR: Background evaluation (algorithm, GEANT4)
Instrumentation & experimentation for validation
M. Verderi, H.Guler (ANR post-doc)

LAL: Beam tuning & control / slow feedback controller
Commissioning & operation / optimization
"Flight simulator" tool, instrumentation studies
P.Bambade, J.Brossard, C.Rimbault
Y.Rénier, M.Alabau (Valencia), S.Bai (IHEP)
+ ANR post-doc to be hired in 2008 (quasi done)

KEK direct partner + UK, SLAC, CERN, IHEP, Valencia

Present French support for ATF2

ANR (2007-2010) : 400k€ project grant to fund
1) three 2-year post-docs at LAL,LAPP and LLR
2) equipment money for mechanical stabilisation work at LAPP

AIL France - Japan : travel & equipment transport
1) 20k€ for LAL-LAPP-LLR in 2007, 25€ requested in 2008

AIL France - China : support for ATF2 including to KEK
1) 3k€ for LAL in 2007, 6k€ requested in 2008

AIL funds within IN2P3 institutional funds…

IN2P3 “institutional” and other (at LAL) :
1) permanent & temporary staff (e.g. 1 contract@LAL)
2) additional travel & equipment (30k€ @ LAL in 2007)
3) Eiffel ministerial 1-year PhD grant for S. Bai @ LAL
4) Orsay university 3-year PhD grant for Y.Rénier @ LAL

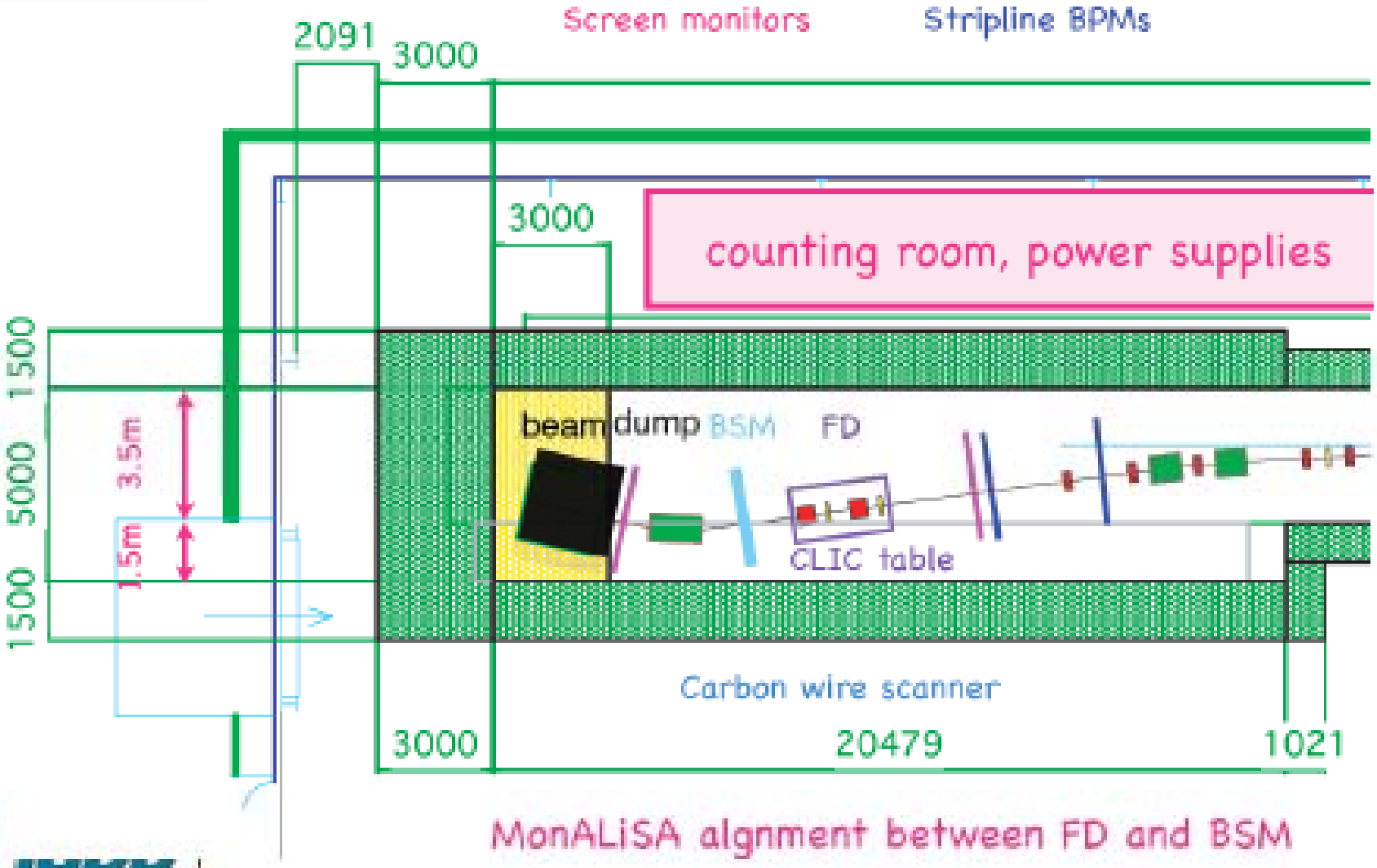
ATF2 vu du LAPP

A.Jeremie

Plus d'infos sur

http://ilcagenda.linearcollider.org/conferenceDisplay.py?confId=1806

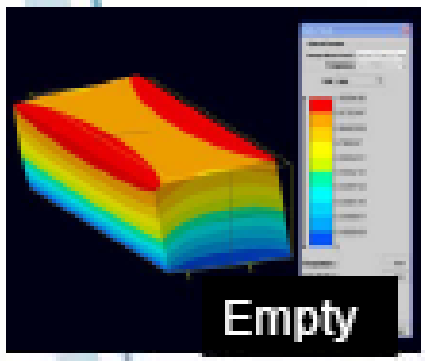
La zone d'intervention du LAPP

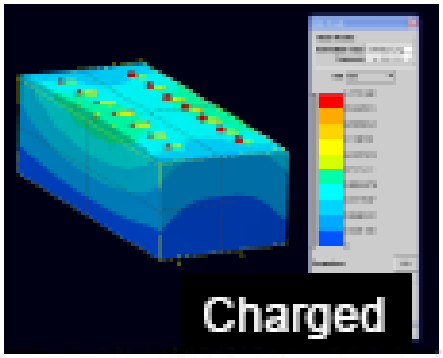


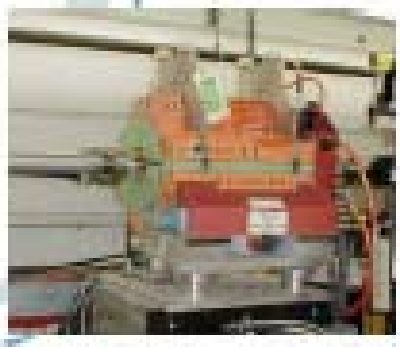
ATF2 at LAPP-Annecy

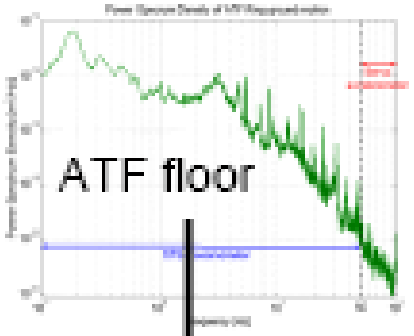
A. Jérémie (LAPP)

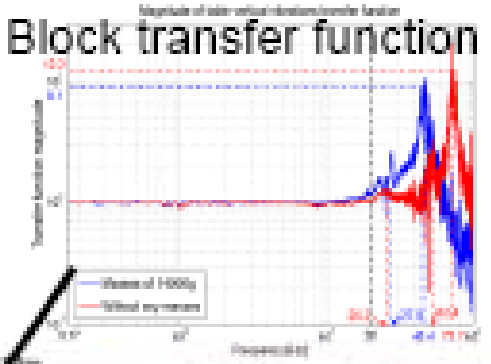
- Design, simulation and construction of FD support: honeycomb block; adapt movers to block; attach support to ATF2 floor
- Need compatibility with IP instrumentation supports
- Vibration measurements at Annecy with all supports and magnets
- Estimation of relative motion at ATF2 using transfer function from LAPP and ground motion measurements from ATF
- Installation and characterisation at KEK in June 2008, monitor in operation
- Open up to beam dynamics

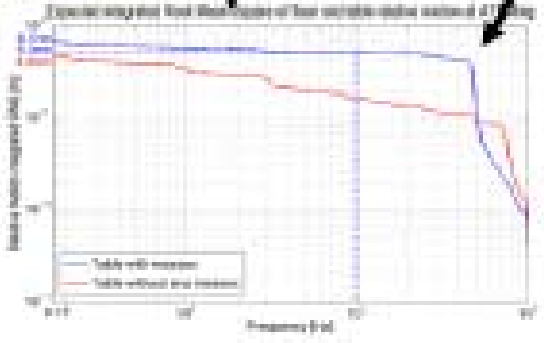








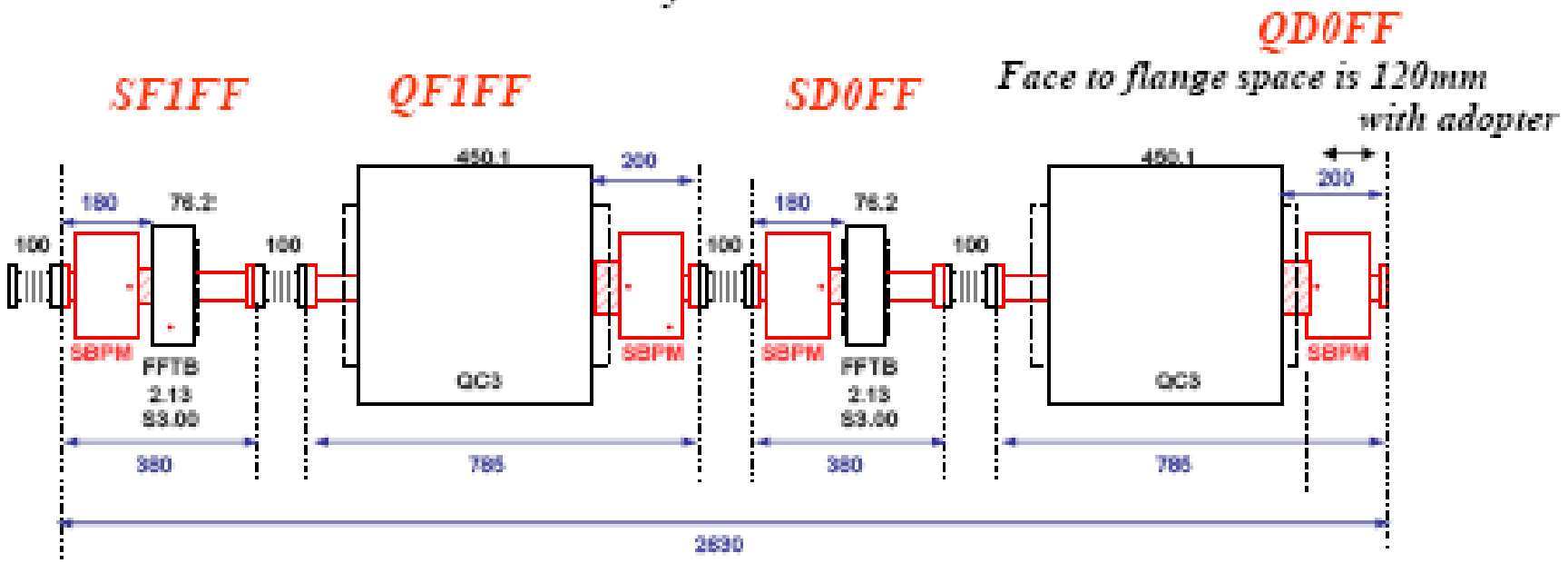




Estimation of relative motion at ATF2: 6nm (just about the specs)

