R&D Activities Beyond S's

Olivier Napoly
GDE
CEA-Saclay

Outline

- S5 : Positron Sources
  - **Undulator based positron source**
  - **Compton based positron source**
- ILC Controls
  - **FLASH LLRF**
  - **FLASH Machine Protection**
- ILC Collider Luminosity Monitoring
  - **Bcal and GamCal**

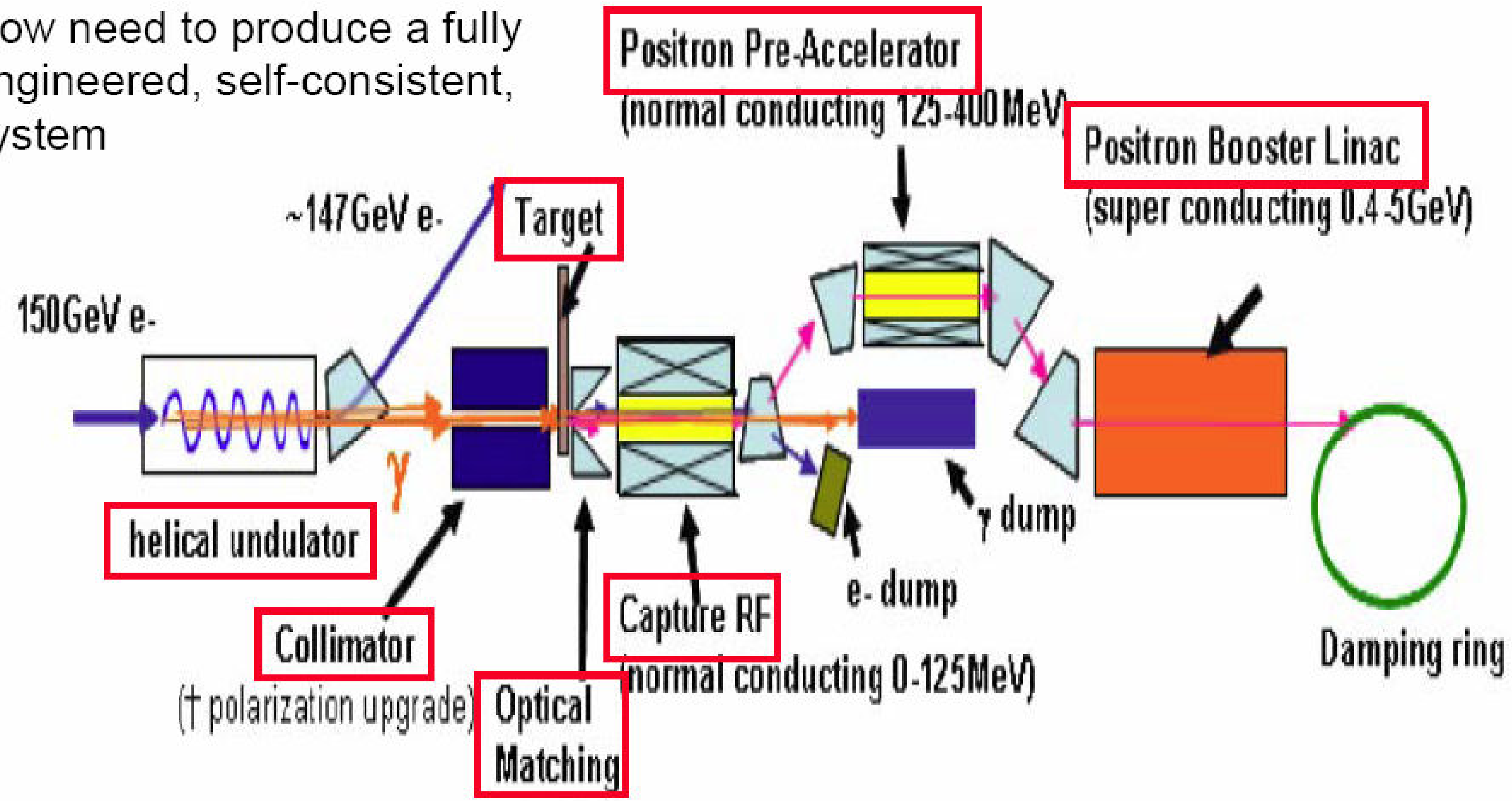
Thanks to: H. Maruyama, J. Sheppard, J. Clarke, A. Variola, M.Grecki, A. Hamdi, C. Grah

Positron Source

Undulator based source - EDR Design

All major items are being studied
(& others not highlighted here)

Now need to produce a fully engineered, self-consistent, system



Positron Source

Layout of ILC Positron Source: January 2007

- Photon production at 150 GeV electron energy
- K=0.92, λ=1.15 cm, 147 m long helical undulator, UK design
- One e+ production station (no backup-- fast target exchange) + KAS
- Pulsed OMD (shielded target)
- Reduced number of BPM electronics and correctors in transport lines
- Keep alive auxiliary source, 10% intensity

  (500 MeV, 2.05×10^{10} e-/bunch, 2625(?) bunches/pulse,

  5 pulses/s into ~4 r.l. W-Re spinning target, collection system same as for main positron production, 400 MeV e+ preBoost, inject into e+ 5 GeV Booster)

Beijing Feb 2007 Jim Clarke John Sheppard

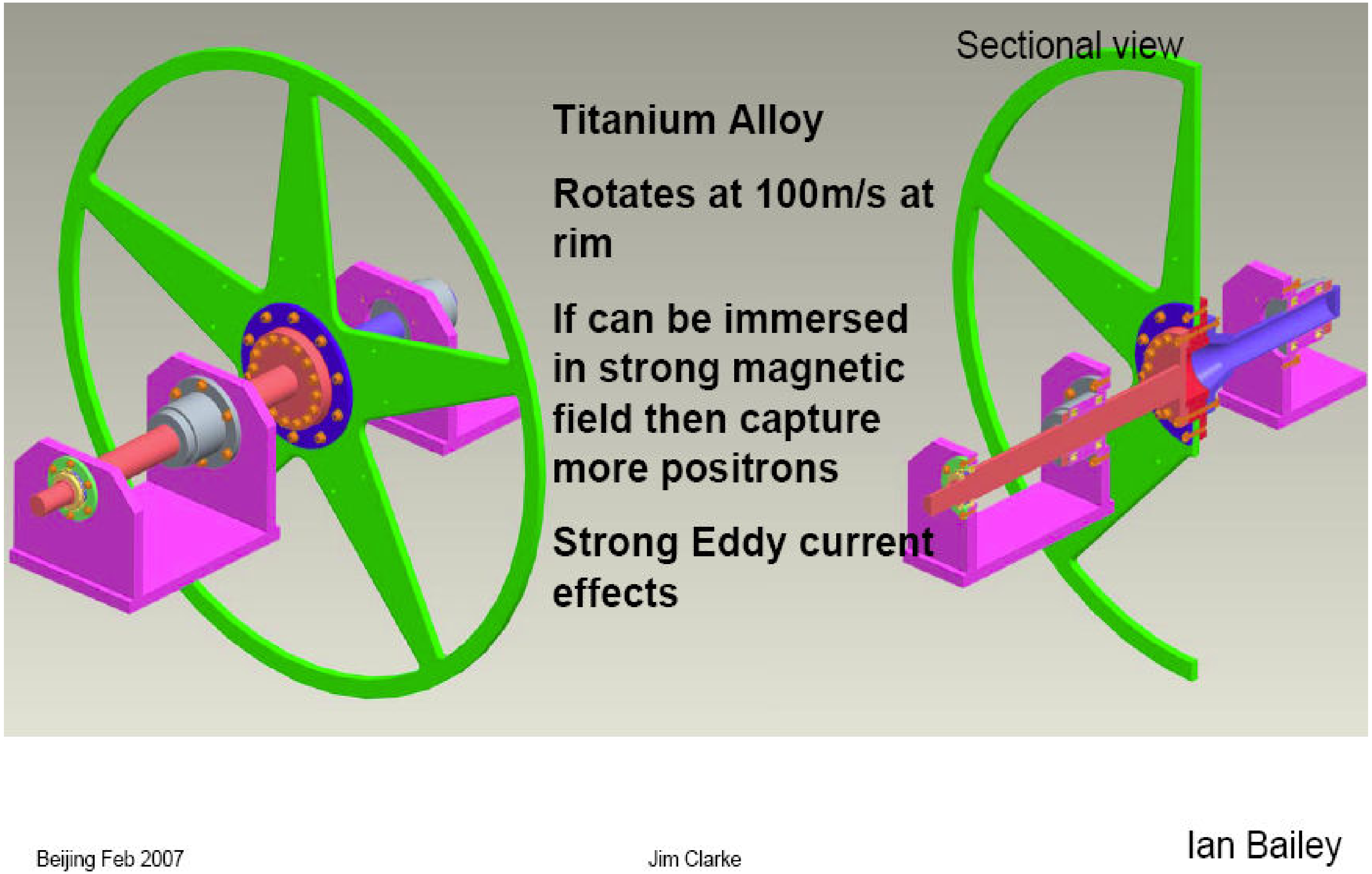
Positron Source

Recent Progress

- Target
- Undulator
- Low Energy Polarimeter
- 30% Polarisation
- Alternative Source

Positron Source

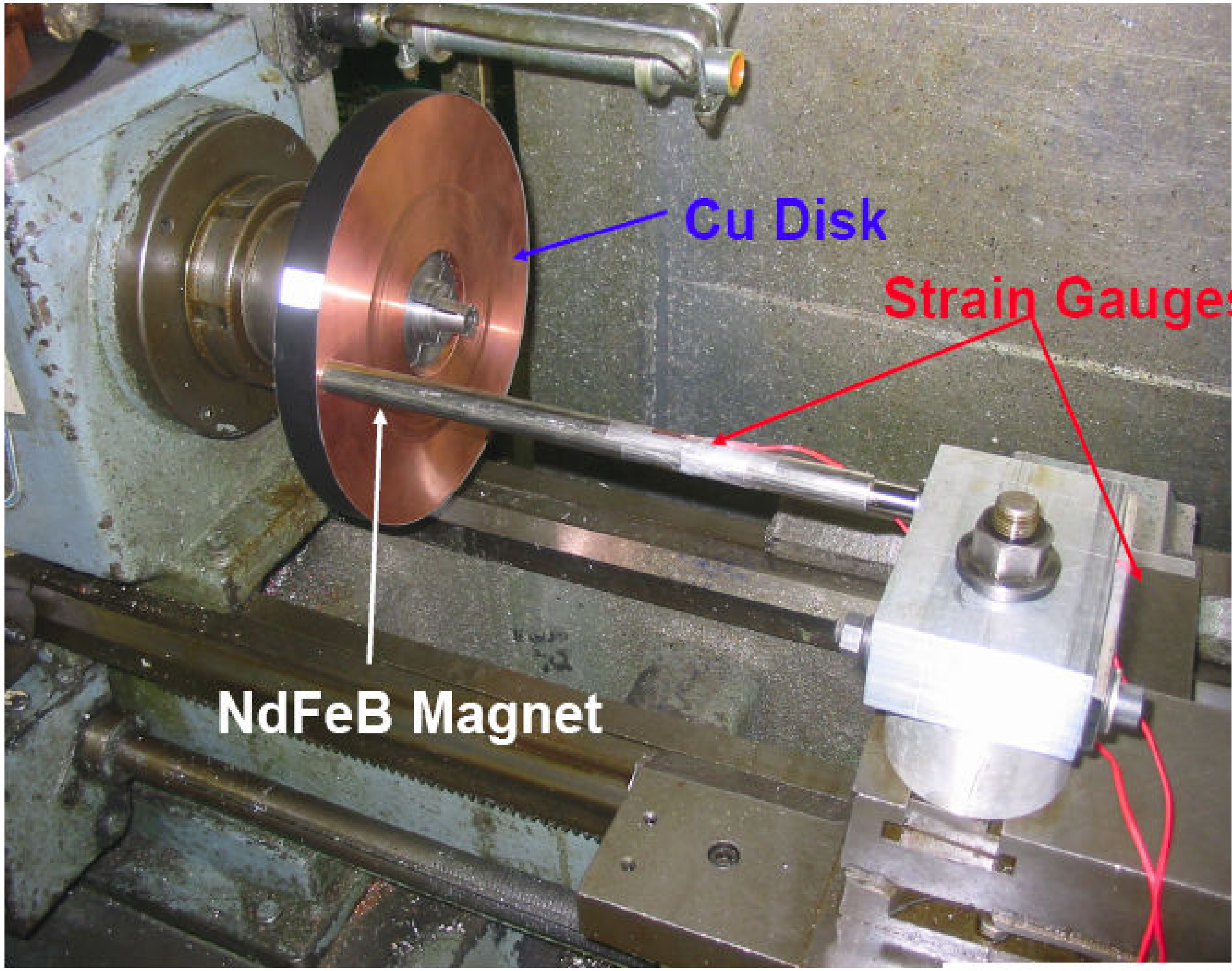
Target Wheel



Ian Bailey

Positron Source

Positron System Spinning Disk Exp & Simulations: ANL, LLNL, SLAC, RAL



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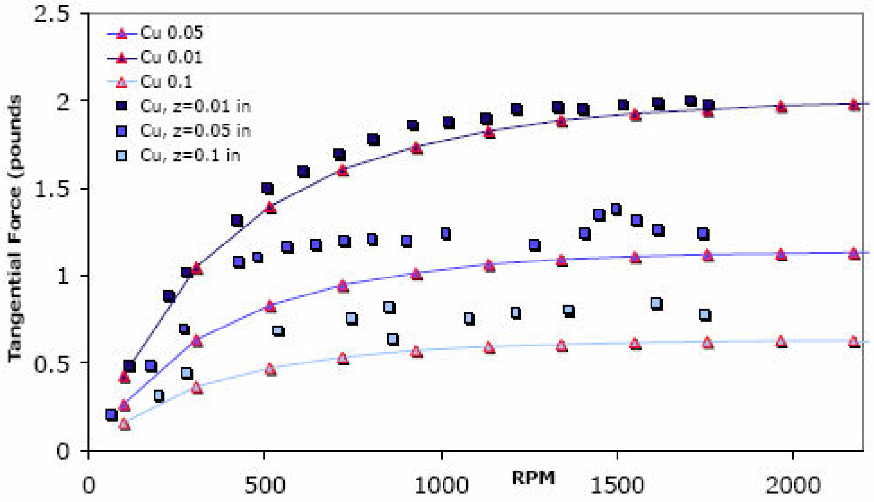
Positron Source