Final Doublet Table Configuration

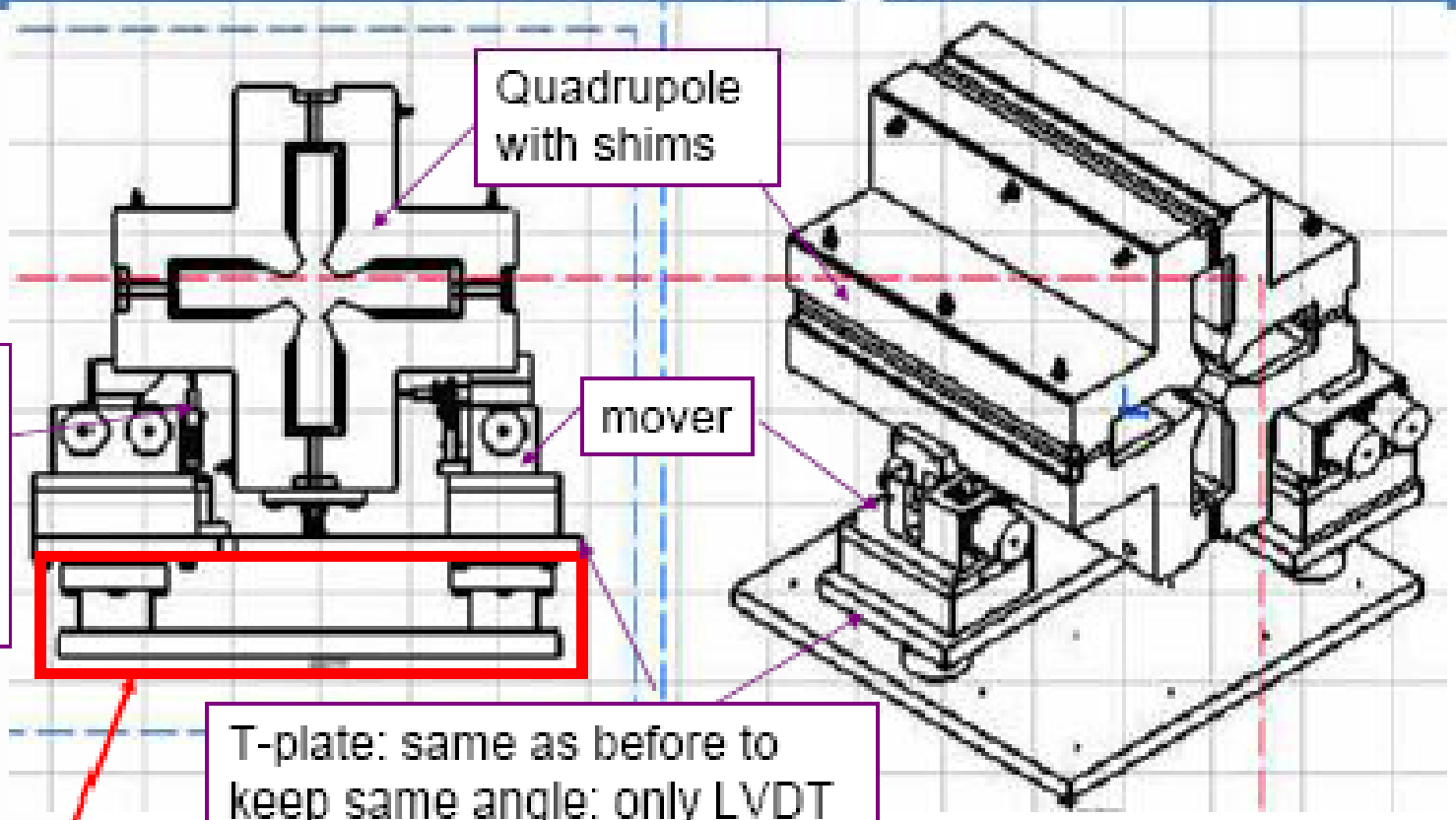
Mark Woodley's device list



These components will be on the table.

Ces aimants sont sur des « movers » tous de FFTB dont il faut ajuster la hauteur pour compenser la différence de hauteur de faisceau

Compensate the height to reach beam height

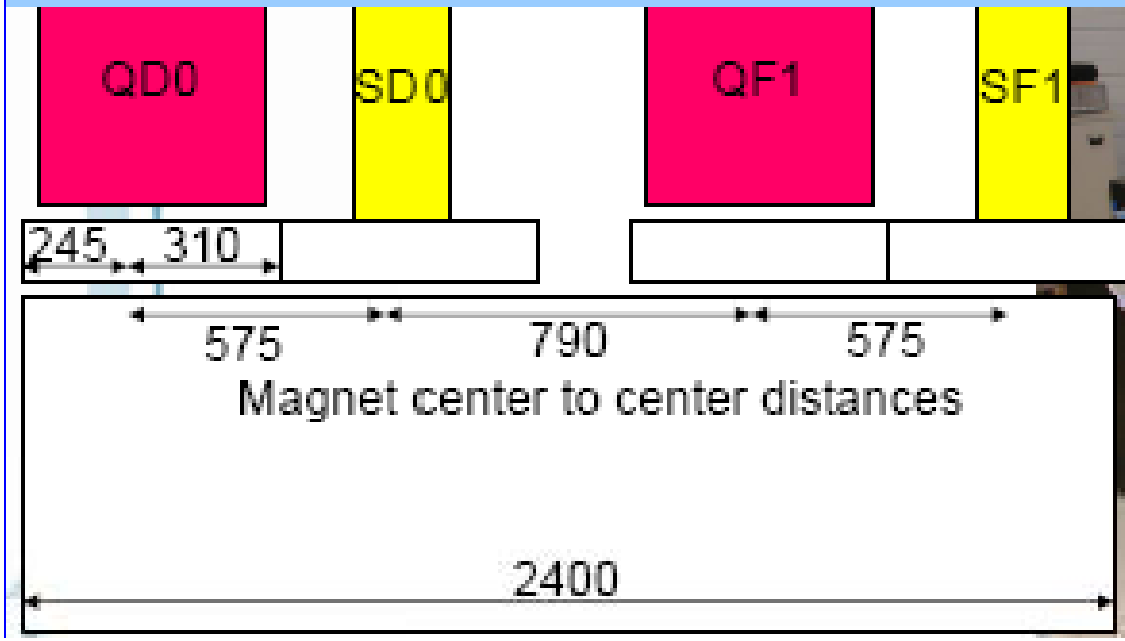


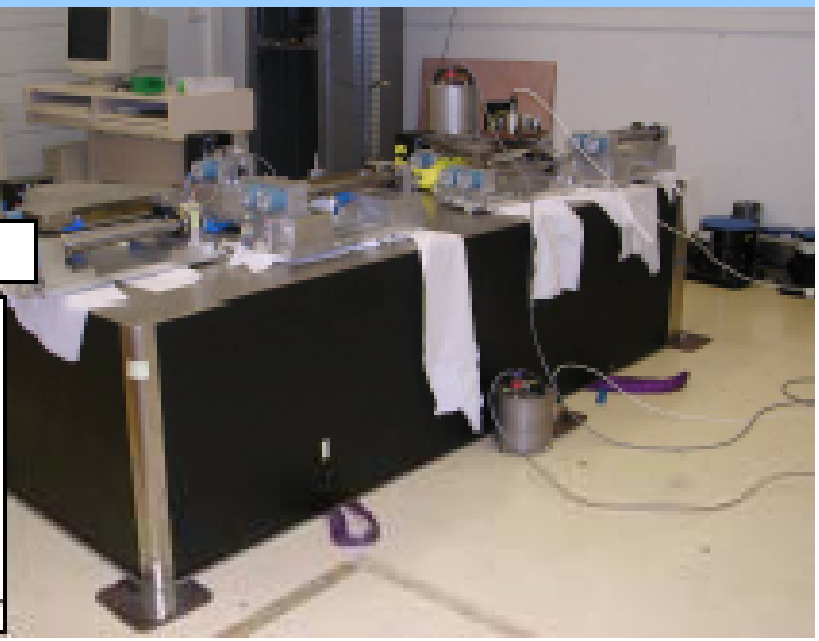
Change the way the mover is fixed on the table

Next step: vibration measurements

Measurement with final "real" objects at LAPP (easier to measure or modify at LAPP than at KEK during the installation rush! Redo once installed at KEK):

- New higher supports
- Movers
- Quadrupoles and sextupoles (no delay expected)
- Waterflow?
- Final steel plate underneath?

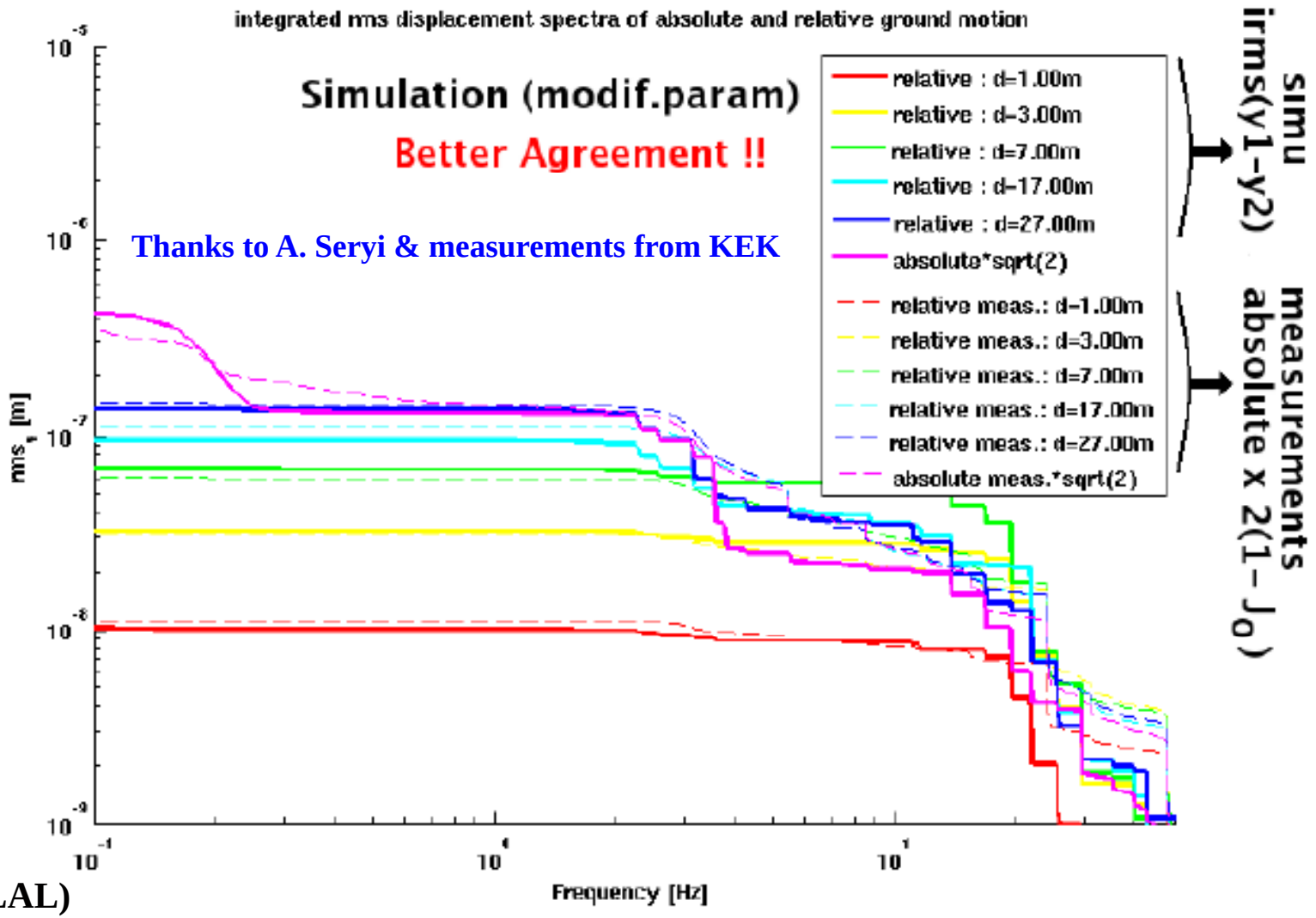




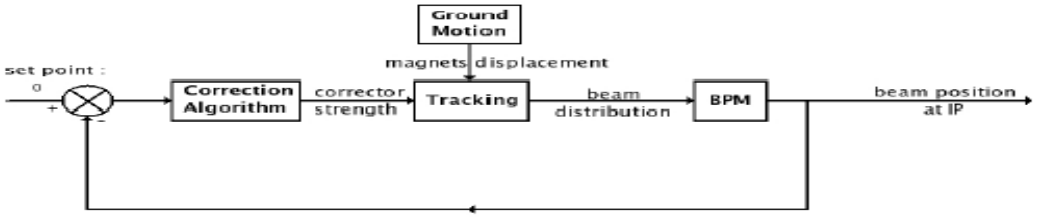
Schedule (subject to discussion)

- February: arrival of new table ("old" belongs to CERN)
- February: vibration measurements
- March: arrival of new mover parts
- March-April: vibration measurements with magnets
- May: vibration measurements with water flow? Do we need with Cherrill's vibration measurements?
- May-June: shipment to KEK
- June-July: installation => but what about access while Shintake monitor commissioning?
- If magnets to be shipped by June, need one month to prepare and ship and receive at KEK, need about two months of measurements so everything should be at LAPP before March.

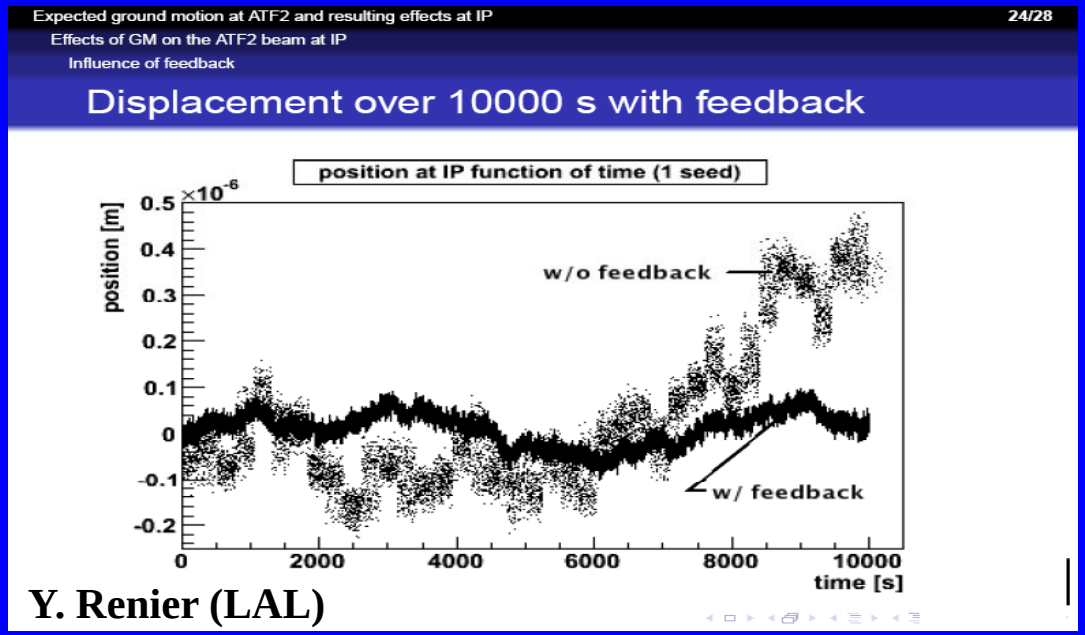
Integrated RMS displacement



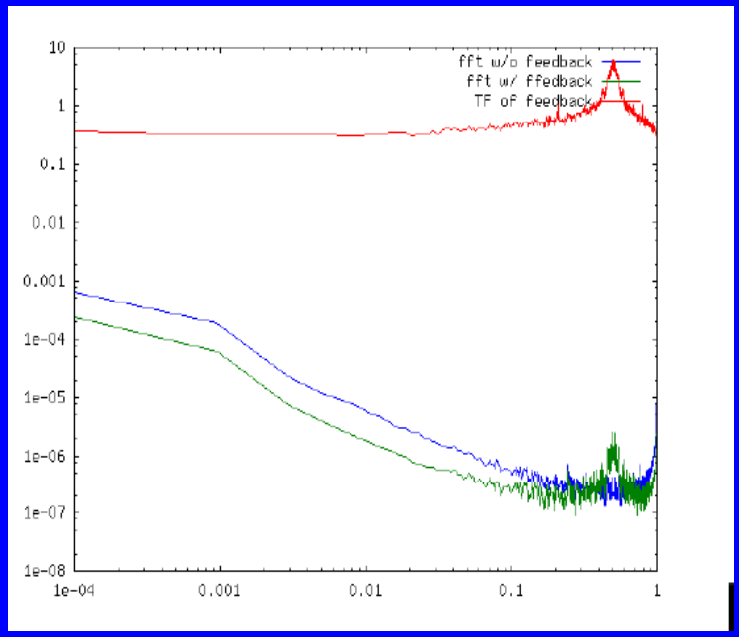
Design beam-based feedback at IP



- For the moment, tracking (and GM modeling) is only done on FF ATF2 line.
- Corrector used is the sweeper magnet after FD used for SM.
- PID Correction Algorithm: $C(p) = k_p + \frac{k_i}{p} + k_d \cdot p$



Y. Renier (LAL)

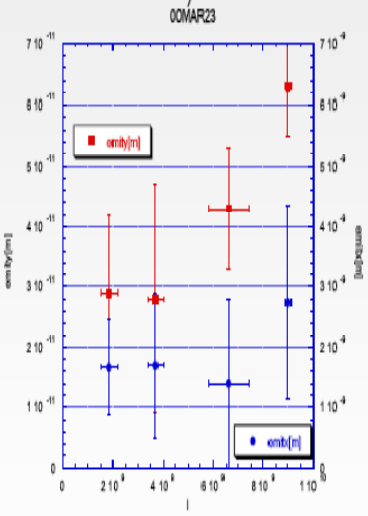


ATF EXT emittance investigation → task force

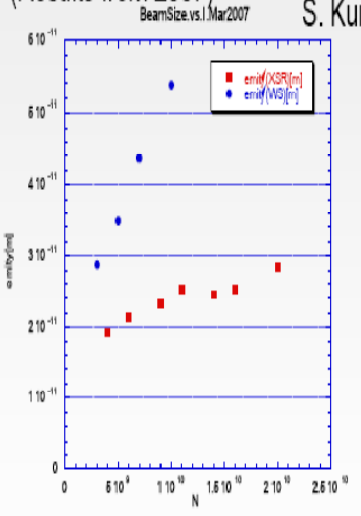
Vertical emittance growth in ATF Extraction Line

Measured vertical emittances are higher than expected, and there is a dependence with the beam current.

(Results from 2000)



(Results from 2007)



S. Kuroda et al.

Hypotheses

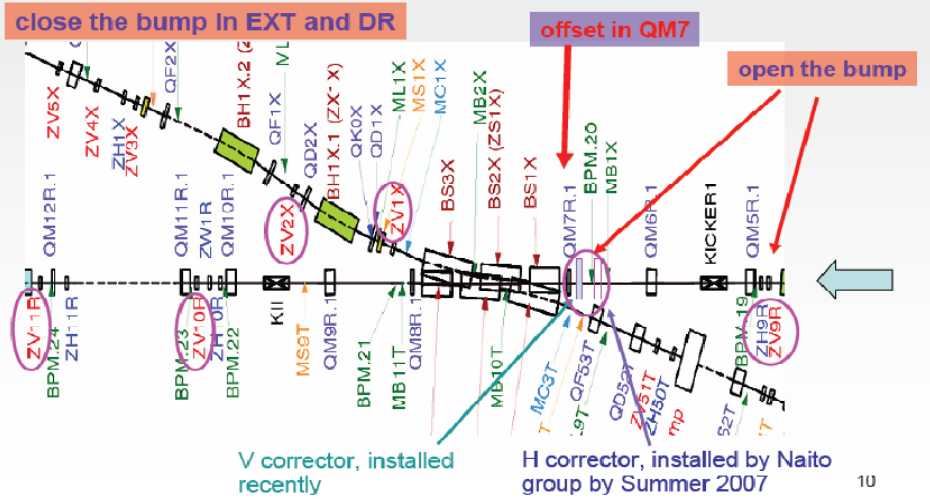
-Non-linearity (coupling)

-Emittance measurement accuracy

-Intensity dependence: wakefields, orbit (BPM) ?

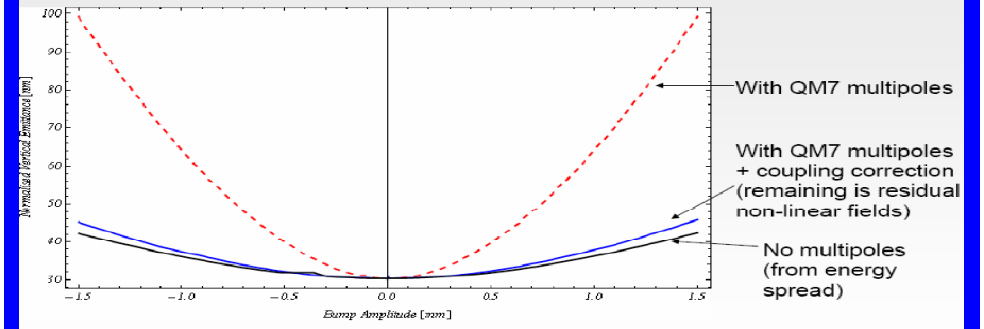
2

Creating bumps in QM7



10

Simulations for variable bump in QM7 with linear coupling correction



Linear coupling induced by QM7 multipoles corrected by adjusting four skew quadrupoles in diagnostic section.

12

→ Must make sure this won't limit ATF2 !

First results with controlled bump in QM7

Reconstructed magnitude -0.81 mm

Emittance reconstruction

No bump

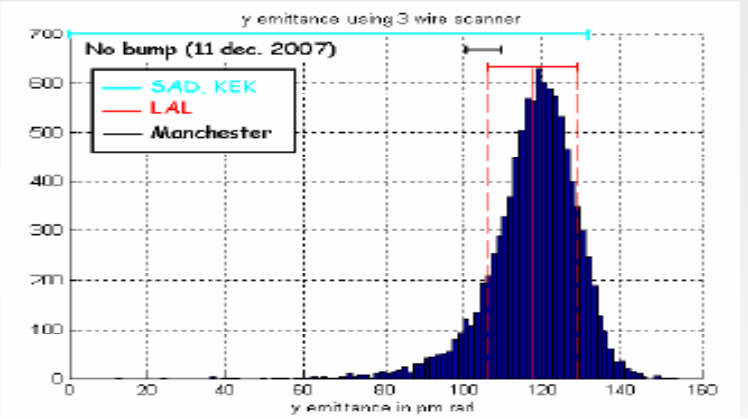
Vertical emittance =

118 +/- 11 pm.rad (J. Brossard, LAL)*

108 +/- 7 pm.rad (A. Scarfe, Manchester)

(52 +84 -52) pm.rad (SAD result)

*Results based on 10 000 test within the error bar. (rejection level of 0.02 %)



With bump

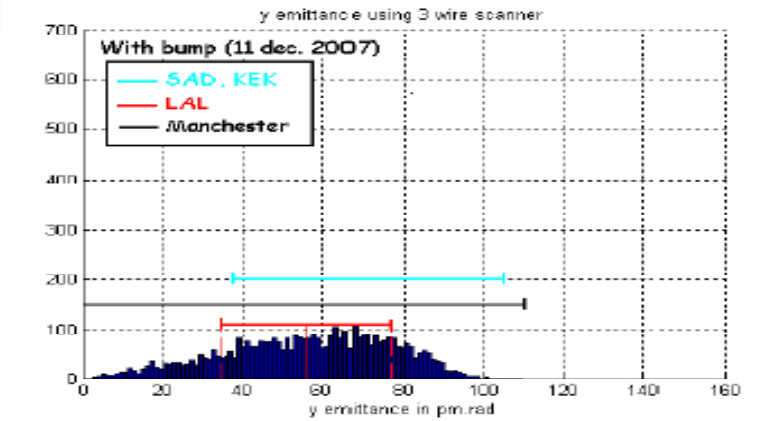
Vertical emittance =

56 +/- 21 pm.rad (J. Brossard, LAL)**

40 +/- 70 pm.rad (A. Scarfe, Manchester)

(47 +58 -9) pm.rad (SAD result)

**Results based on 10 000 test within the error bar. (rejection level of 54.42 %)



Learning control room work

→ will continue more systematically in 2008

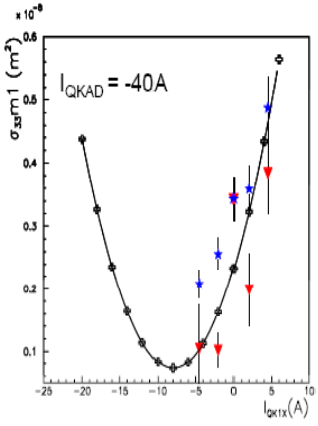
M. Alabau (IFIC - LAL)
J. Brossard (LAL)

Investigate emittance reconstruction methods:

1. Multiple wire scanners → χ^2 minimisation (constraints ?)
2. Combine normal + skew quad scans → reliable xy coupling ?

QK1X scan at MW1X wire scanner:
coupling estimation using MAD8

• A "virtual" skew, QKAD, quad. of type QK1X is introduced at the beginning of the Ext line.
• Its strength varies until fitting with the measured points at MW1X with QK1X scan.
→the coupling is reproduced for
I_{QKAD} : [-50; -35]A ≡ Ks[-0.258 ; -0.180]m^{-1}



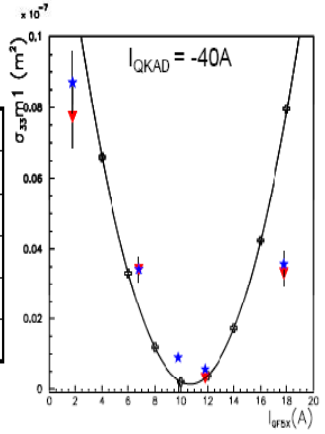
C. Rimbault (LAL)

Fifth ATF2 Project Meeting , 19-21 dec. 2007, KEK, Japan

QK1X scan at MW1X wire scanner:
coupling estimation using MAD8

• A scan of QF5X is simulated with different value of Ks_{QKAD}, and emittances are recontructed.