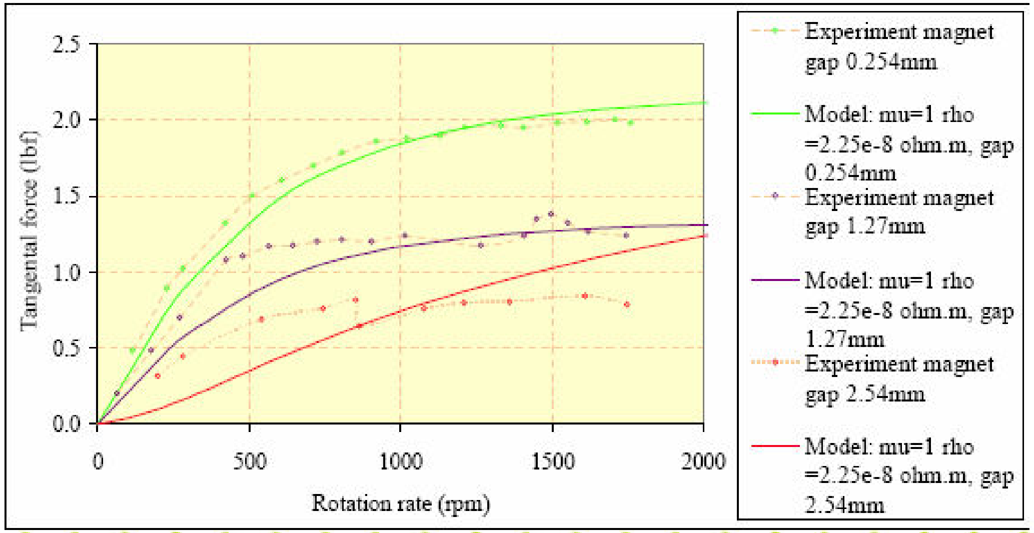
Theory vs Experiment



Variable is distance between the magnet and the disk

ANL
Wei Gai

RAL
Jim Rochford



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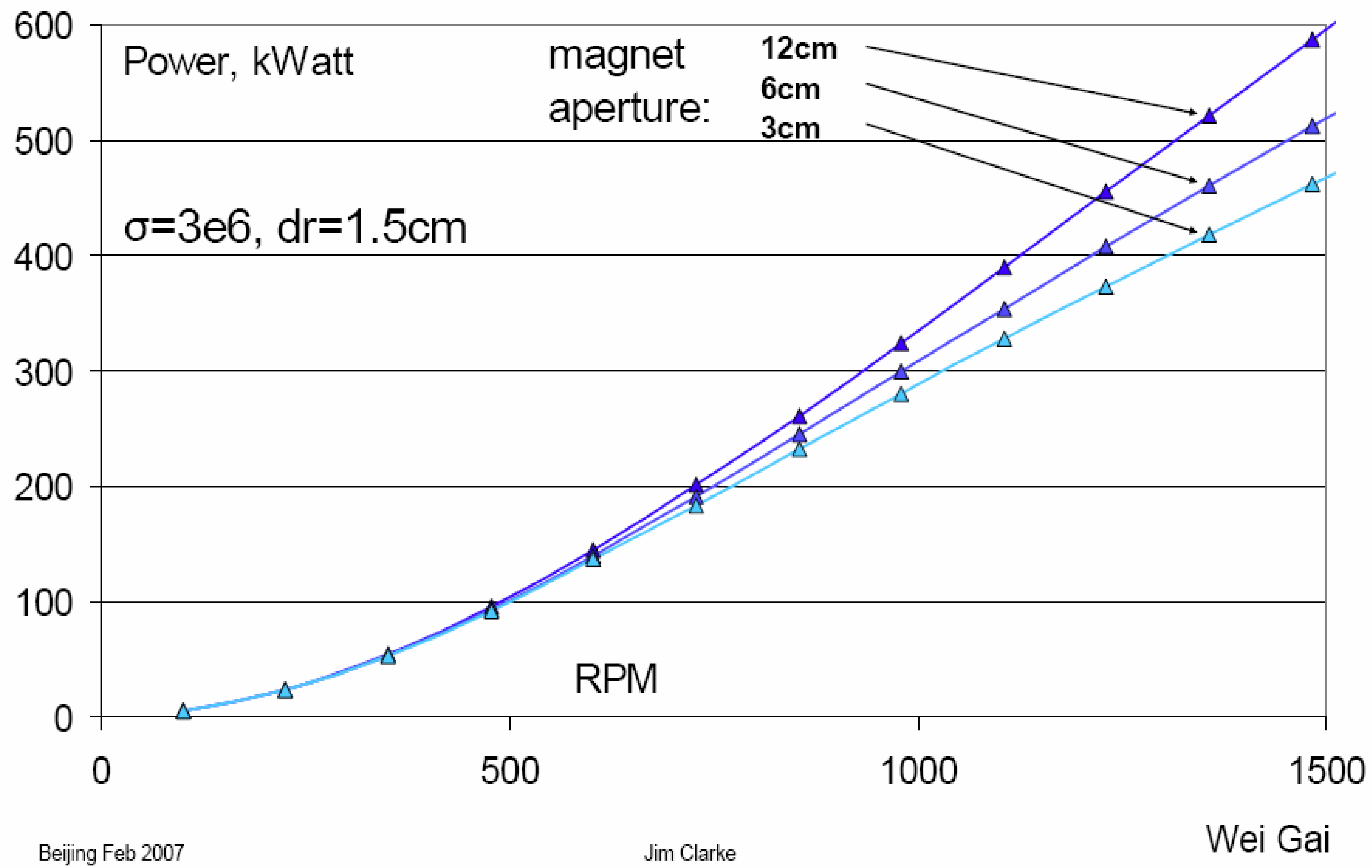
Positron Source

Results for actual target in 5T field



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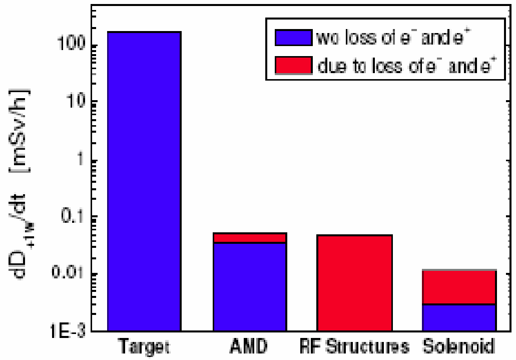
Positron Source

Target Activity

Andriy Ushakov



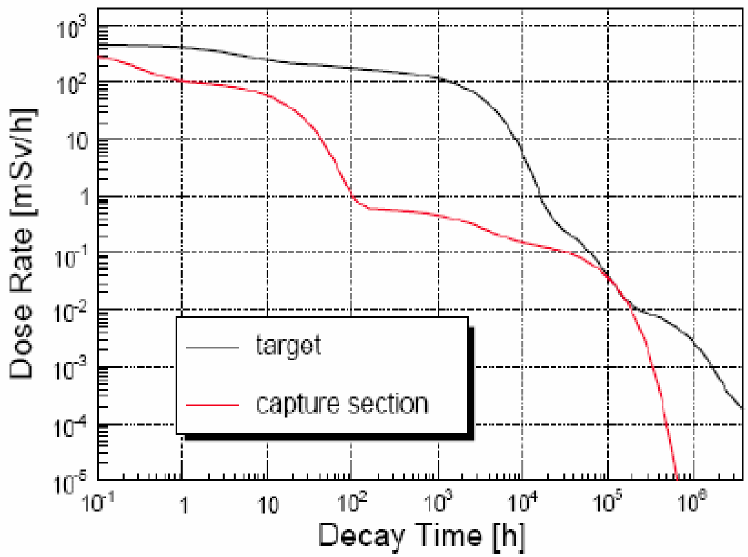
Dose rate after 5000 h of source operation and 1 week shutdown

Source part	$\dot{D}_{1w}$ [mSv/h]
Target	$167 \pm 9.5\%$
AMD	$0.077 \pm 100\%$
RF Structures	$0.109 \pm 82\%$
Solenoid	$0.024 \pm 100\%$

Target dose rate remains high for ~ 1 year

20mSv/hr is typical limit for manual handling

Remote handling essential



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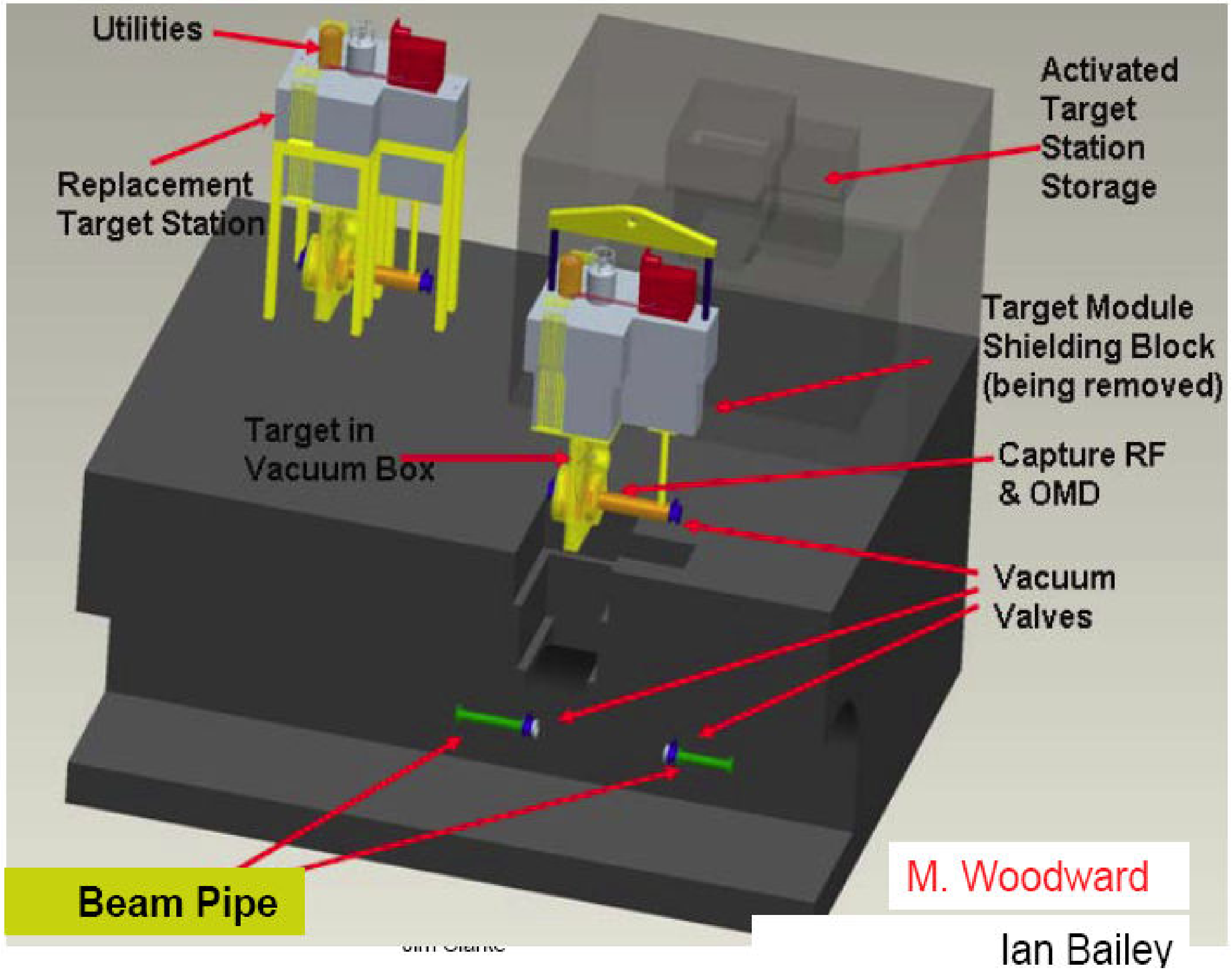
Positron Source