I_{QKAD} (A)	Ks_{QKAD}(m^{-1})	ε_x (nm.rad)	ε_y(pm.rad)
0	0	1.12 ± 0.20	317 ± 73
-35	-0.1804	2.02 ± 0.09	248 ± 17
-40	-0.2062	2.02 ± 0.09	284 ± 21
-45	-0.2320	2.03 ± 0.09	319 ± 27
-50	-0.2578	2.02 ± 0.09	354 ± 33

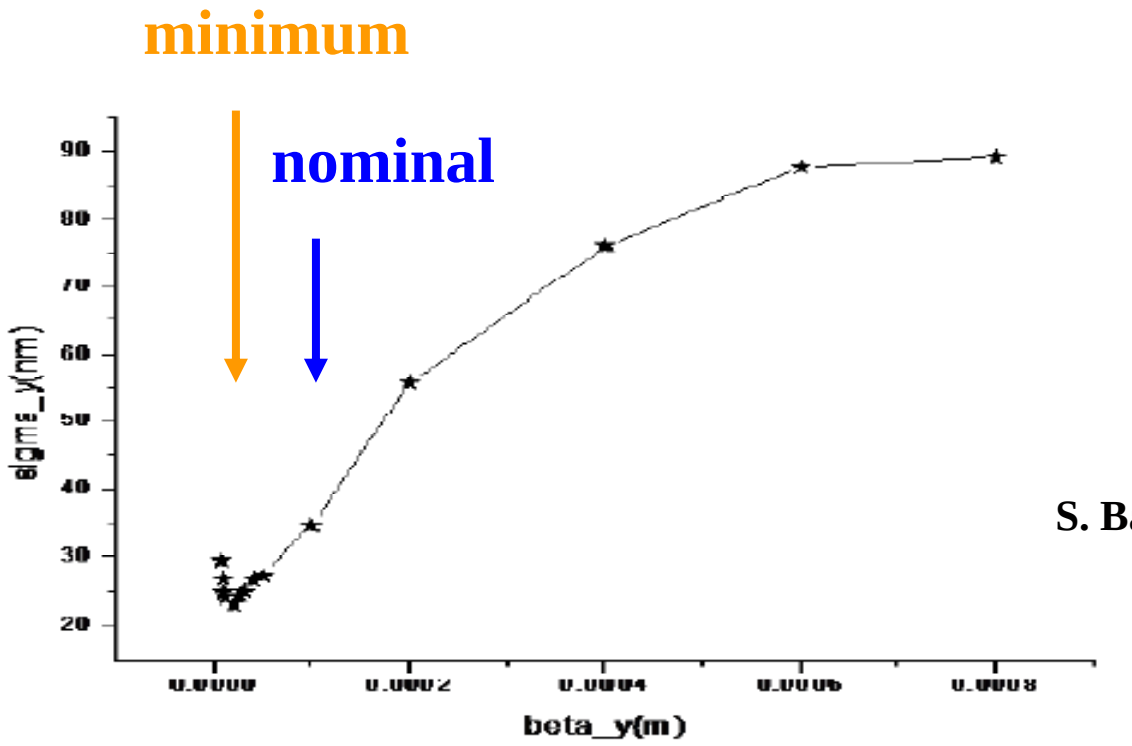


Fifth ATF2 Project Meeting , 19-21 dec. 2007, KEK, Japan

→ Dedicated schemes for flat beams (error analysis…)
→ Develop practical tools for efficient control room work

1. Increasing β_y → gradual approach with looser tolerances
2. Reducing β_y → enhanced performance

Variable beam size at the interaction point
(Gaussian fit to core)



S. Bai (IHEP / LAL)

3. Idem at displaced IP locations hosting other instruments
4. Prepare magnet knobs for orthogonal waist scanning

Contribution to “flight simulator” for ATF2

(collaboration with CERN, SLAC and KEK)

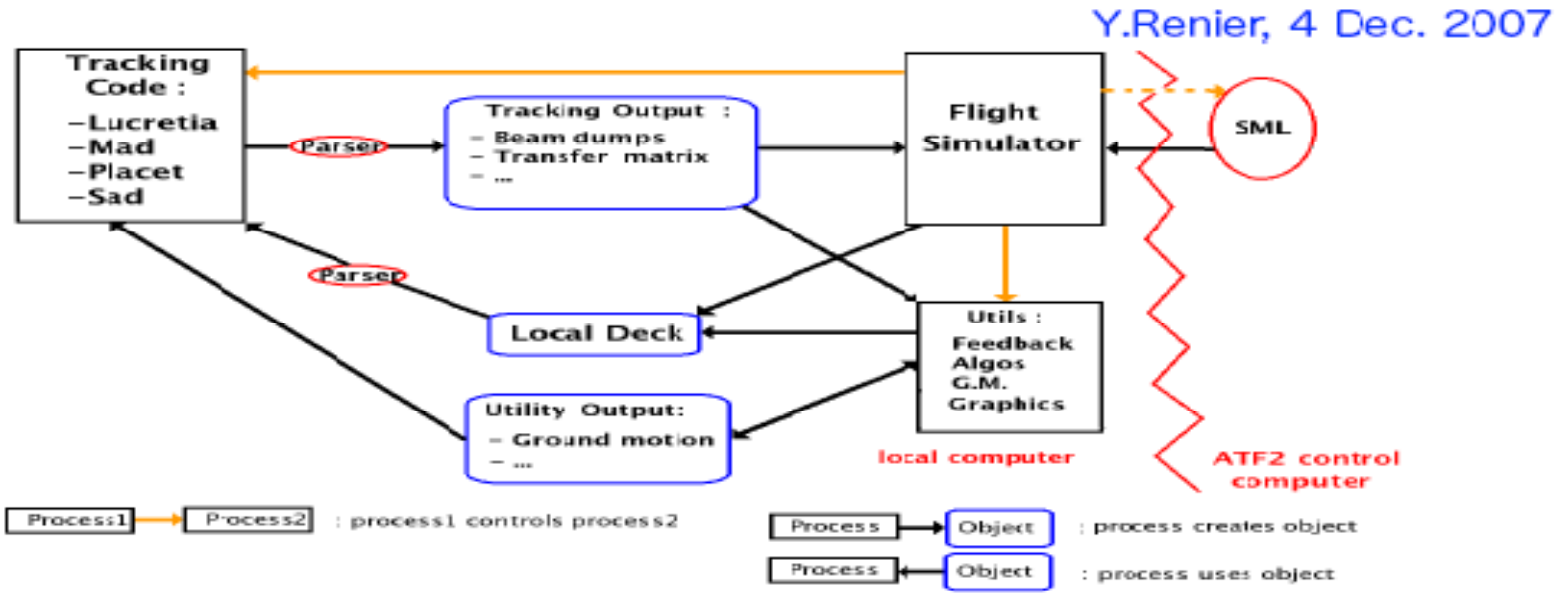


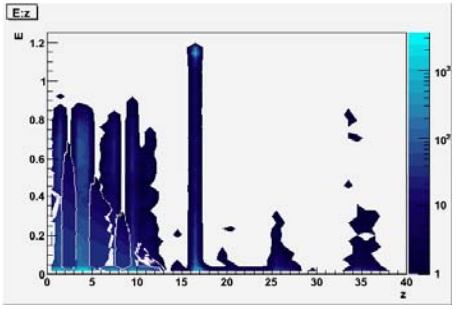
Figure 1 : Block diagram of changes induced by using several codes in the flight simulator

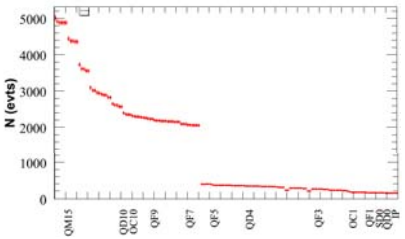
Possible action plan

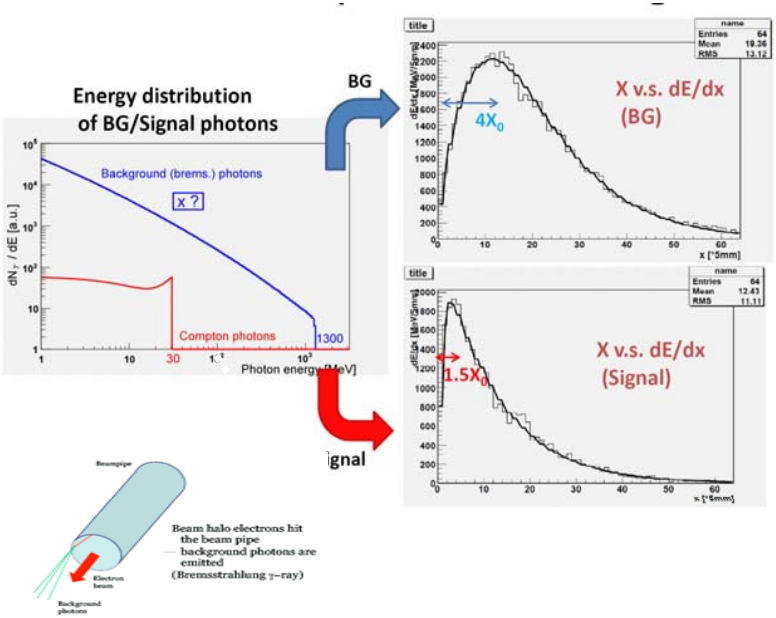
1) Identify optics codes to be supported.
2) Agree on format for the common optics deck (for instance AML ?)
3) Identify minimal set of utilities (feedback and tuning algorithms, GM, ...)
4) Identify required output and agree on common corresponding file formats.
5) Create command files for each optics code compatible with the common deck format (for instance AML ?)
6) Create parsers for the corresponding output files.
7) Create the defined minimal set of utilities, preferably in a given interpreted language e.g. Matlab and, for specific cases such as GM, adapt existing ones to satisfy 4)
8) Create parsers for the deck and output files for the other optics codes.

ATF2 Background : what can we learn ?

•BDSIM Simulation

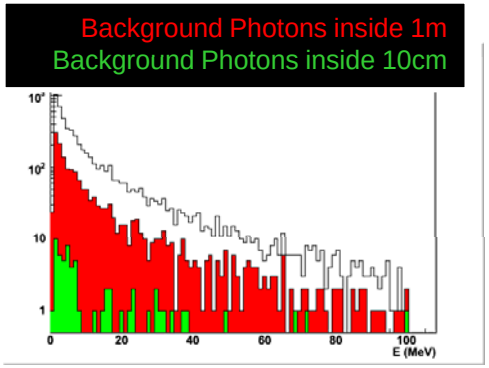






Generated 100% flat HALO

- ΔE=0.1% Gaussian
- From 0.1% → 1% electron in Halo
- Signal : 2-4 10^3 Compton signal photons
- → Use Collimator to eliminate the background photons



Photons spectrum from the Beam Position measurement device (Shintake monitor)

H. Guler (LLR)

On going studies: Trying to describe the background normalization

→ Better describe the HALO (Shape, population, energy distribution)

→ Include (design) collimator to eliminate background

Further steps:

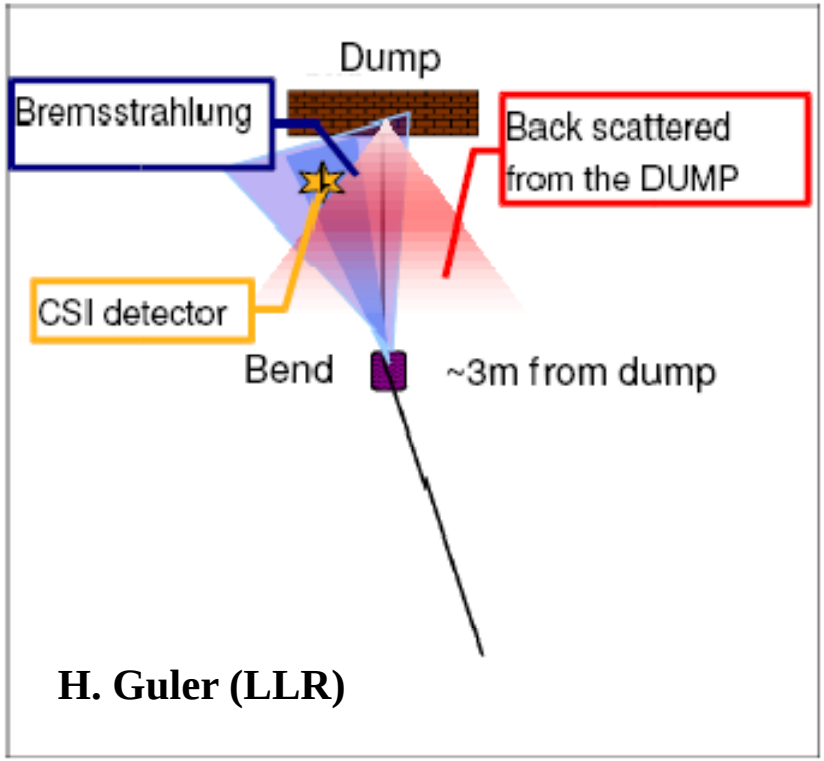
→ Background from the dump

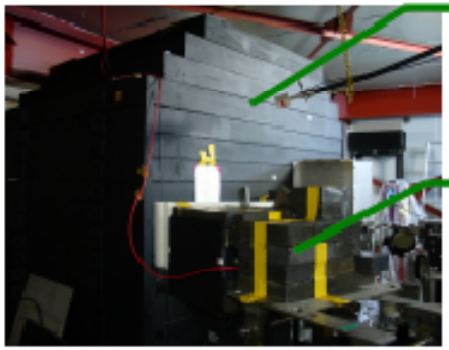
→ Photons and charged particles

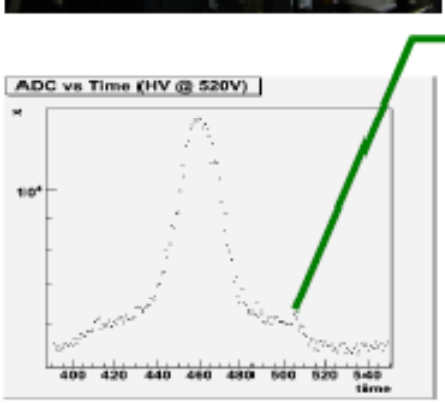
→ Neutrons

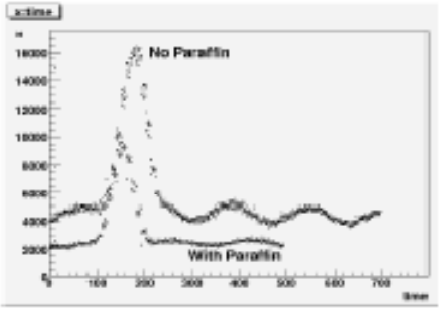
→ Special techniques → “event biasing methods”

Background measurement @ ATF (KEK)









- Pure CSI detector + PMT (from Tokyo University)
- Measured background (gamma and neutrons) around indicated position. No PID yet : signal was integrated through ADC signals
- Attent to measure beam HALO with the CSI detector and wire scanners.

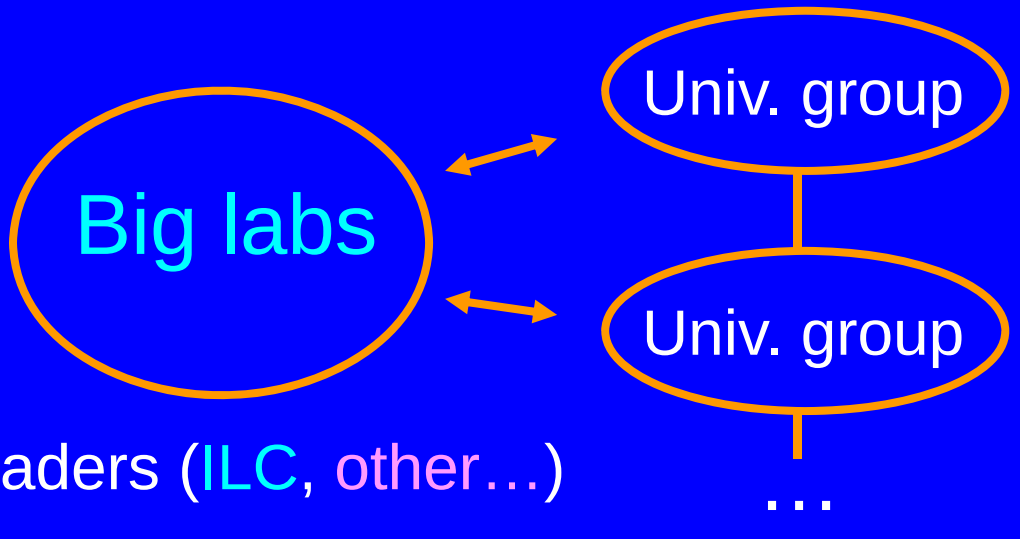
Present aims of French **ATF2** involvement

(2008 – 2010)

- Significant impact on ATF2 commissioning and beam experimentation, characterisation of IP stability, understanding and control of beam-induced backgrounds, instrumentation → presence at KEK…

- Research within international collaborative environment for accelerator R&D, as HEP experiments

- project “tasks”
- practical learn by doing
- academic endeavour
- publish or perish…
- research bids / contracts



Training impact : future leaders (ILC, other…)

Concluding remarks

- 2-3 exciting years ahead of us !
- Scope for significant contributions towards a future linear collider → ILC & CLIC BDS+MDI
- interesting three-way collaboration:
  - UE team (France, UK, Spain…)
  - Japan + China
  - and our American colleagues and friends…

Additional slides

Main present French ILC activities

- Linac technology: SC cavities (processing & control), cryogenics, RF couplers → XFEL & DESY
- Injectors, sources (Compton based e+)
- MDI & BDS ↔ ATF2 (experimentation)
- Detector R&D: → EM calorimetry (CALICE), Silicon sensors (vertexing & tracking), TPC
- Physics studies, phenomenology
- Communication & outreach
- International project framework and governance

Established R&D programs ▪▪▪▪▪► contribute to global ILC project

Emphasis on feasibility demonstration and risk reduction ?

Delays from recent ILC cuts ?

SLAC

1) magnets, power supplies, beam position monitors, magnet movers, misc.

→ 95% completed, KEK will help finalise : minor hardware, travel…

2) damping ring beam position monitor upgrade
(needed for further DR emittance reduction)

→ unclear at present…

3) Commissioning & optimisation, “flight simulator”

→ More remote work & through link up with partner teams…

UK

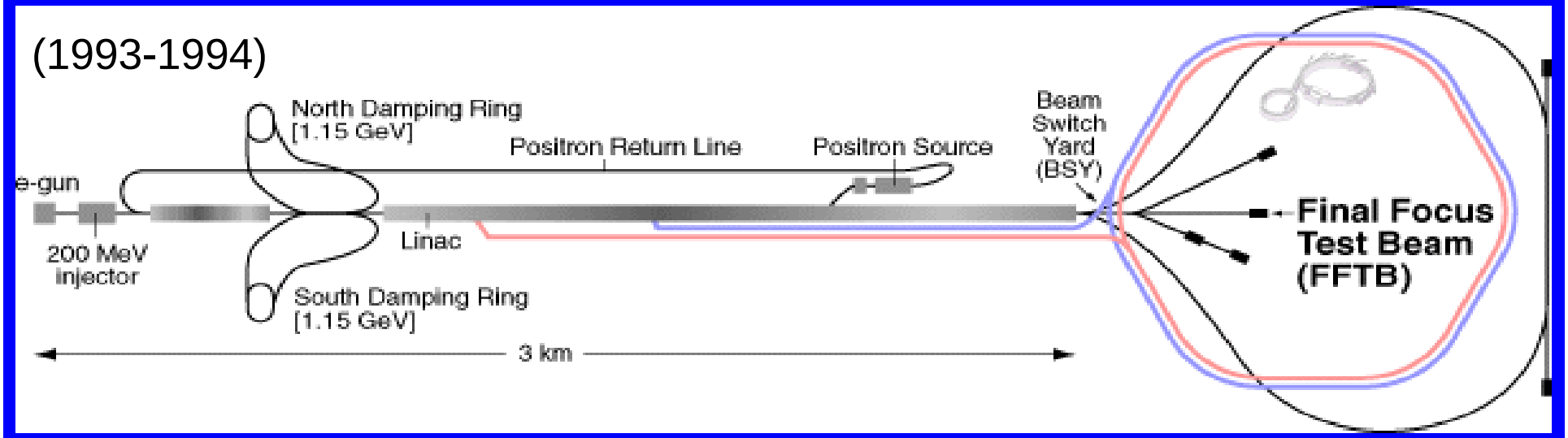
4) Beam instrumentation, feedback, commissioning & tuning

→ expect slower continuation under “generic LC R&D” (EUCARD)

ATF2 startup should be on time

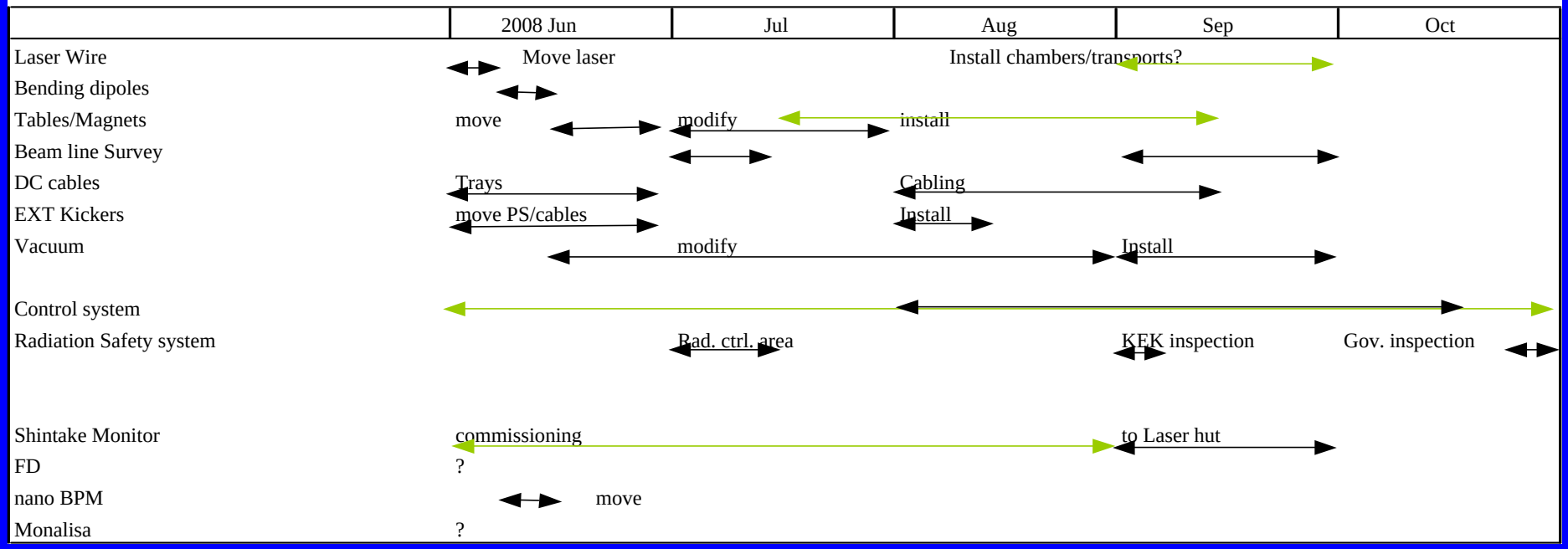
Partners (we ?!) may be asked to do more…

Wasn’t FFTB sufficient ?

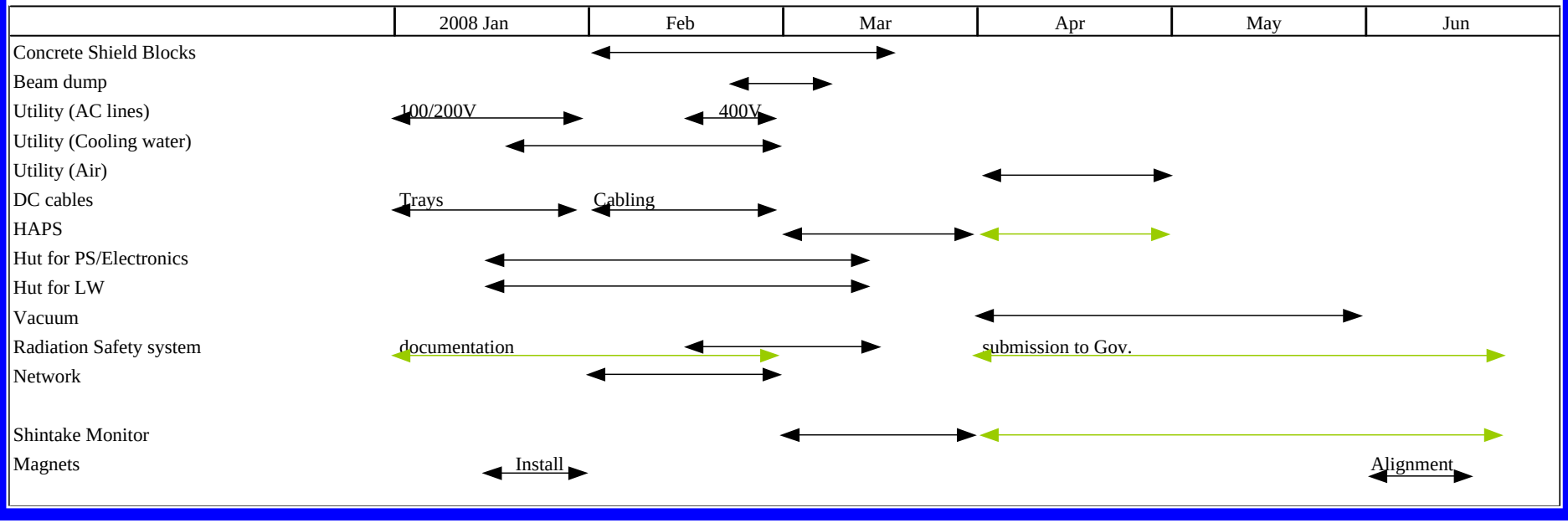


1. Not operated as dedicated facility
   → small beam sizes shown but little reproducibility and systematic study
2. Long-term stabilisation issues not addressed
3. Final Focus not based on new principle of local chromaticity correction