Target Removal/Replacement Showing Storage Cell

Time to change targets estimated at 53 hours

Important because 2nd target removed



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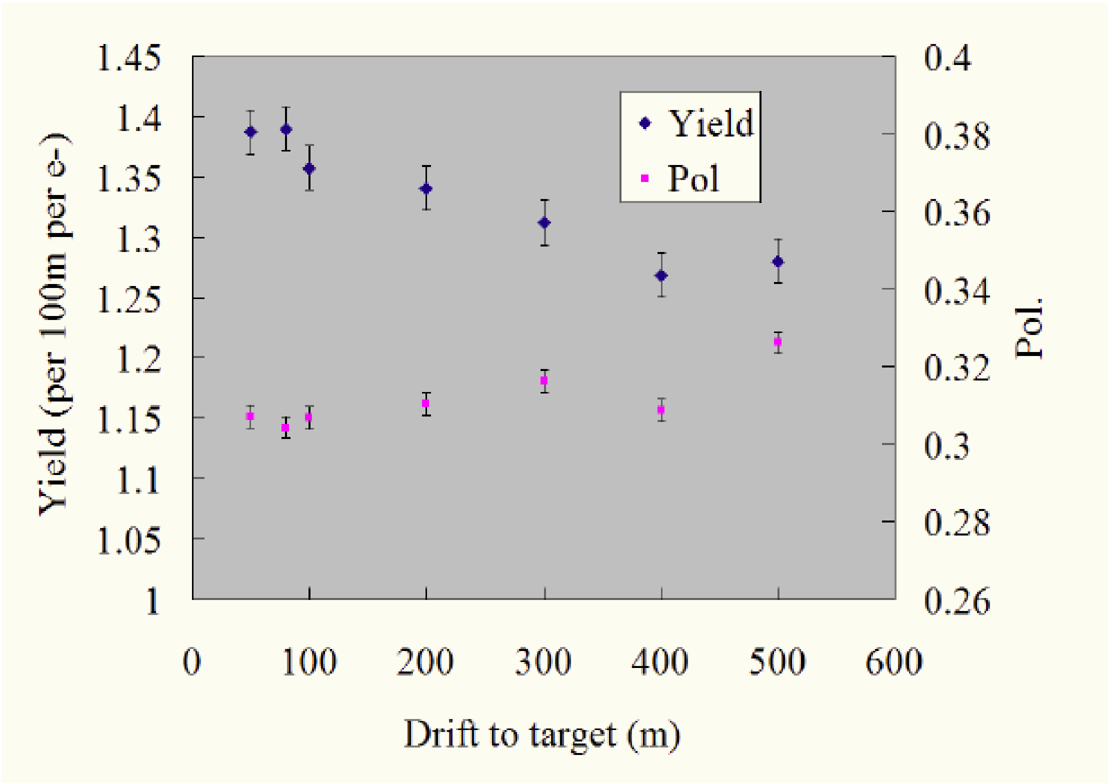
Positron Source

~30% Polarisation Available for Free



60% polarisation requires additional undulator

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Wei Gai

Positron Source

Example Enhancements to Physics

- Updated summary table is in progress (led by Gudi Moortgat-Pick)
- 30% provides significant gains so should ensure it can be transported and measured at IP

$(P(e^-), P(e^+))$	Effects for $P(e^-) \longrightarrow P(e^-)$ and $P(e^+)$	Gain w.r.t. (80%,0%)& Requirement (80%,60%)	(80%,30%)
Statistics:			
$P_{\rm eff}$	V,A processes	95%	88%
$\Delta A_{LR}/A_{LR}$	due to error propagation	×3	×2
Standard Model:			
top threshold	Electroweak coupling measurement	× 3	× 2
$t\bar{q}$	Limits for FCN top couplings improved	× 1.8	× 1.4
CPV in $t\bar{t}$	Azimuthal CP-odd asymmetries give access to S- and T-currents up to 10 TeV	$P^T_{e^-} P^T_{e^+}$	$P^T_{e^-} P^T_{e^+}$ ×0.8
W^+W^-	TGC: error reduction of $\Delta\kappa_\gamma$, $\Delta\lambda_\gamma$, $\Delta\kappa_Z$, $\Delta\lambda_Z$	×1.8	
	Specific TGC $\tilde{h}_+ = {\rm Im}(g_1^R + \kappa^R)/\sqrt{2}$	$P^T_{e^-} P^T_{e^+}$	$P^T_{e^-} P^T_{e^+}$
CPV in γZ	Anomalous TGC $\gamma\gamma Z, \gamma ZZ$	$P^T_{e^-} P^T_{e^+}$	$P^T_{e^-} P^T_{e^+}$
HZ	Separation: $HZ \leftrightarrow H\bar{\nu}\nu$	×4	× 2
	Suppression of $B = W^+\ell^-\nu$	×1.7	
$t\bar{t}H$	Top Yukawa coupling at $\sqrt{s} = 500$ GeV	×2.5	×1.6

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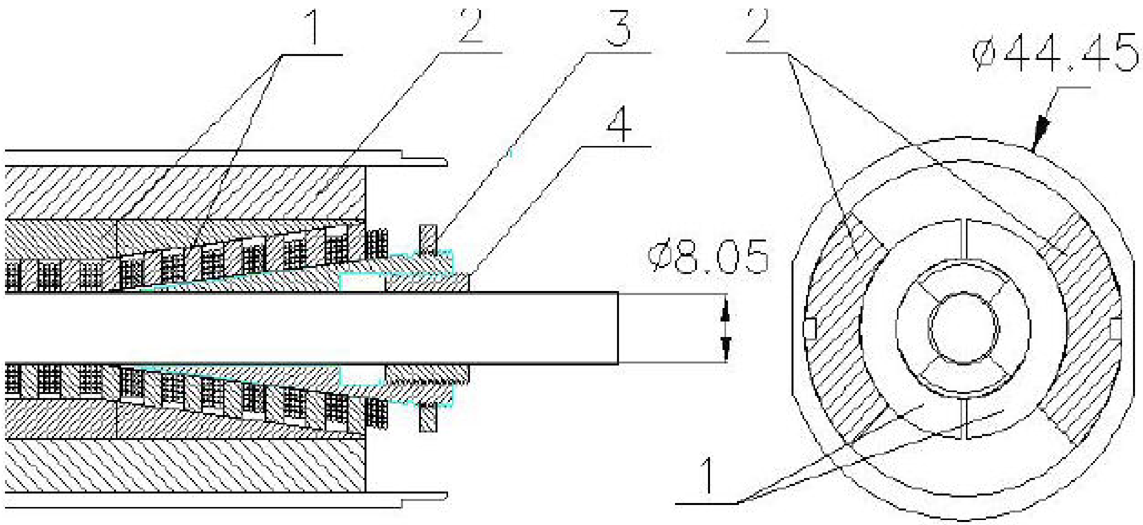
Positron Source

Cornell Undulator design



Details of design. 1–Iron yoke, 2–Copper collar, 3, 4–trimming Iron nuts.
Inner diameter of Copper vacuum chamber is 8mm clear.

Period kept even

Beijing Feb 2007

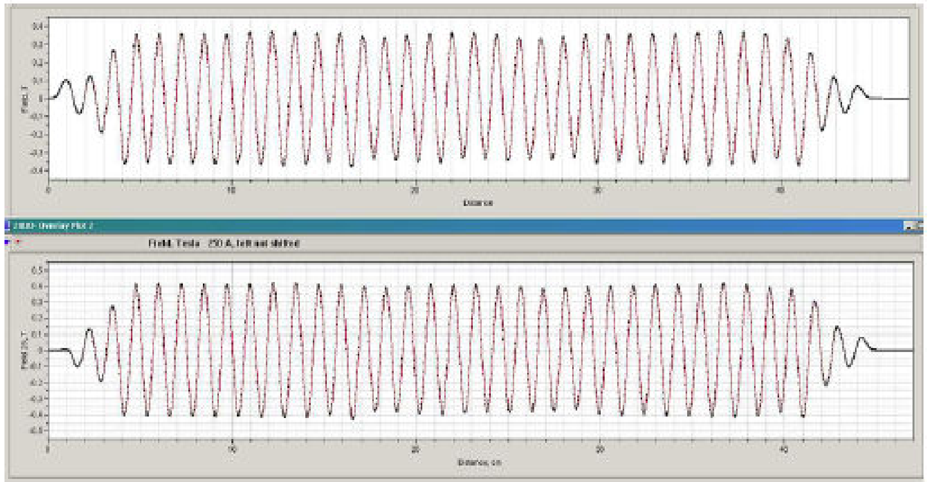
Jim Cl

Alexander Mikhailichenko

Positron Source

10 and 12 mm period Cornell undulators

10 (12) mm period undulator prototype has achieved field just before quench of 0.45 (0.64) T.

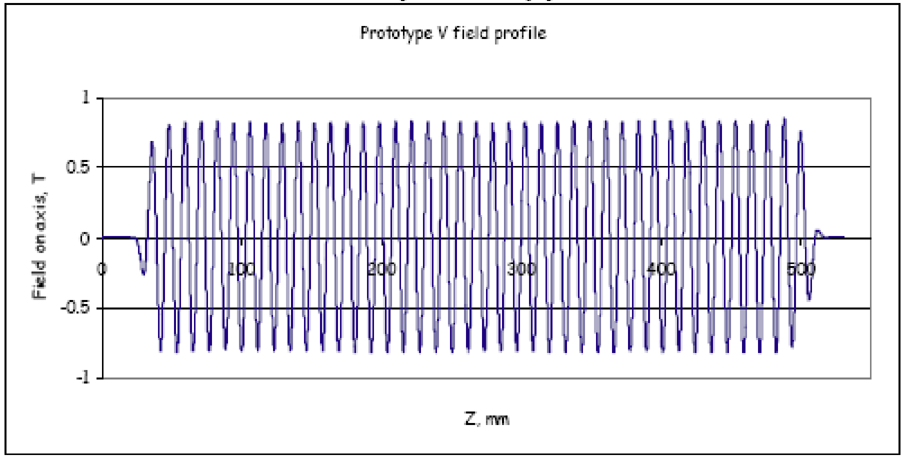


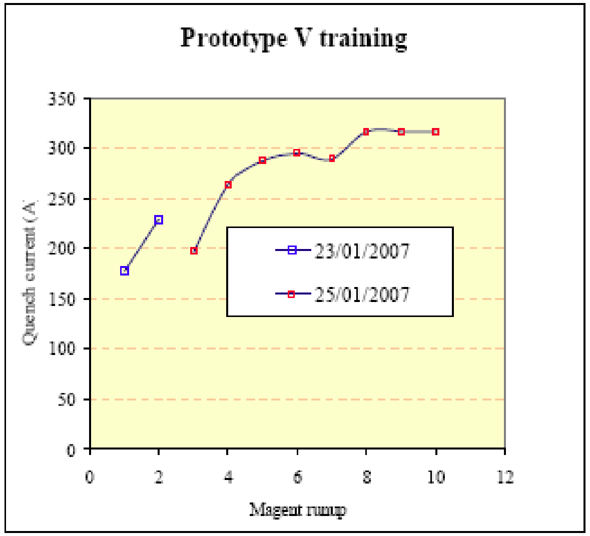
Alexander Mikhailichenko

Positron Source

UK Undulator Prototypes

1st results from prototype 5 at RAL





Measured field at 200A

0.822 T +/- 0.7 %
(spec is +/- 1%)

Prototype 5 details

Period : 11.5 mm
Magnetic bore: 6.35 mm
Configuration: Iron poles and yoke

Quench current 316A

Equates to a field of 1.1 T in bore

RDR value is 0.86 T

80% of critical current (proposed operating point) would be 0.95 T

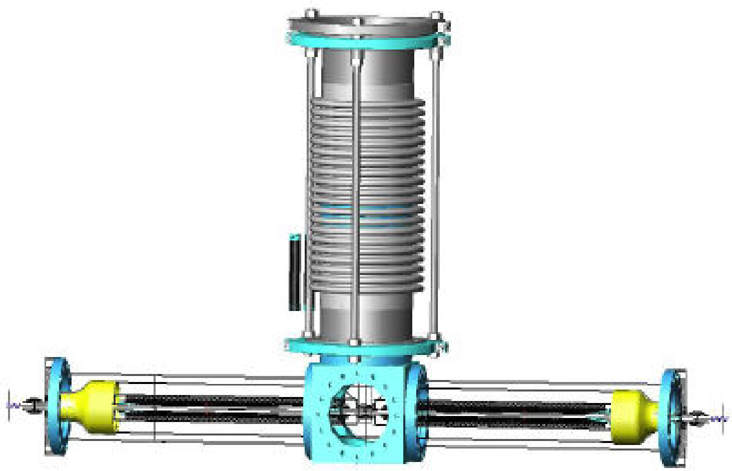
Jim Clarke

Jim Rochford

Positron Source

Cornell FY2008 Project Activities and Deliverables

Optimization of prototype(s) having 8 mm aperture and 10 mm period. Calculations of emittance and alignment perturbations in the undulator will be completed in this year. Materials and equipment required for fabrication and test of 2x30 cm long models will be obtained and used for prototype shown in Figure below



FY2009 Project Activities and Deliverables

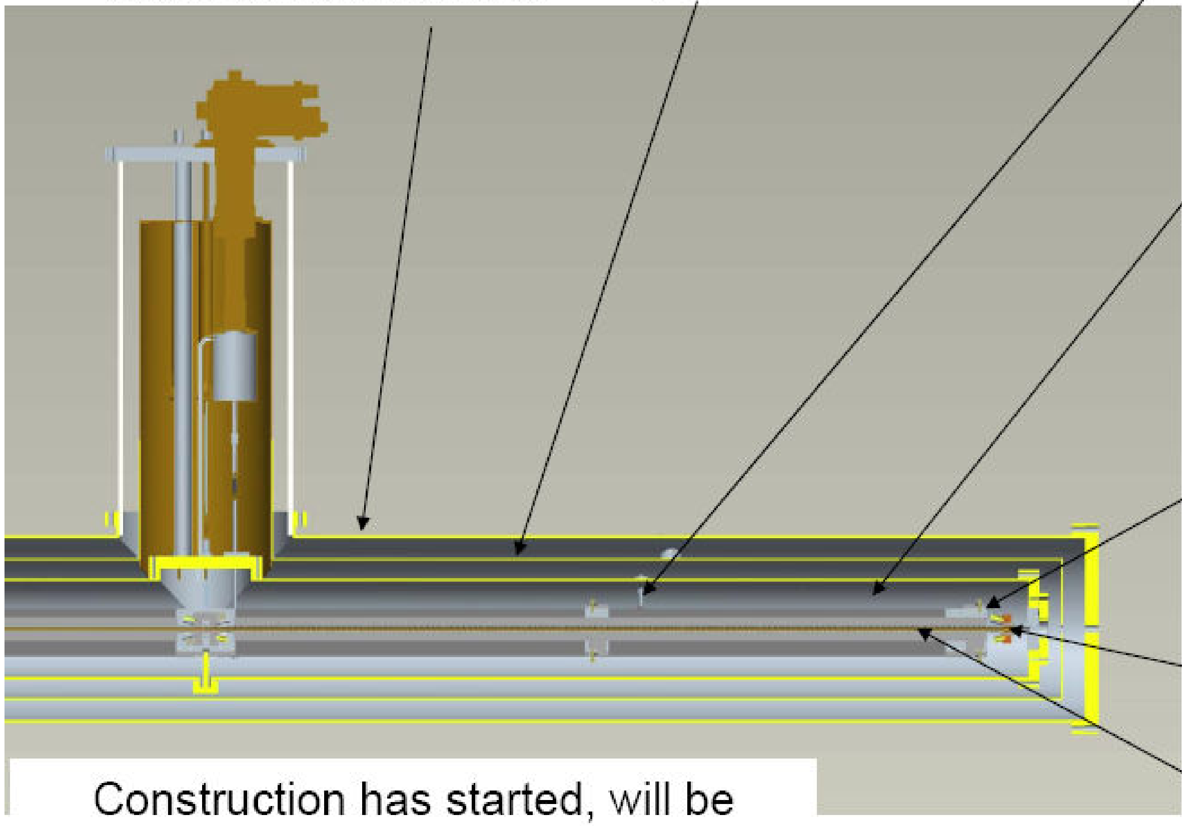
Fabrication and assembling the 4-6-m long section will be accomplished in this year.
Design of Hall probe system for the field measurements in 6-m long module will be accomplished
Note that the field measurements must be done in vacuum at cryogenic temperature.