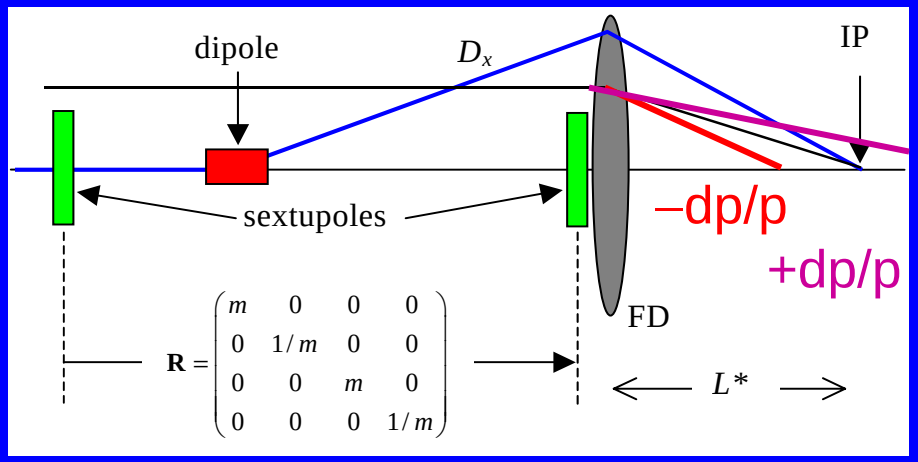
EXT-ATF2 area

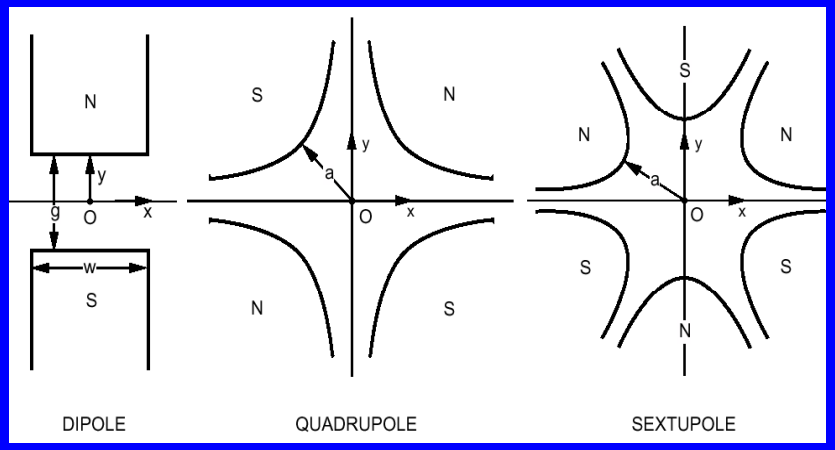


ATF2 area



Optical telescope to minimize β*



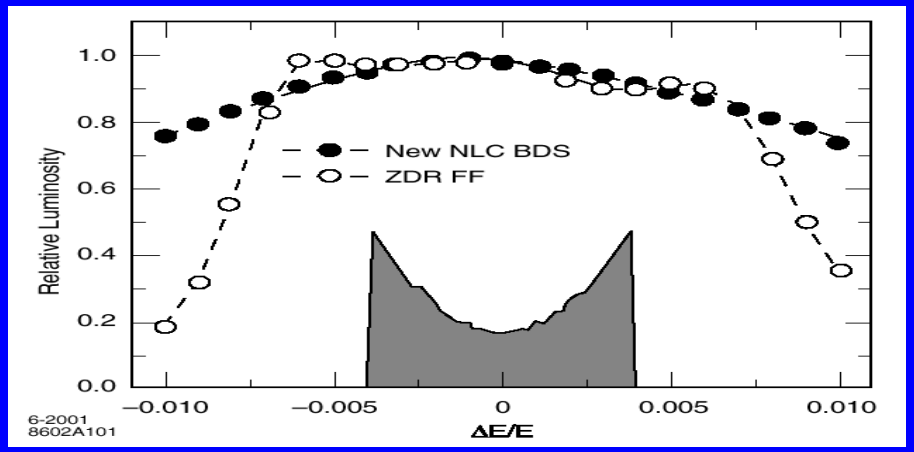


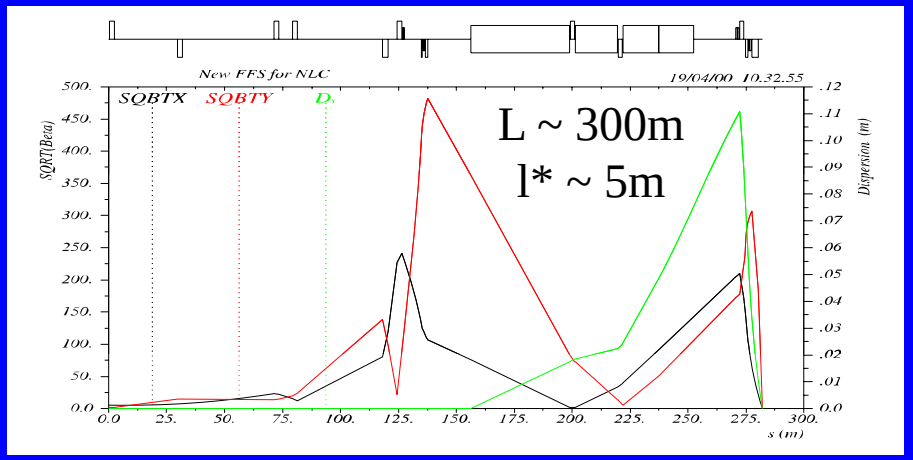
local chromaticity correction with pairs of sextupole doublets → optical bandpass

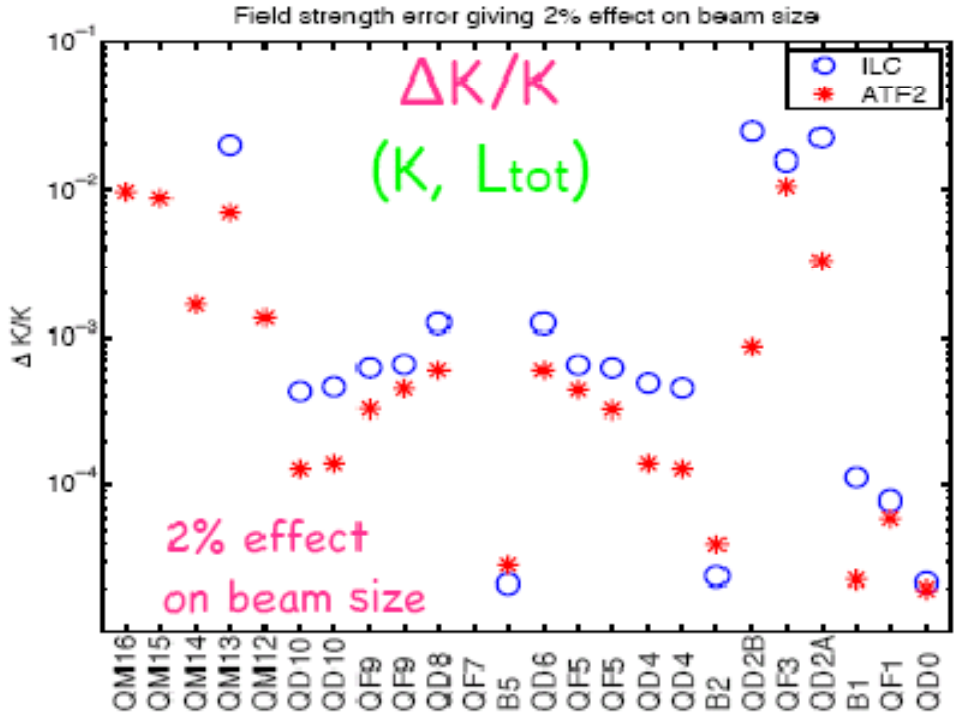
Just bends the trajectory

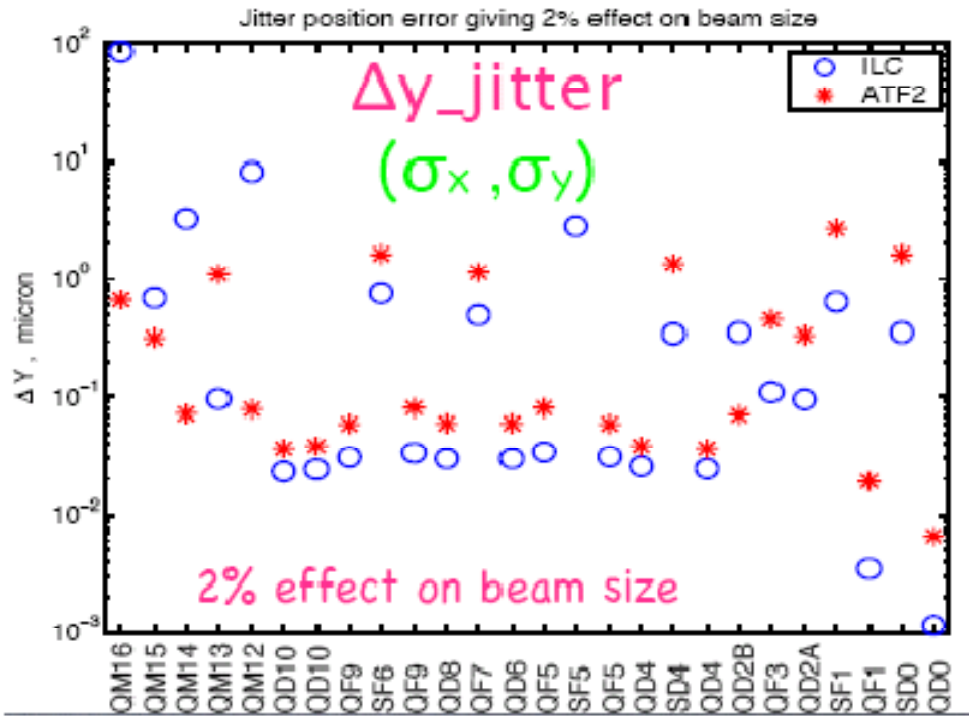
Focus in one plane, defocus in another:
$x' = x' + G\,x$
$y' = y' - G\,y$

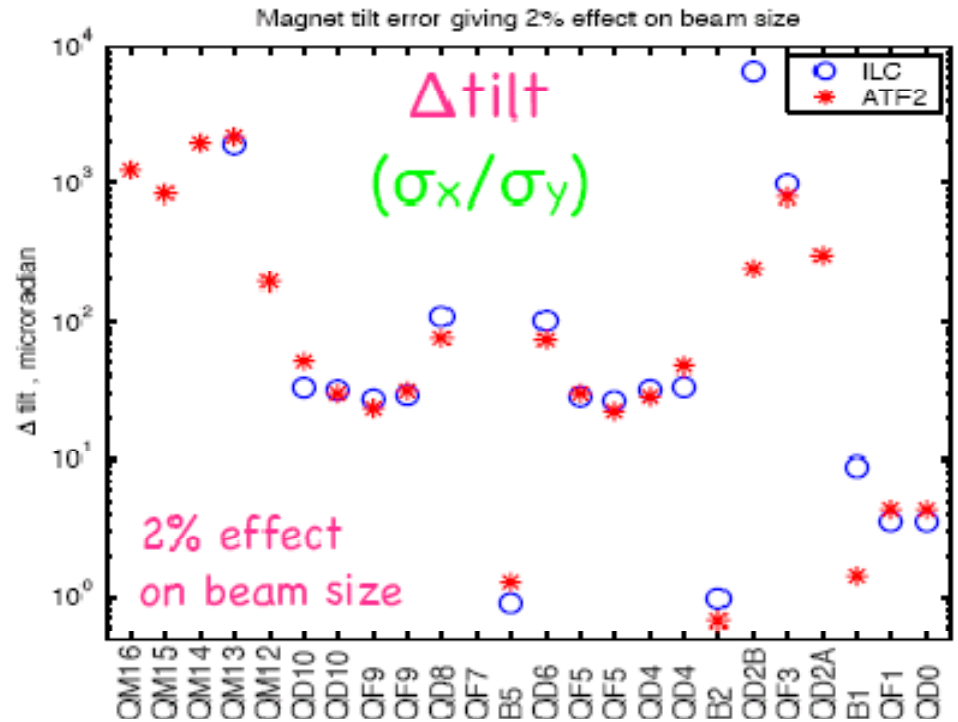
Second order focusing
$x' = x' + S\,(x^2 - y^2)$
$y' = y' - S\,2xy$

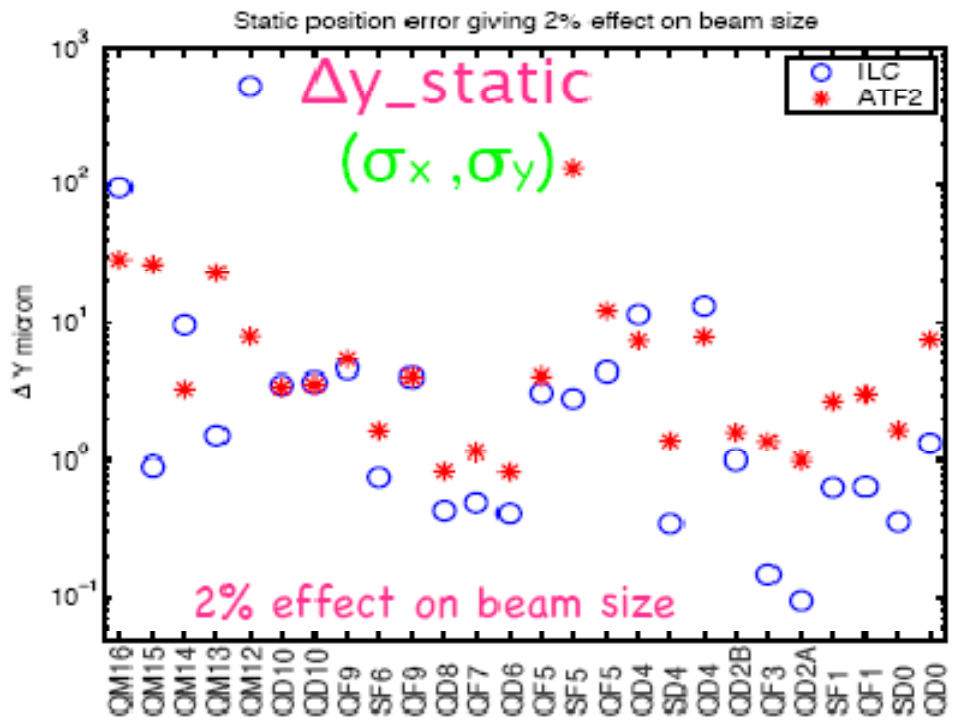





Field strength error giving 2% effect on beam size
ΔK/K
(K, Ltot)
2% effect
on beam size
ILC
ATF2
Δ K/K
QM16 QM15 QM14 QM13 QM12 QD10 QD10 QF9 QF9 QD8 QF7 B5 QD6 QF5 QF5 QD4 QD4 B2 QD2B QF3 QD2A B1 QF1 QD0


Jitter position error giving 2% effect on beam size
Δy_jitter
(σx ,σy)
2% effect on beam size
ILC
ATF2
Δ Y , micron
QM16 QM15 QM14 QM13 QM12 QD10 QD10 QF9 SF6 QF9 QD8 QF7 QD6 QF5 SF5 QF5 QD4 SD4 QD4 QD2B QF3 QD2A SF1 QF1 SD0 QD0


Magnet tilt error giving 2% effect on beam size
Δtilt
(σx/σy)
2% effect
on beam size
ILC
ATF2
Δ tilt , microradian
QM16 QM15 QM14 QM13 QM12 QD10 QD10 QF9 QF9 QD8 QF7 B5 QD6 QF5 QF5 QD4 QD4 B2 QD2B QF3 QD2A B1 QF1 QD0


Static position error giving 2% effect on beam size
Δy_static
(σx ,σy)
2% effect on beam size
ILC
ATF2
Δ Y micron
QM16 QM15 QM14 QM13 QM12 QD10 QD10 QF9 SF6 QF9 QD8 QF7 QD6 QF5 SF5 QF5 QD4 SD4 QD4 QD2B QF3 QD2A SF1 QF1 SD0 QD0

Variable $\beta_{x,y}$ at longitudinally displaced IP

Beam size at focal point is a function of choice of FD effective focal length (L*) and injected beam matching

→ L* adjusted by FD strength (orthogonal combinations for x and y waist positions in z)
→ injected beam adjusted by QM12,13,14,15,16

During commissioning, Honda monitor and wire scanner at displaced IP, respectively at -54cm and +39cm, with resolutions of 300-1000 nm.