Alexander Mikhailichenko

Positron Source

UK 4m Prototype Module

Jim Rochford



Construction has started, will be complete by Autumn 07

Positron Source

Positron yields from different 100m undulators

	BCD	UK I (RDR)	UK II	UK III	Cornell I	Cornell II	Cornell III
Period (mm)	**10.0**	**11.5**	**11.0**	**10.5**	**10.0**	**12.0**	**7**
K	**1.00**	**0.92**	**0.79**	**0.64**	**0.42**	**0.72**	**0.3**
Field on Axis (T)	**1.07**	**0.86**	**0.77**	**0.65**	**0.45**	**0.64**	**0.46**
Beam aperture (mm)	Not Defined	5.85	5.85	5.85	8.00	8.00	
First Harmonic Energy (MeV)	10.7	10.1	12.0	14.4	18.2	11.7	28
Yield(Low Pol, 10m drift)	~2.4	~1.37	~1.12	~0.86	~0.39	~0.75	~0.54
Yield(Low Pol, 500m drift)	**~2.13**	**~1.28**	**~1.08**	**~0.83**	**~0.39**	**~0.7**	**~0.54**
Yield(60% Pol)	~1.1	~0.7	~0.66	~0.53	~0.32	~0.49	~0.44

Target: 1.42cm thick Titanium

Wei Gai

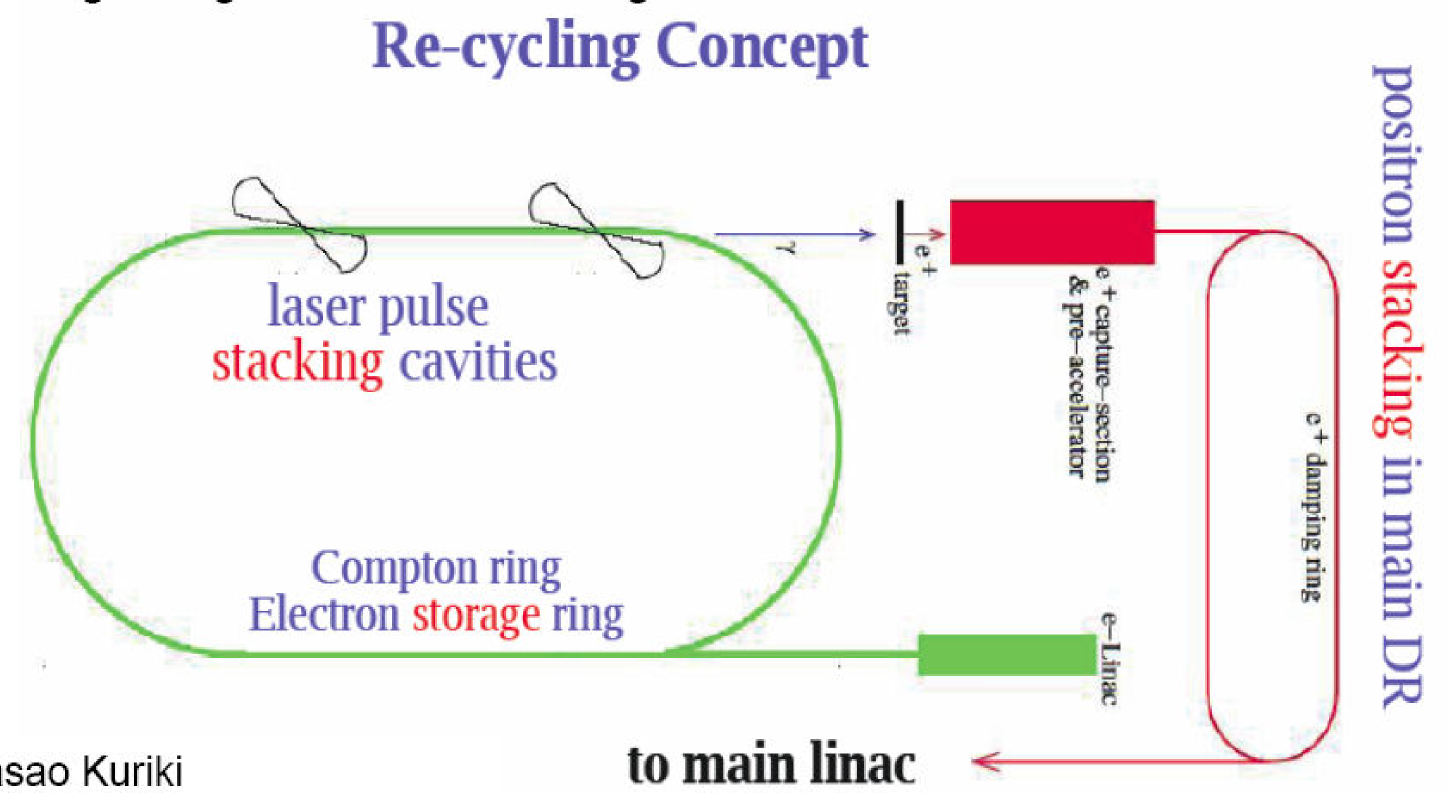
Positron Source : Alternative

ACD Positron Source - Laser Compton Scheme

R & D also ongoing on laser compton source

3 different schemes under consideration:

Storage Ring Based with stacking in DR

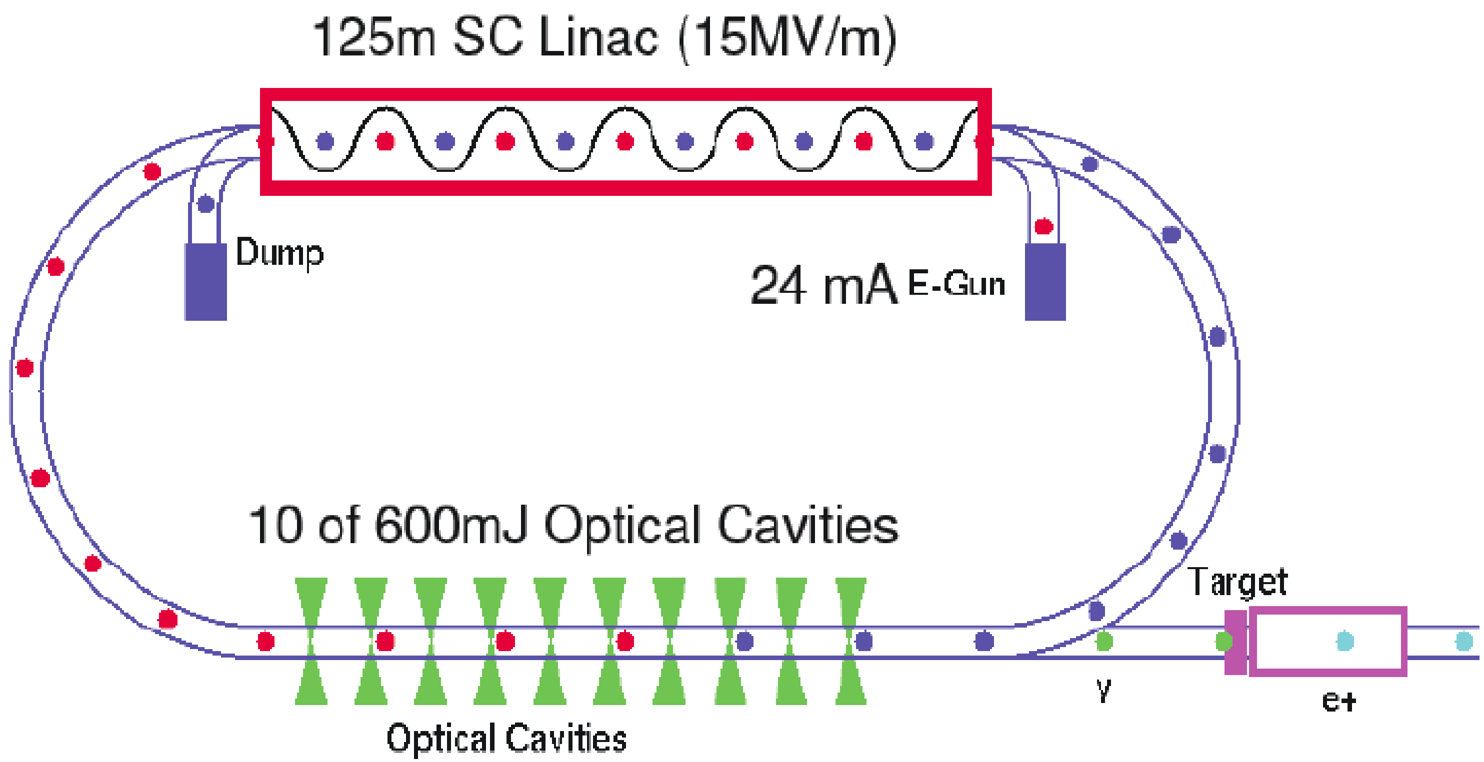


Masao Kuriki

Positron Source : Alternative

ERL Based Compton Source

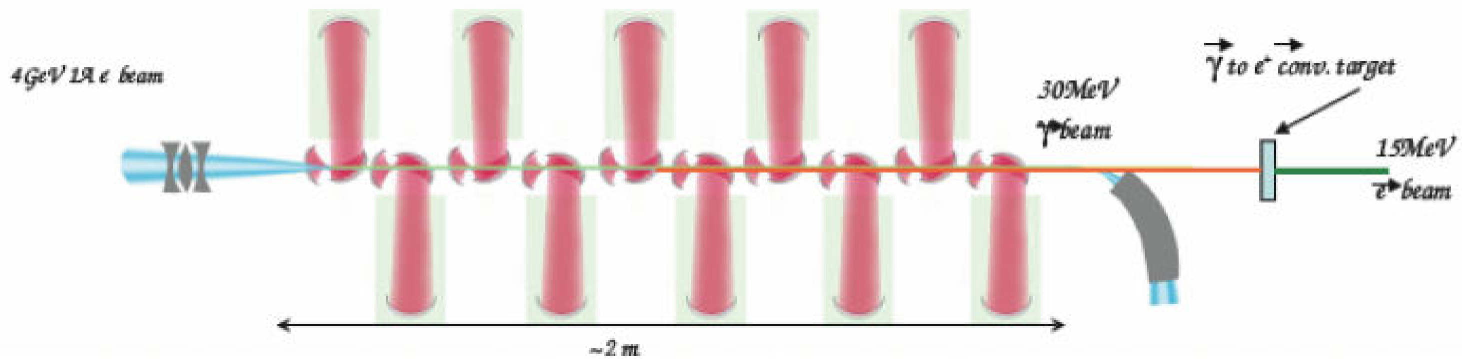
Energy Recovey Linac Based with stacking in DR



Positron Source : Alternative

Linac Based Scheme – no stacking in DR

- polarized - ray beam is generated in the Compton back scattering inside optical cavity of CO_2 laser beam and 4 GeV e-beam produced by linac.
- The required intensities of polarized positrons are obtained due to 10 times increase of the e-beam charge (compared to non polarized case) and 5 to 10 CO_2 laser system IPs.
- Laser system relies on the commercially available lasers but need R&D for the new mode of operation
- 5ps 10J@0.05 Hz CO_2 laser is operated at ATF



Polarised positron source based on Compton scattering

Different advantages in respect of the undulator baseline solution:

1) Source independence from the main LINAC – no interference with the main e^- beam
2) No need of deceleration for low center of mass energy collisions.
3) Timing can be adjusted with the DR injection. No extra delay lines
4) Easy to switch the polarisation (switch the laser polarisation).
5) Less energy deposition per pulse in the target
6) Compactness (no long transport lines)
7) Possible demonstrators prior to ILC
8) Applications as hard-x /gamma source for other physics field

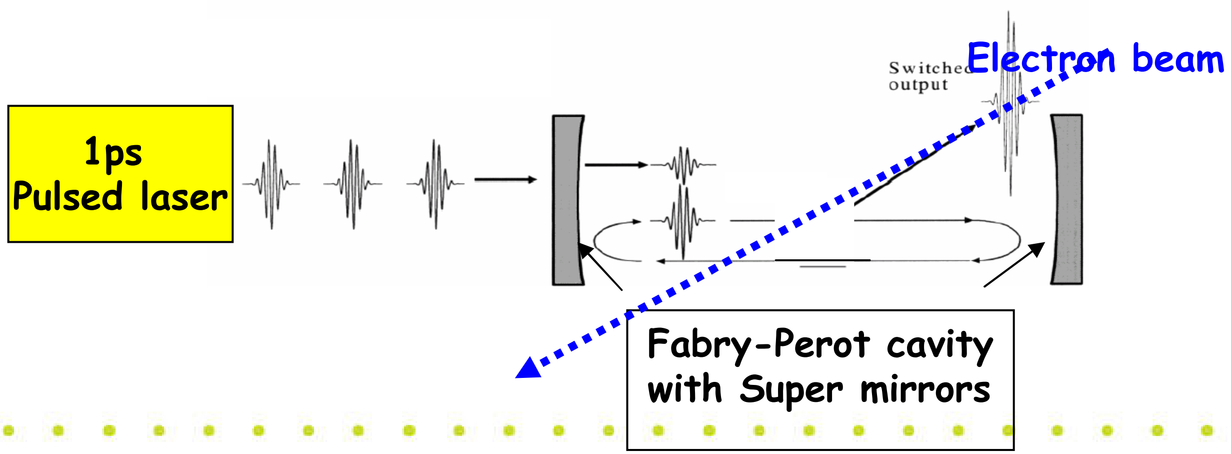
BUT:

- Very low cross section for Compton scattering, requires extremely high charge bunch and high power laser pulses
- Anyway requires stacking in the DR or in a dedicated accumulation ring

Three different scheme for Compton production:

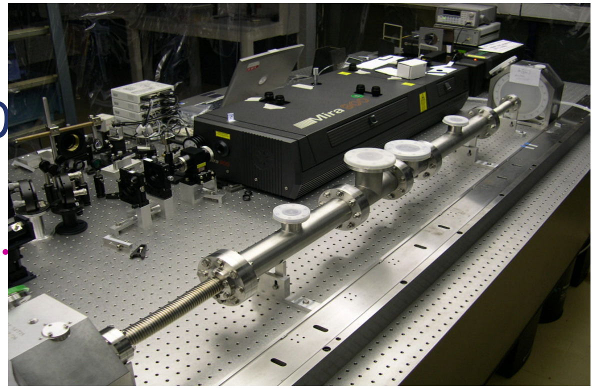
1. Compton ring + YAG laser (adv = high frep) – Stacking idea started from LAL (K.Moenig)
2. ERL + YAG laser (adv = short bunch length, low power dump, no beam stability problems due to ΔE caused by Compton effect, power consumption) – Idea from LAL (A.Variola)
3. Linac + CO2 laser (adv = high laser power)

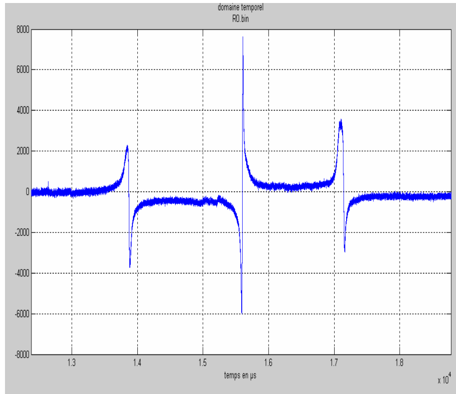
In the first two schemes it is necessary to amplify the laser pulses energy in a high finesse optical resonator.



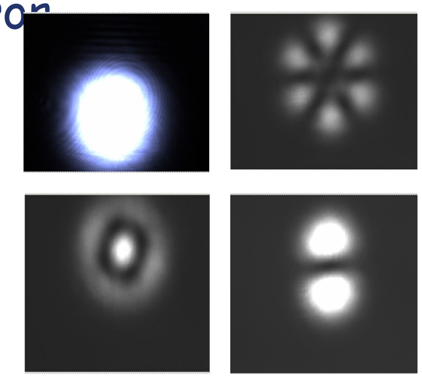
The Compton scheme, to be successfull needs the development of high average power laser, high frep and high amplification factor in Fabry Perot cavities with micrometic waists. To assess all this point in LAL Orsay we are involved in different R&D activities:

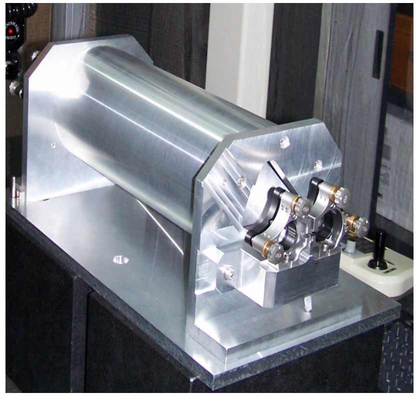
1) Development of high finesse optical resonator (Gain~ 10^4-10 in low power regime.
STATUS : Experimental phase.
Error signal digitalised.
Feedback actuators tested





2) Development of a non planar four mirror resonator to reduce the waist size without losing mechanical stability
STATUS : Experimental phase.
Measurements of the beam waist





3) Funds requested to ANR to develop a fiber laser with 200W average power in the 20-50 MHz regime STATUS : Funding request pending

Accelerator schemes

- An extensive simulation work (Parmela, Transport, EGS, Geant4, Superfifh and Poisson) is carried out to optimize the efficiency of the capture section:
  - Analysis of the AMD and of the QWT capture systems.
  - Polarisation included in EGS and Geant4.
  - Optimisation of the magnetic field and of the capture cavities phases.
  - Transport and post acceleration system
  - Bunch compressor

  GOAL: attain 2-3 % $\gamma/e^{+}_{captured}$ efficiency @ 60% polarisation

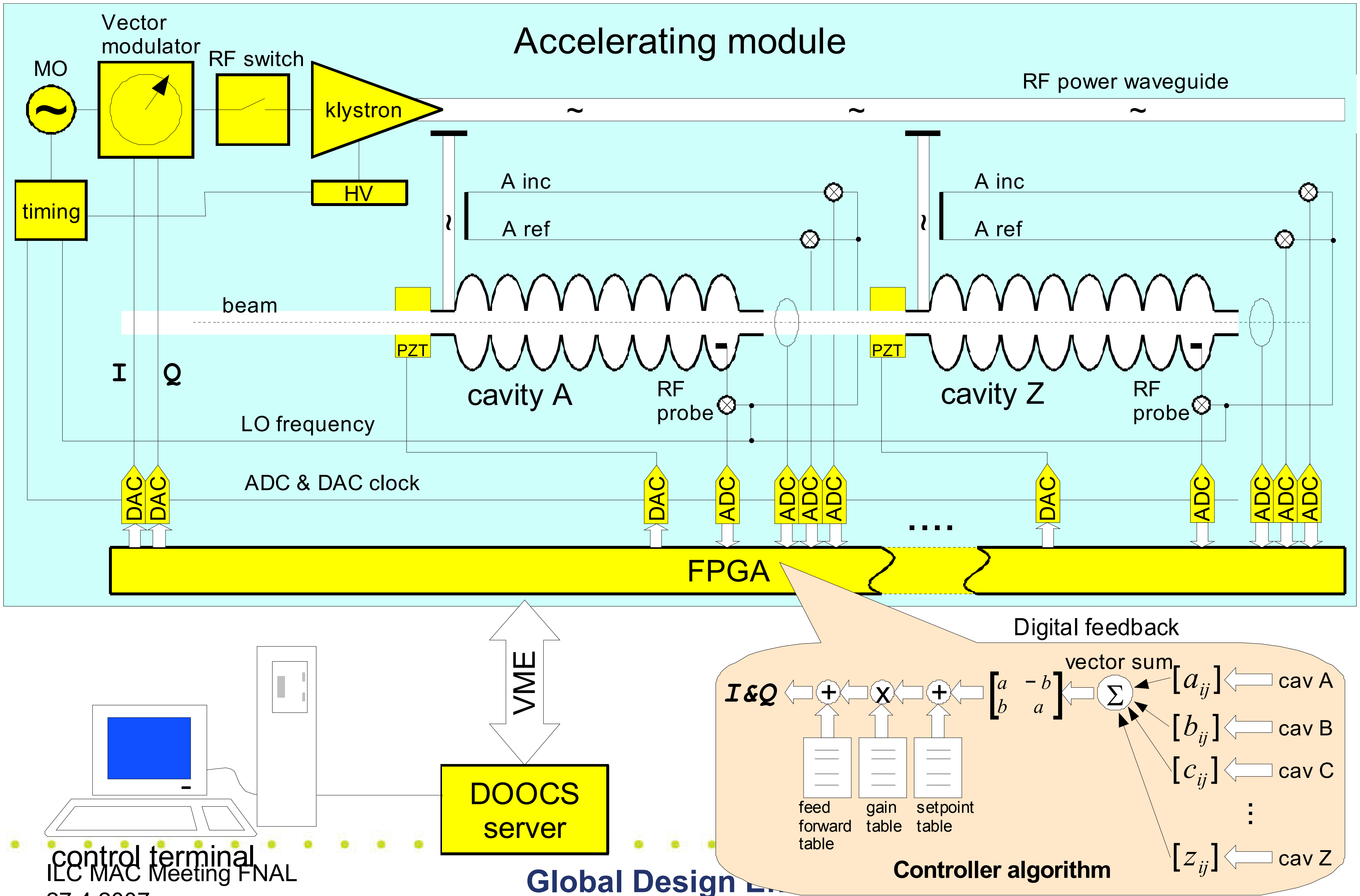
Actually we focalised our effort on the scheme proposed by LAL where the Compton production is carried out by an high efficiency ERL linac and high frep and power lasers stored in high Gain optical cavities. The main advantage is the short bunch length that allows increasing the cross section despite to the Compton collision crossing angle.

LLRF at FLASH

RF Control Requirements

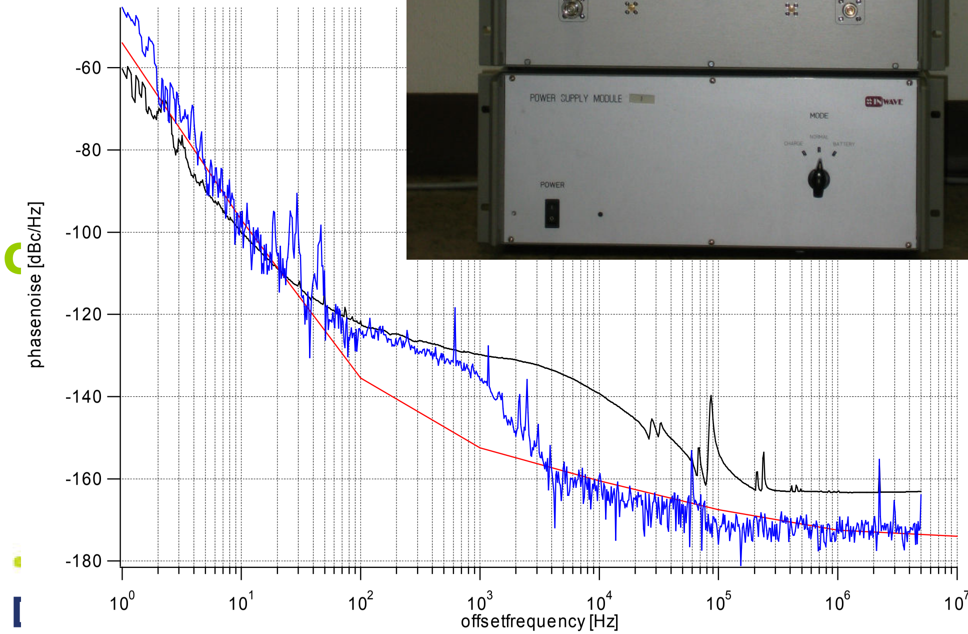
- Maintain Phase and Amplitude of the accelerating field within given tolerances to accelerate a charged particle beam (e.g. XFEL: 0.01% for amplitude and 0.01 deg. for phase)
- Minimimize Power needed for control
- RF system must be reproducible, reliable, operable, and well understood.
- Other performance goals
  - **build-in diagnostics for calibration of gradient and phase, cavity detuning, etc.**
  - **provide exception handling capabilities**
  - **meet performance goals over wide range of operating parameters**

RF Control System



Developments and achievements

- hardware
  - master oscillator and frequency distribution system
  - downconverter
  - digital control
  - radiation monitoring
  - transient detection
  - Lorentz force detuning
- software
  - automation
  - algorithms and applicatio
  - fault tolerant systems