Procedure to control β_y at displaced IP

1) For close to nominal values at IP+39cm, use QM12~16 to obtain:
   $\beta_x = 2 \times \beta_x^{nominal} = 0.008$m
   $\beta_y = 4 \times \beta_y^{nominal} = 0.0004$m
   at the nominal IP
2) use QD,QF to fit $\alpha_x = \alpha_y = 0$ at IP+39cm, step by step...
3) use SD0,4 & SF1,5,6 to zero $T_{122}, T_{126}, T_{166}, T_{342}, T_{346}$

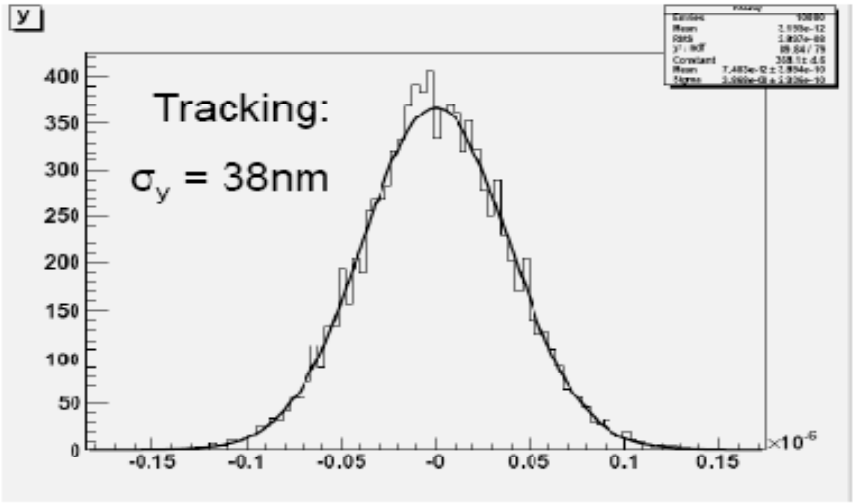
Configuration [m^{-2}]

KLQM12FF = 3.347954E-01
KLQM13FF = 9.109371E-01
KLQM14FF =-1.126109E+00
KLQM15FF =-3.172467E-01
KLQM16FF = 6.492773E-01
KLQD0FF = -1.117399E+00
KLQF1FF = 7.030127E-01

S. Bai (IHEP / LAL)

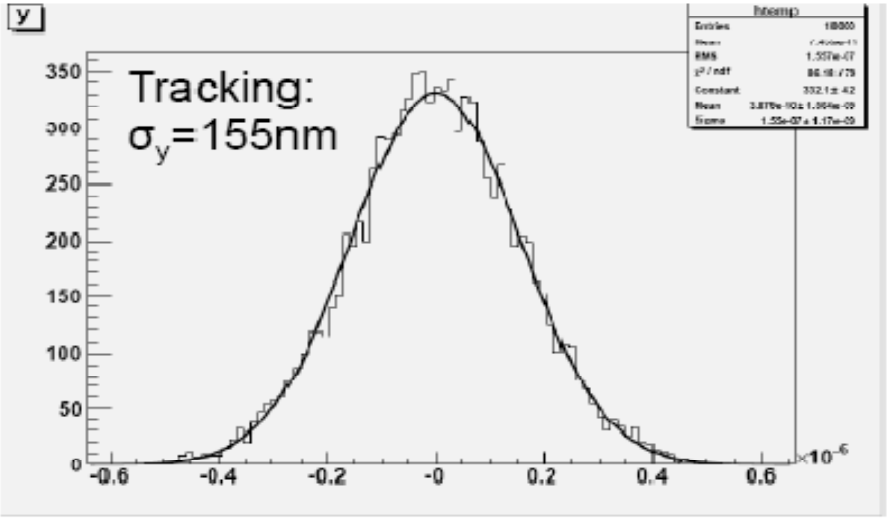
Close to nominal beam size at IP-54cm

Linear optics β_x =0.005m, β_y=0.00011m → σ_y = 37nm

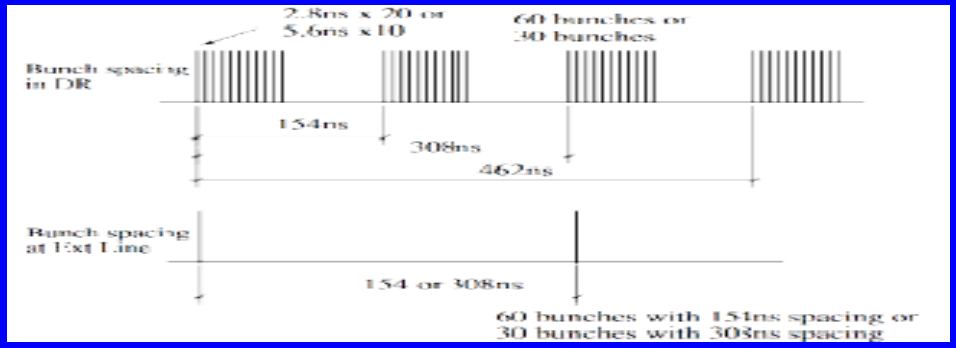


Close to 20 $\times \beta_y^{nominal}$ at IP-54cm

Linear optics β_x =0.004m, β_y=0.002m → σ_y = 153nm

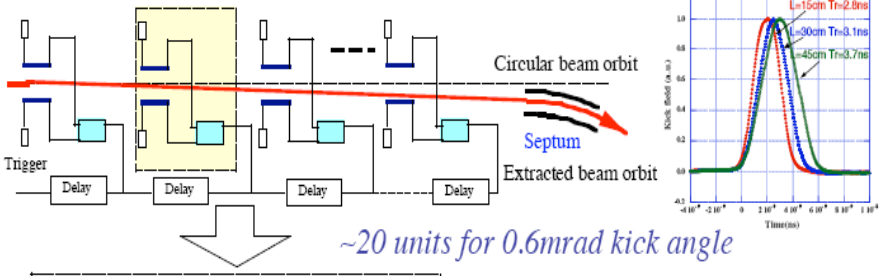


Fast ns rise-time kicker tests for train (de-)compression and production of ILC-like train

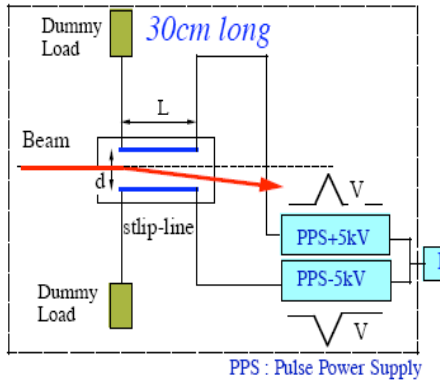


T. Naito (KEK)

Strip-line kicker system for ILC



~20 units for 0.6mrad kick angle



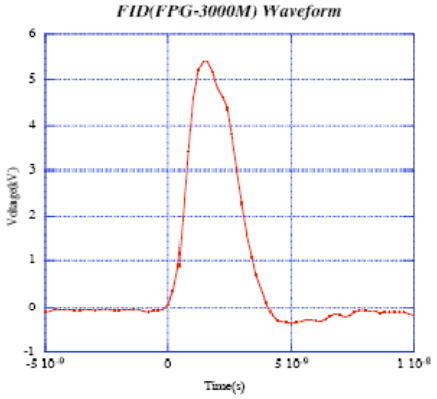
$$\Delta\theta = 2g\frac{eV}{E}\frac{L}{d}$$

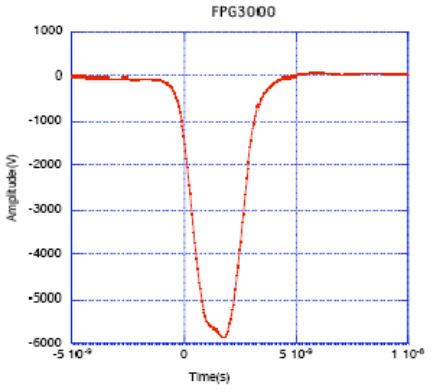
L = strip – line length
d = distance between the electrodes
V = pulse voltage
E = Beam energy

$$g = \tanh\left(\frac{\pi\omega}{2d}\right)$$

ω = strip – line width
d = distance between the electrodes

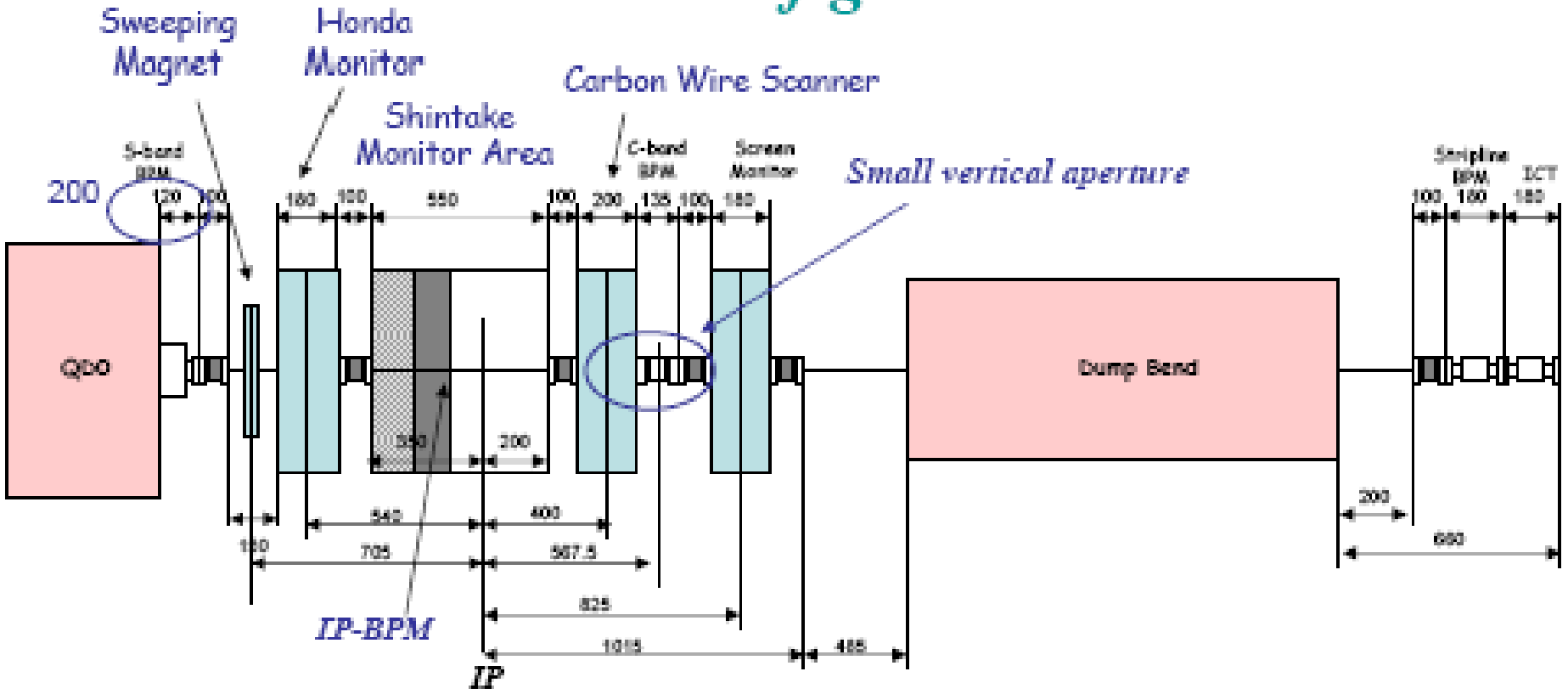
Pulse power supply (FID FPG5-3000M)





Pulse width(FWHM) = 2ns
Pulse height = 5.8kV
Rise time = ~1.5ns(5%~95%)
Rep. rate = 3MHz, 3000pulses/5Hz
Time jitter = ~29ps
Amplitude Jitter = 0.72%
(limited by the scope resolution)

IP configurations (octobre 2007)