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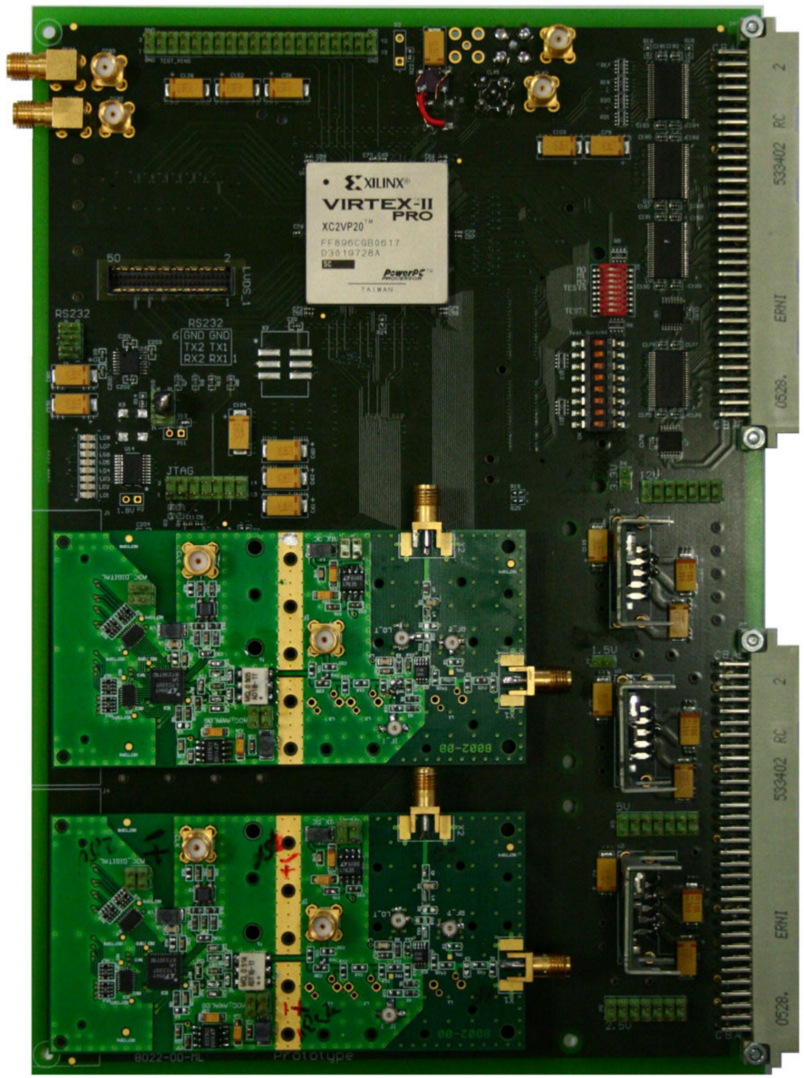

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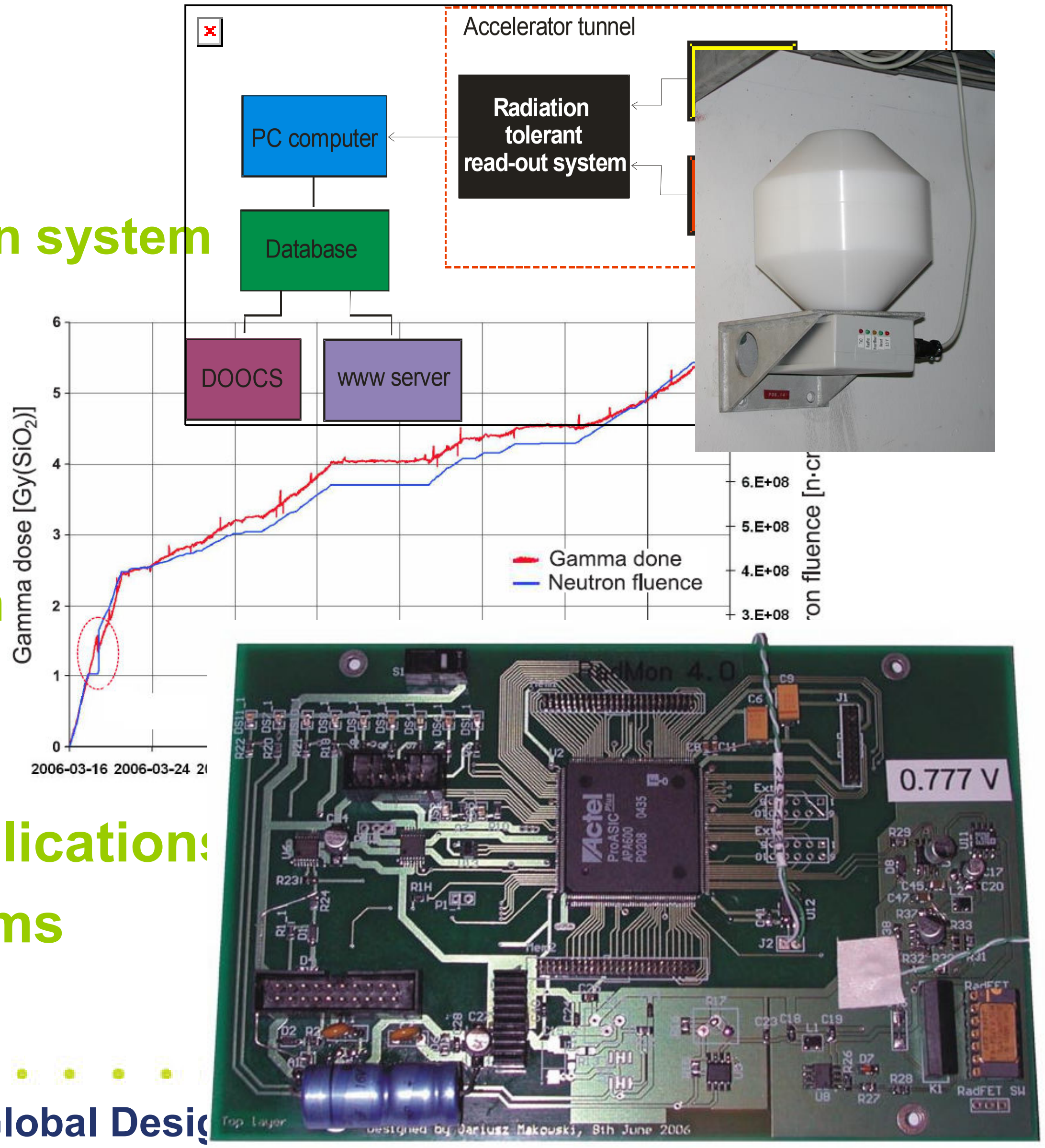

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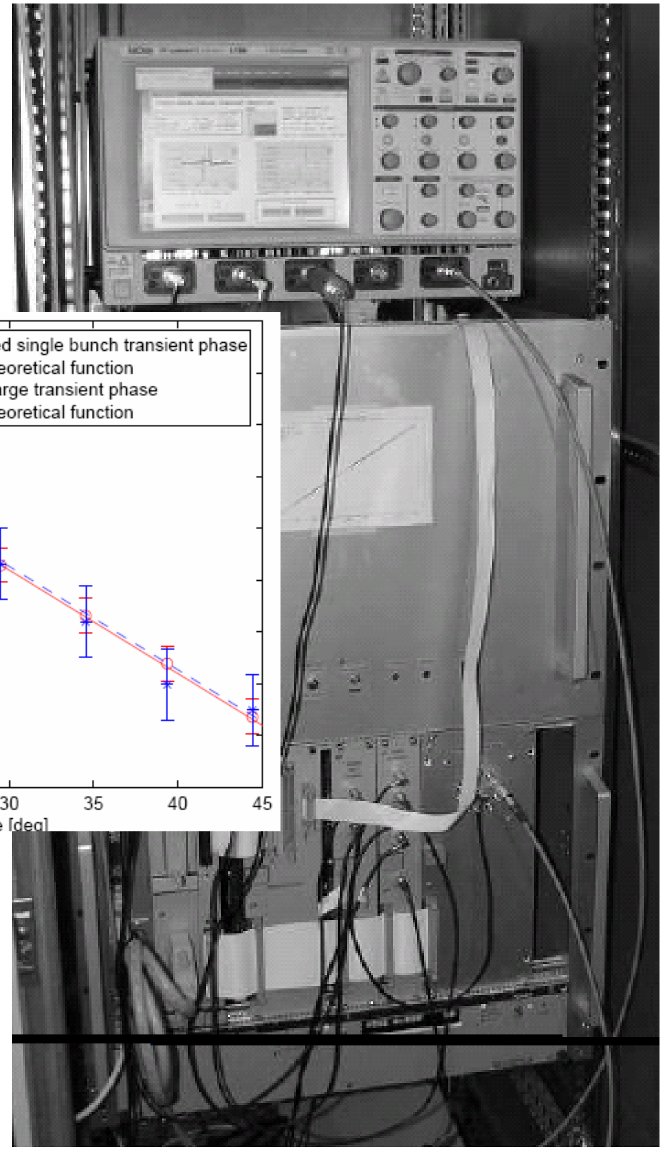

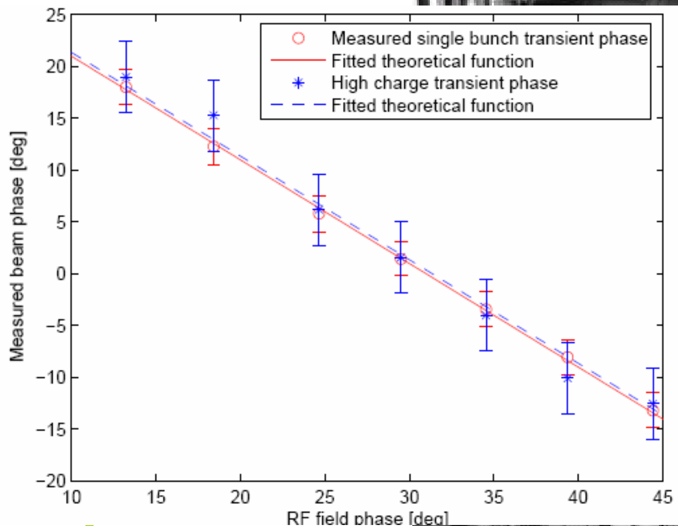

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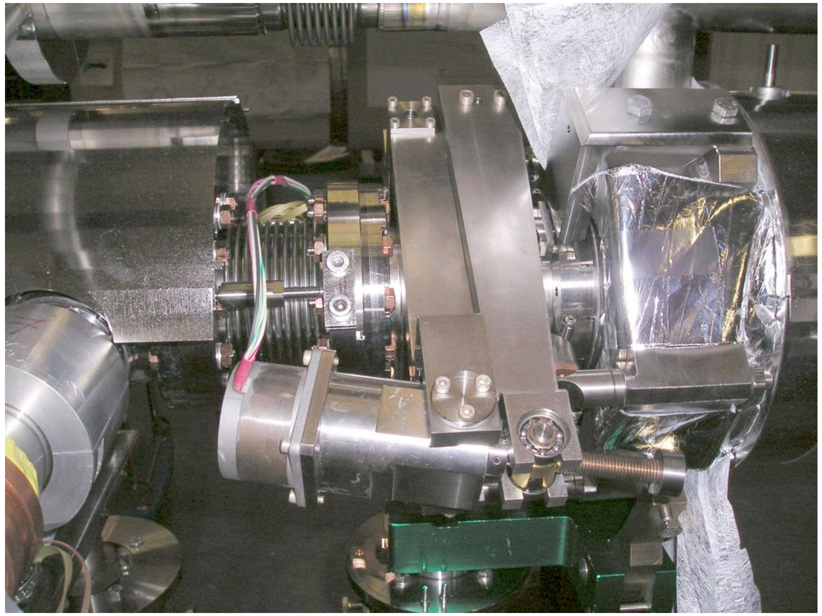
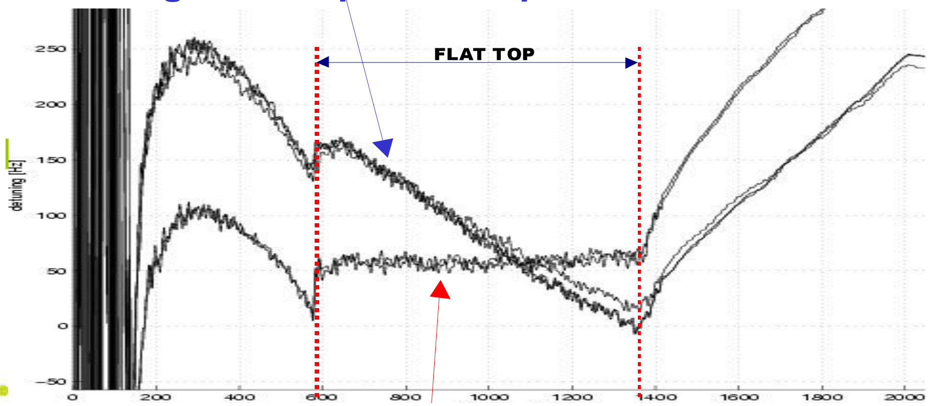