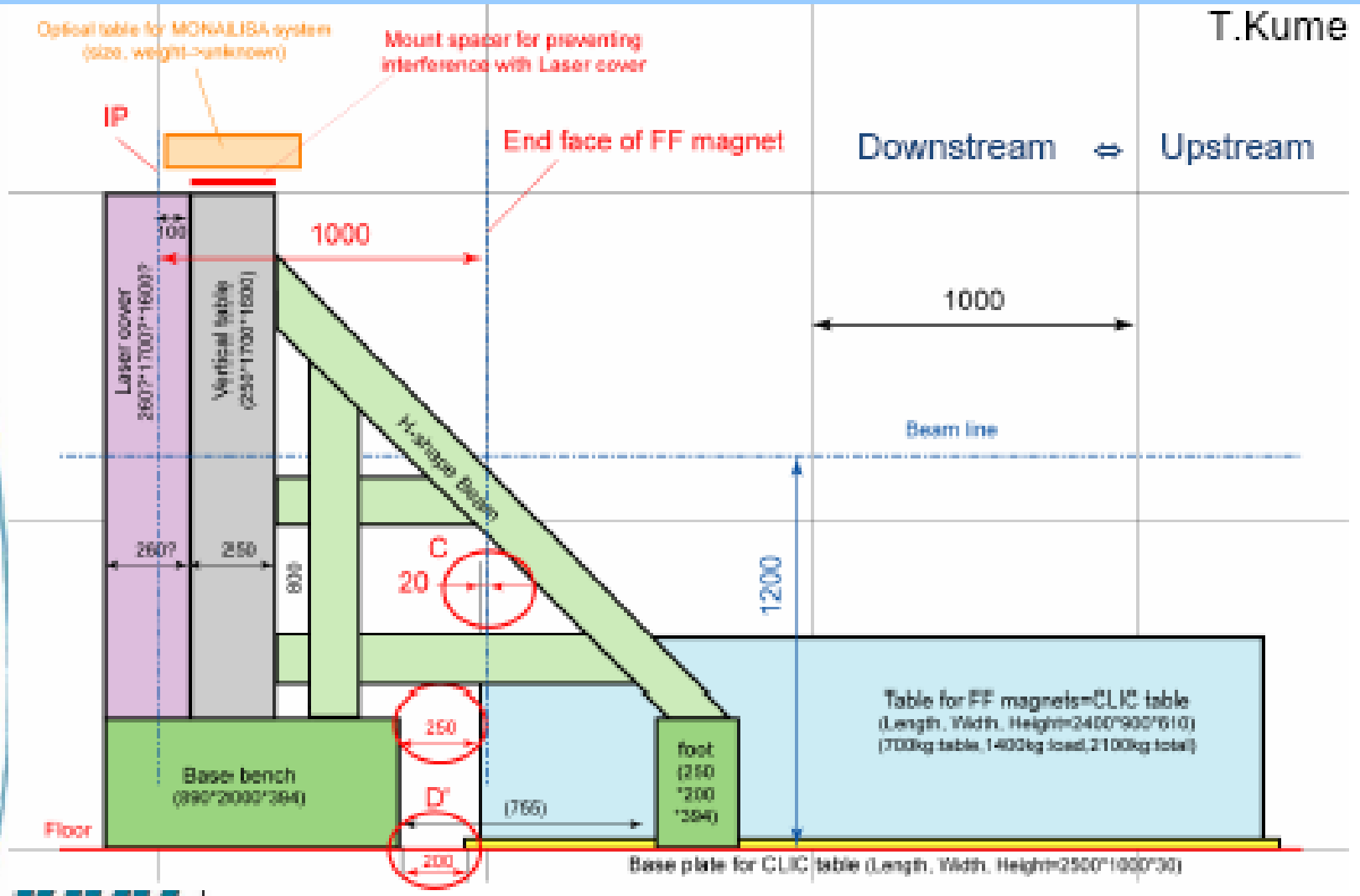
We must fix the follows …

C-band BPM --- *This BPM is very important for Quad-BPM offset measurement, especially for the measurement of the final doublet QD0, QF1, but the vertical aperture is almost same to QD0 (minimum aperture).*

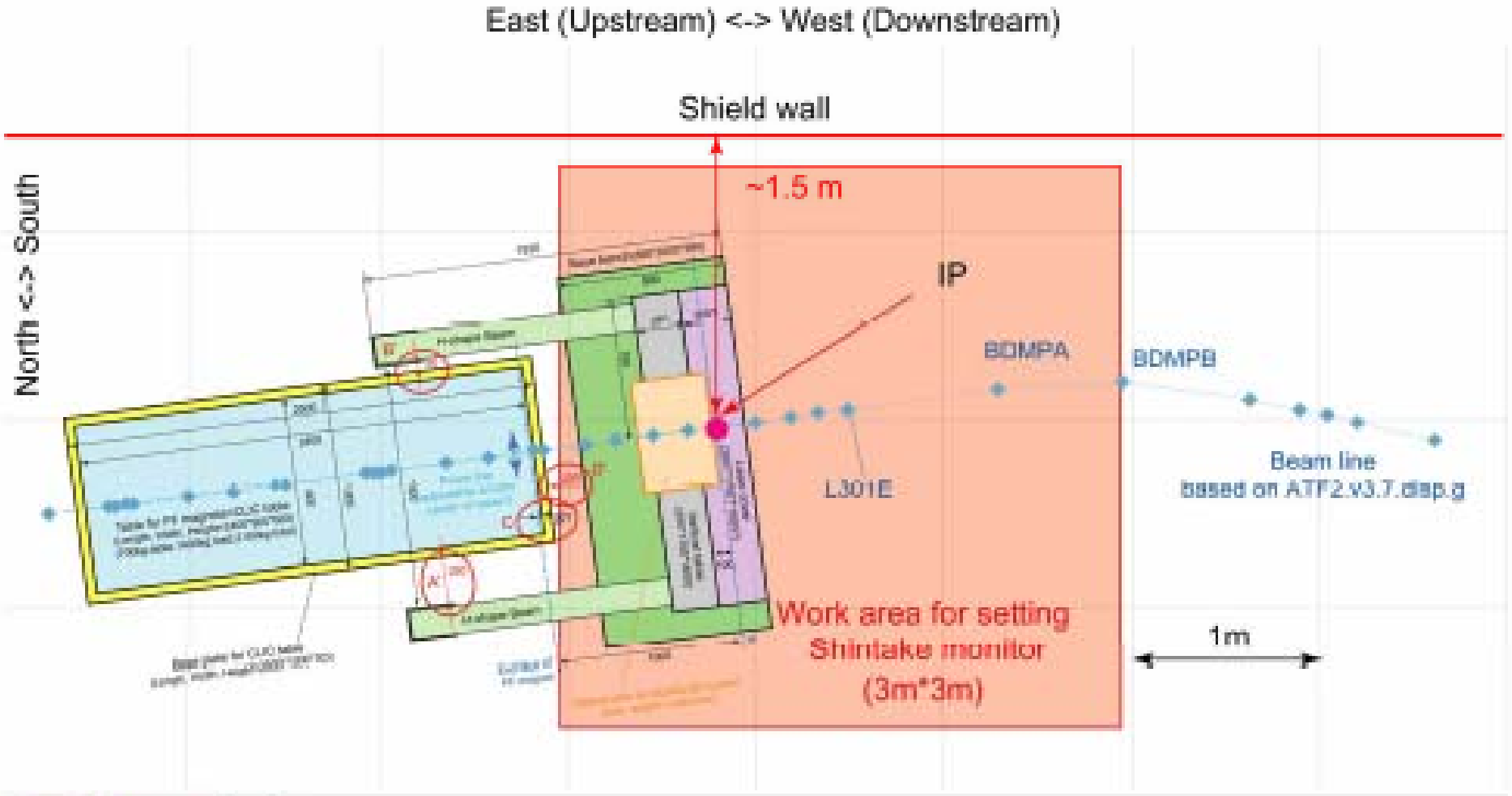
Sweeping Magnet --- *Sweeping magnet is used for the vertical beam position at IP & IP FB. 70mm is difficult to put the sweeping magnet !*

Shintake monitor mount-side view assuming distance between end face of CLIC table and FF magnet is 20 mm, distance between end face of FF magnet and IP is 1000 mm

T.Kume KEK

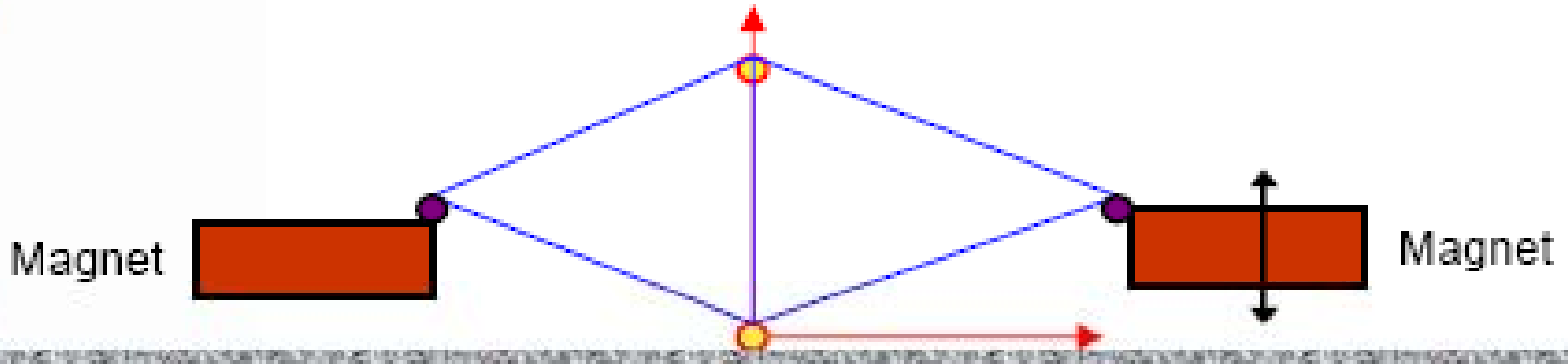


Shintake monitor mount-top view



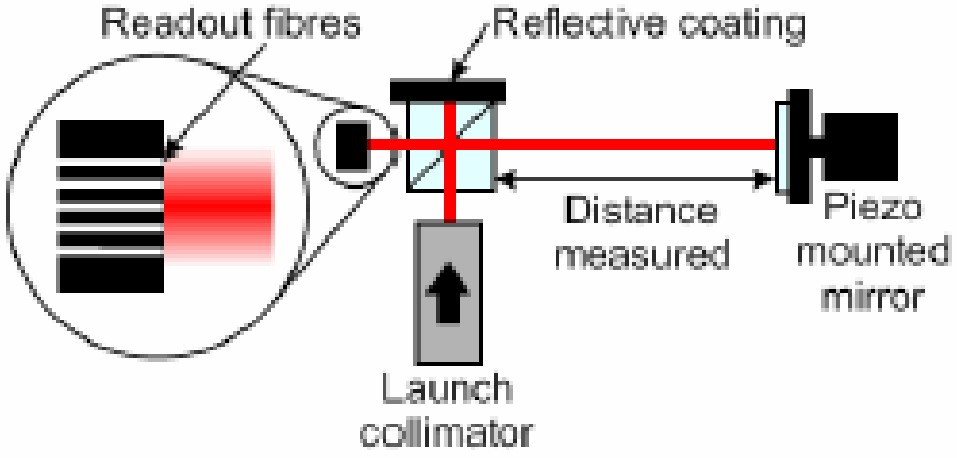
Monitoring, Alignment & Stabilisation with high Accuracy

D.Urner, Oxford



Ground

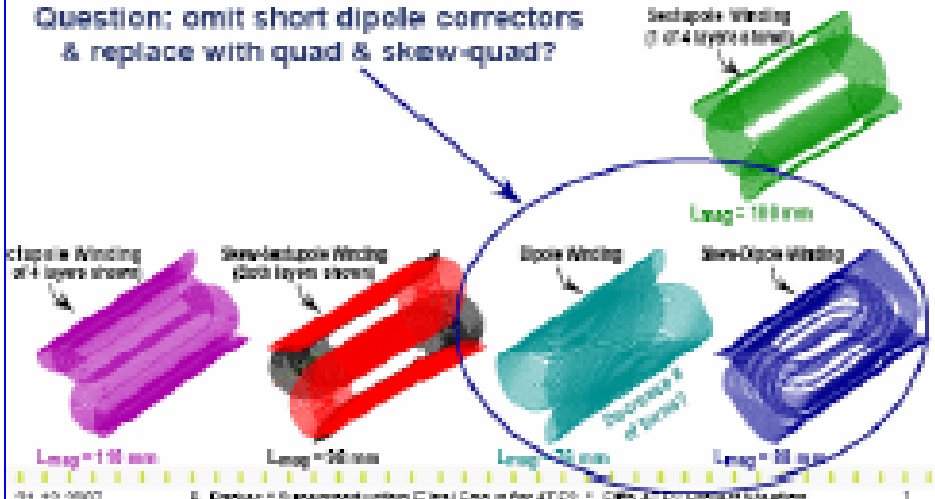
Sur ATF2, ce sera entre QD0 et le Shintake Monitor



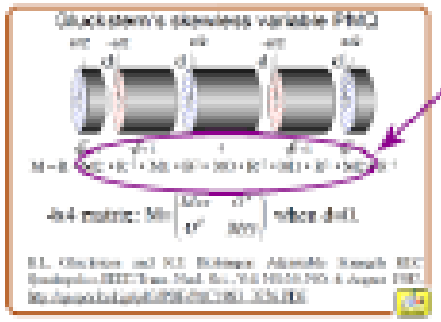
Futur lointain pour remplacer QD0

Superconducting ATF2 Final Focus

Question: omit short dipole correctors & replace with quad & skew-quad?



Permanent Magnet ATF2 Final Focus



Check how this works with:

- Overlap with detector solenoid?
- Degree of cancelation with real errors?

With μ about 1.05, how much does this distort a 3 T solenoidal (end) field?