Detuning without piezo compensation ≈ 180Hz



Detuning with piezo compensation < 10Hz

Developments and achievements

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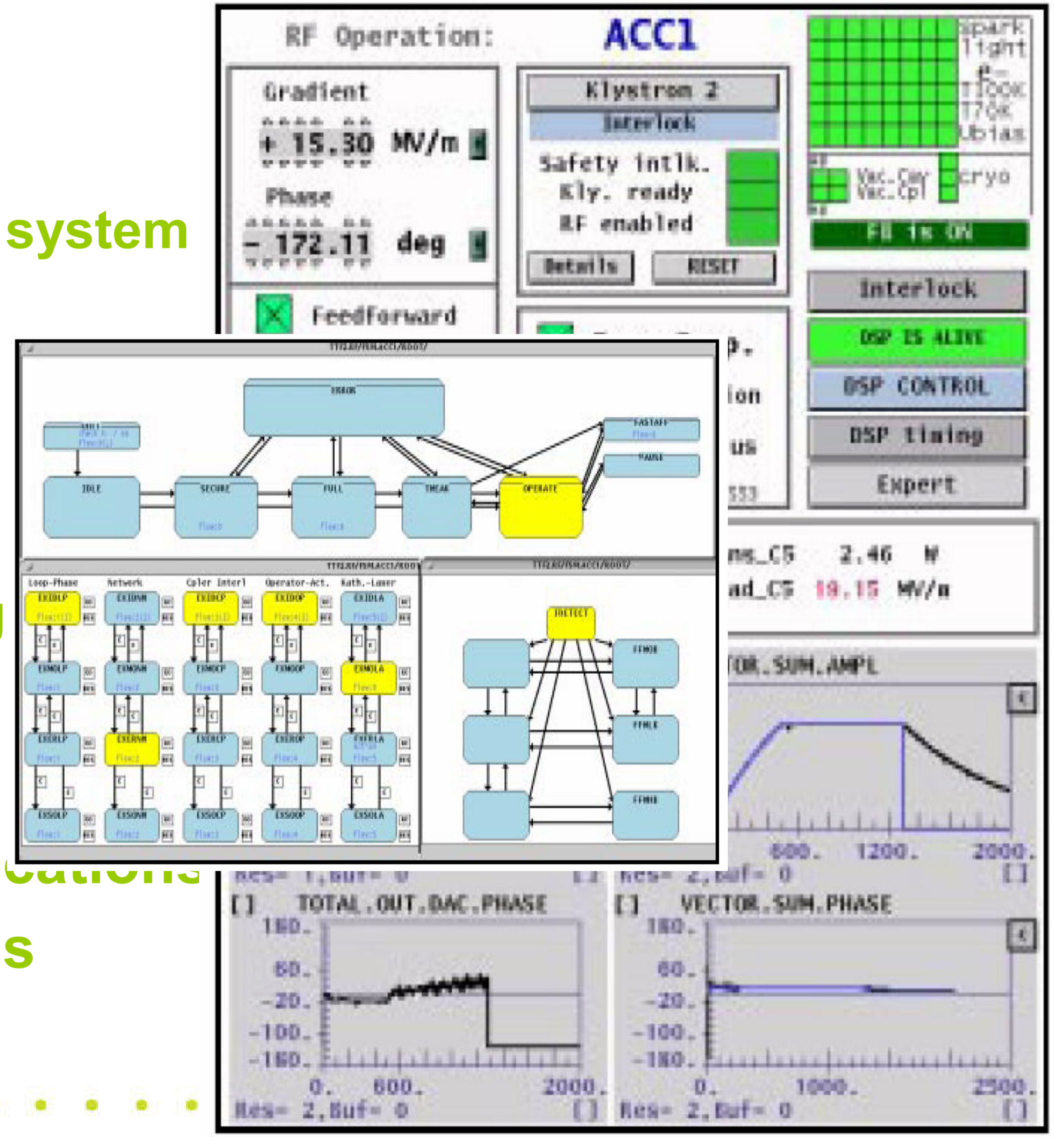

Developments and achievements

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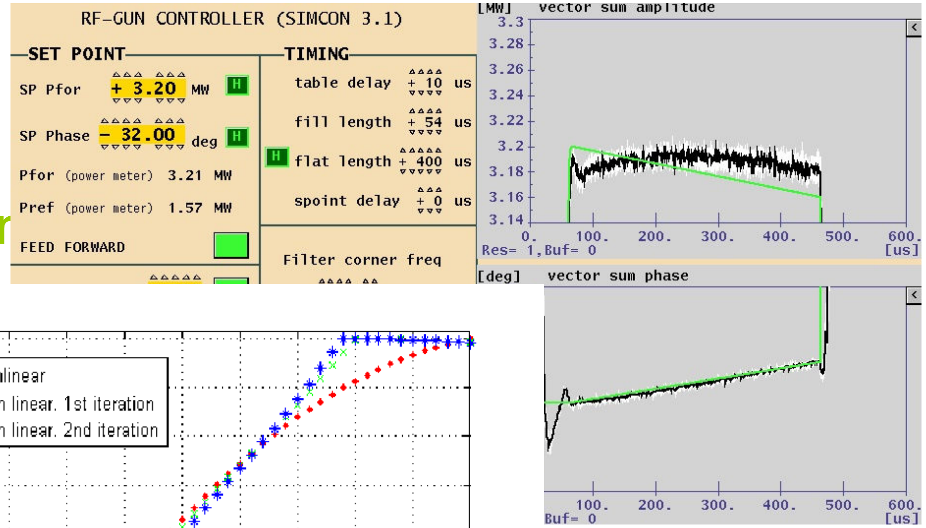

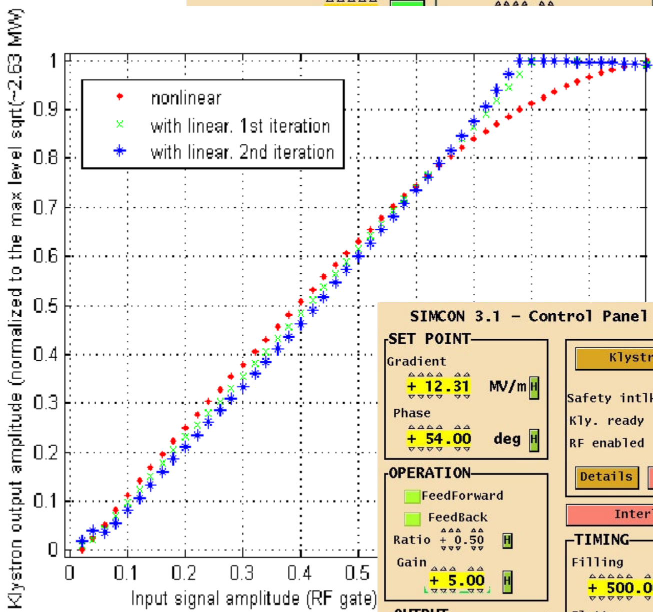

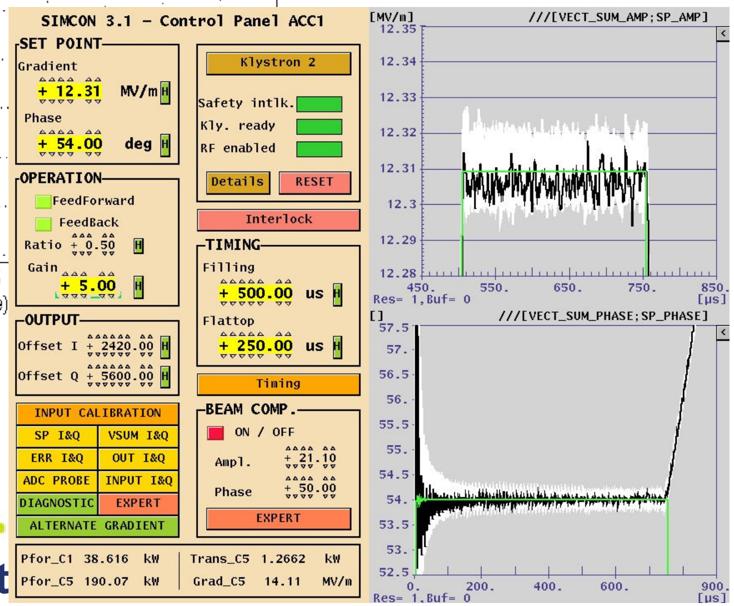

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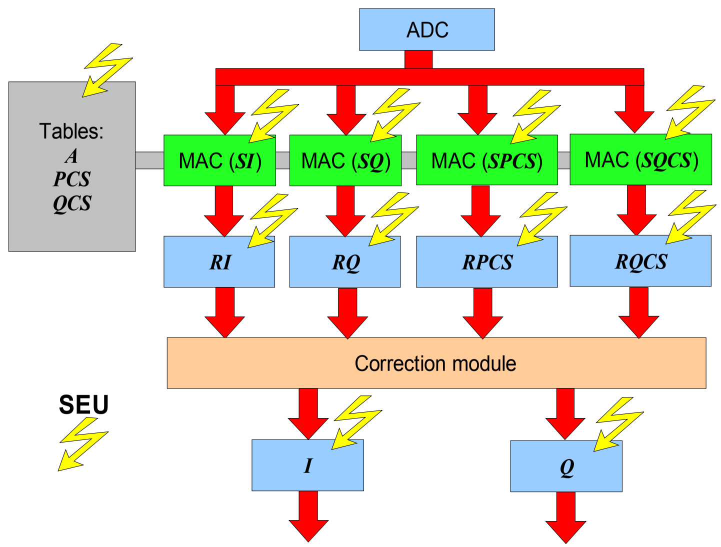
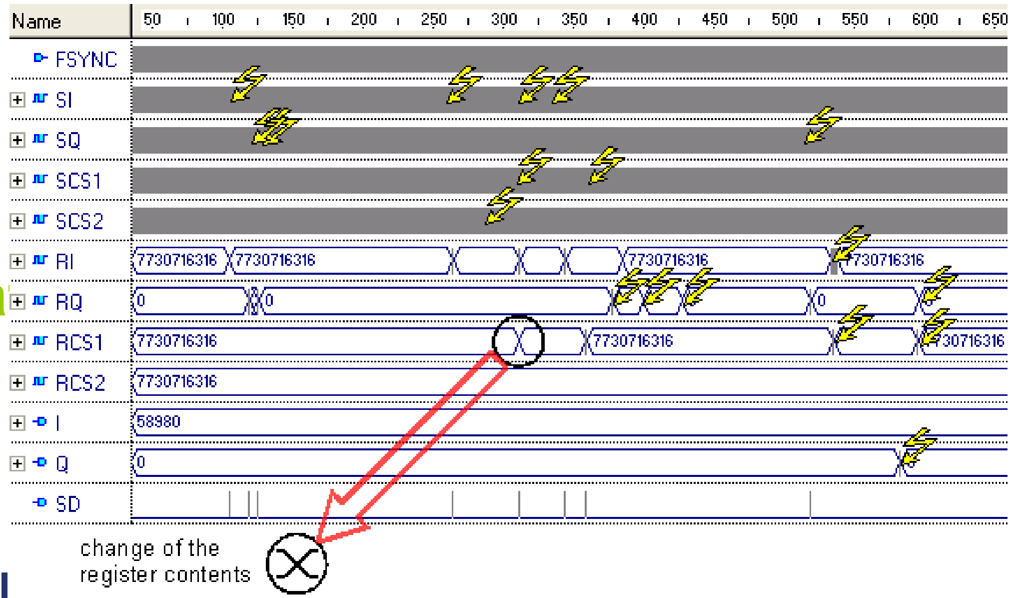


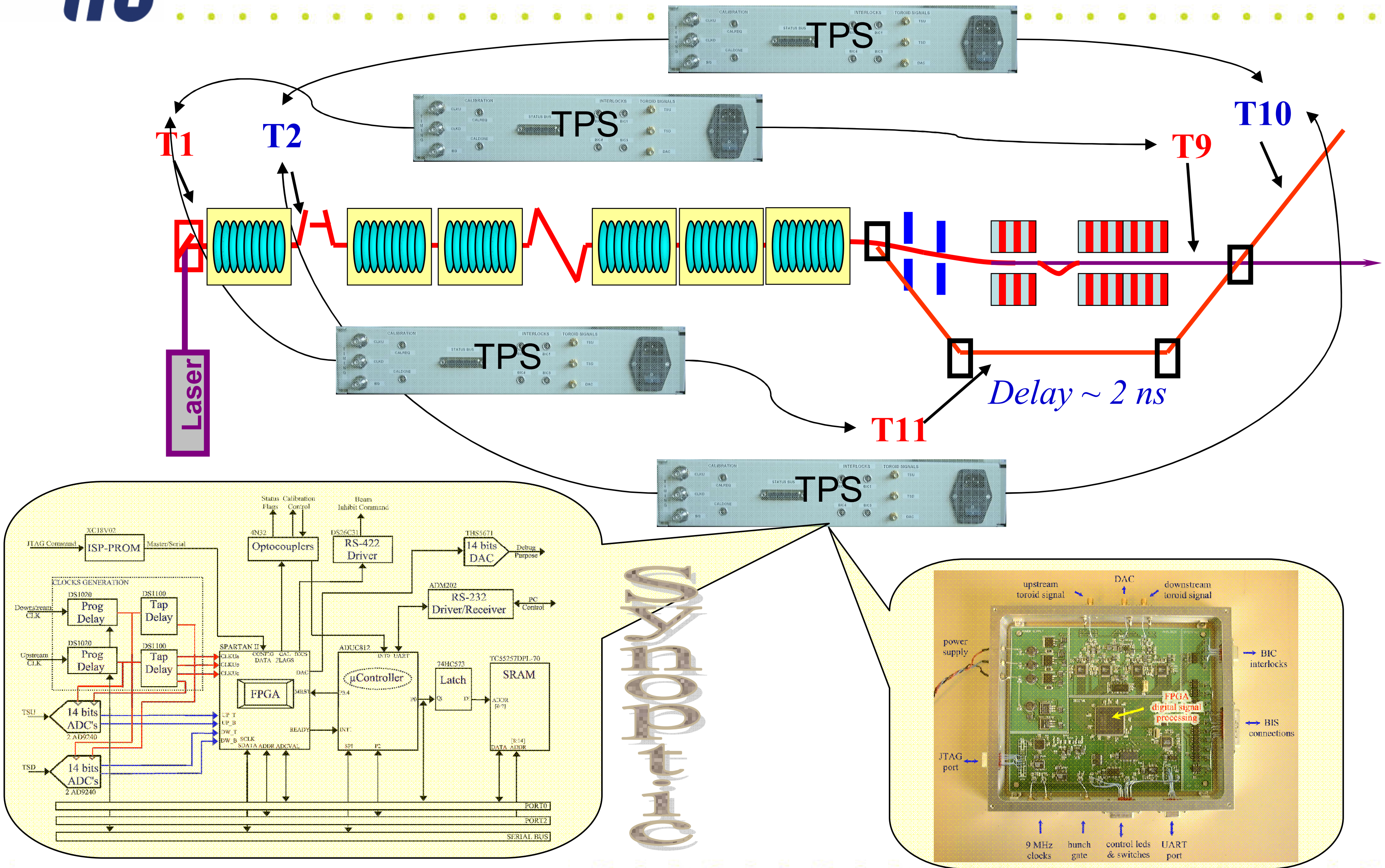


Machine Protection System at FLASH

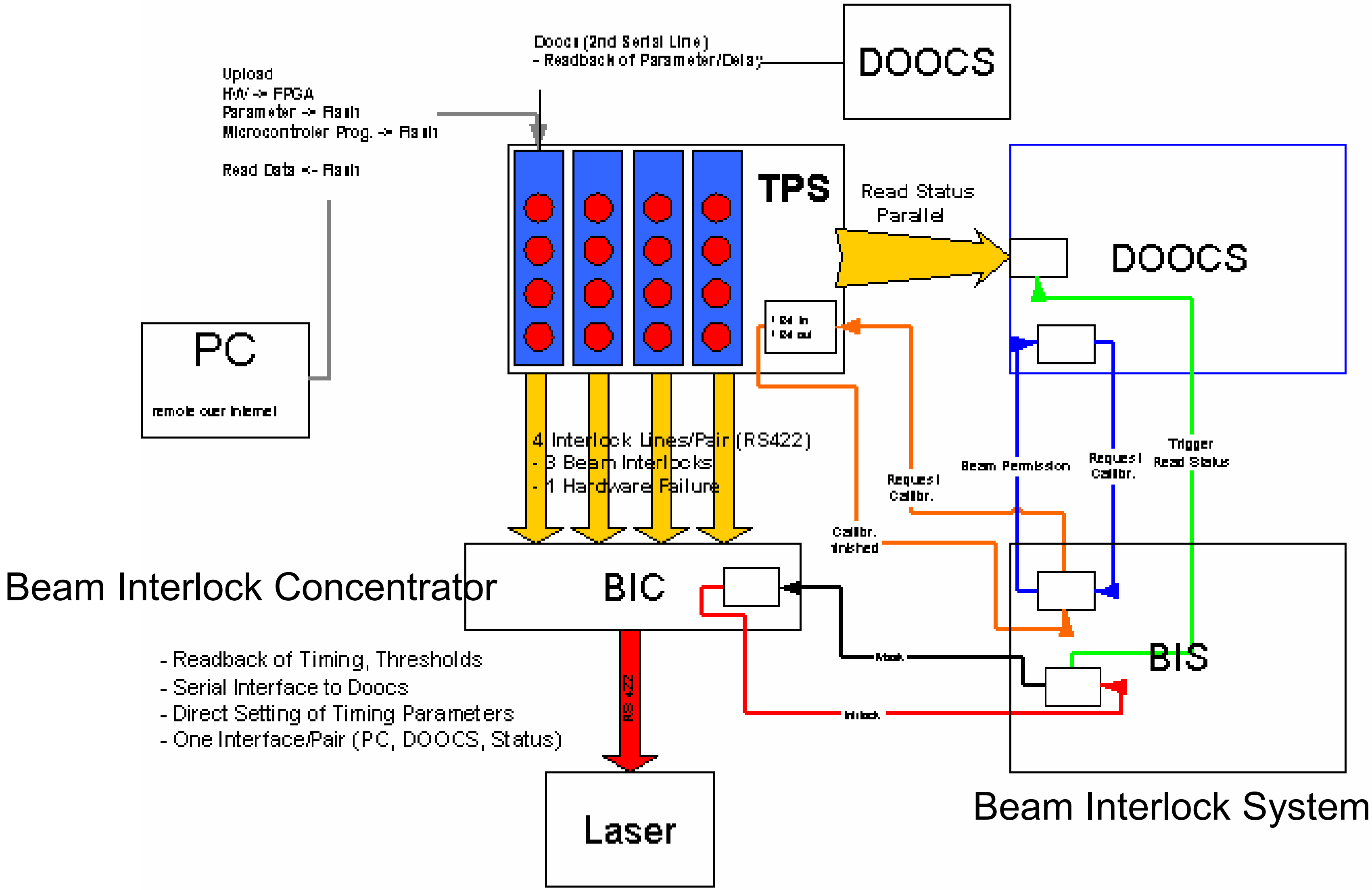
dapnia
cea
saclay

DESY

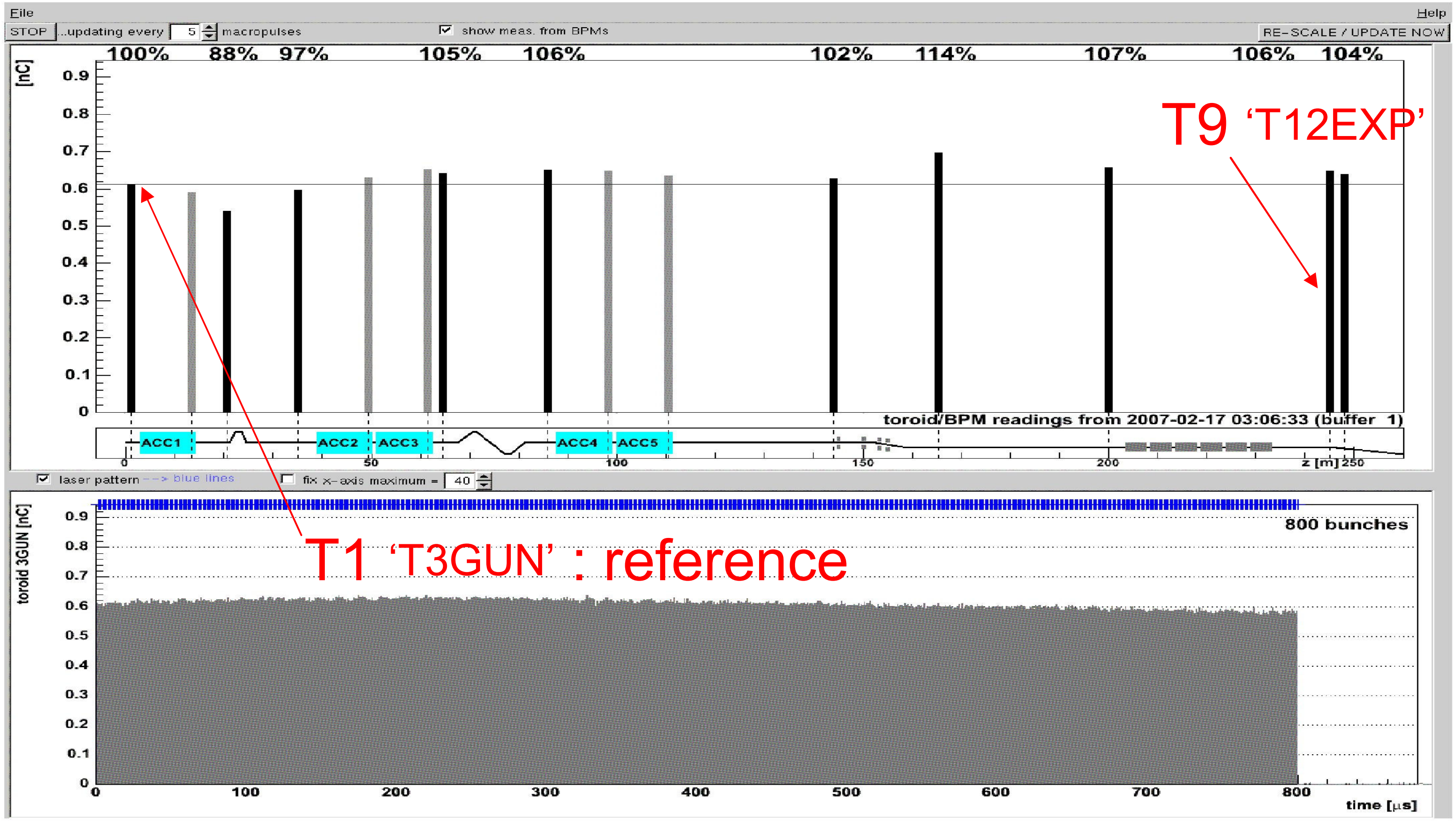
Toroid Protection Systems on FLASH



Interface with FLASH electronics



Bunch charge measurement on FLASH



• Hardware and software tested with all machine protection modes on the FEL beamline with up to 800 bunches (1MHz bunch frequency) during FEL studies - WK7 (16 February 2007)

Next steps

- Charge Thresholds instruction using the µController
- Improvement of Calibration procedure
- Commissioning of 2 racks simultaneously in Long Bunch Train) using :

  [T2(ACC1output),T10(dump)] +FEL beamline [T1(Gun),T9(Exp)]

  or

  [T2(ACC1output),T10(dump)] + Bypass [T1(Gun),T11(Byp)]

- Improvement of timing hardware

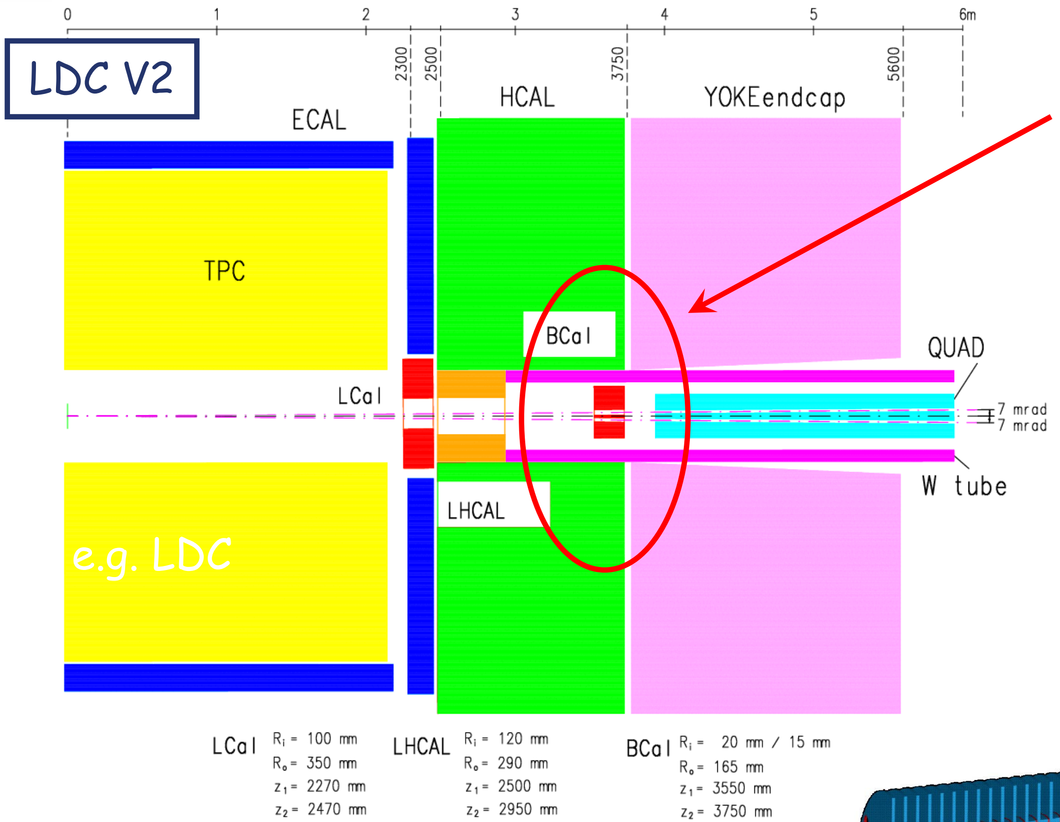
- *Manpower : Hamdi, Schreiber, Froehlich, Goerler*

Fast Luminosity Monitoring

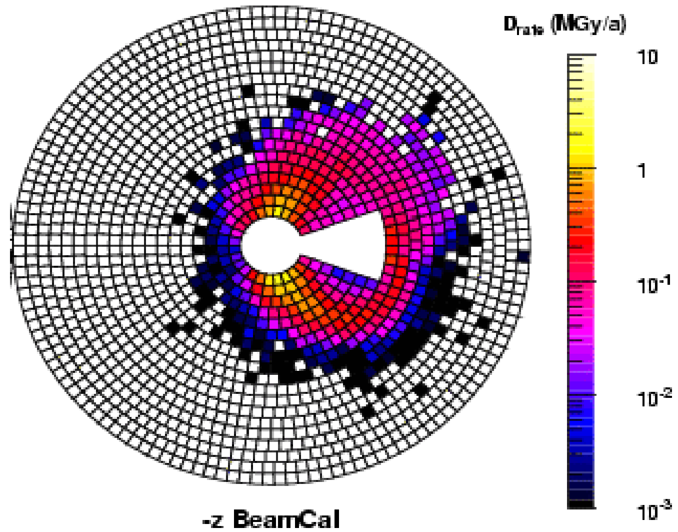
FCAL Collaboration
High precision design

DESY

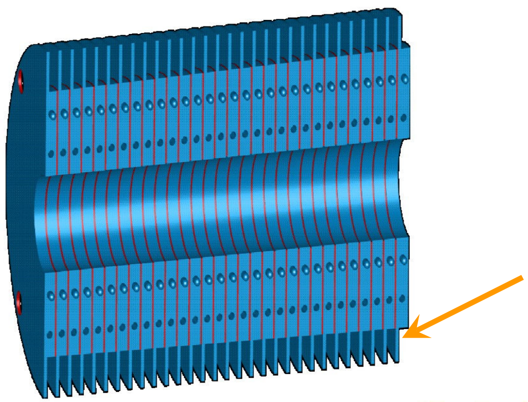
The Forward Region



BeamCal will be hit by a large amount of electron-positron pairs stemming from beamstrahlung.



BeamCal: sandwich em. calorimeter
Length = 30 X_0
3.5mm W + .5mm radiation hard sensors
~ 10^4 - 10^5 channels
~ 1.5 cm < R < ~10(+2) cm



Space for electronics

GamCal – Using Photon Information

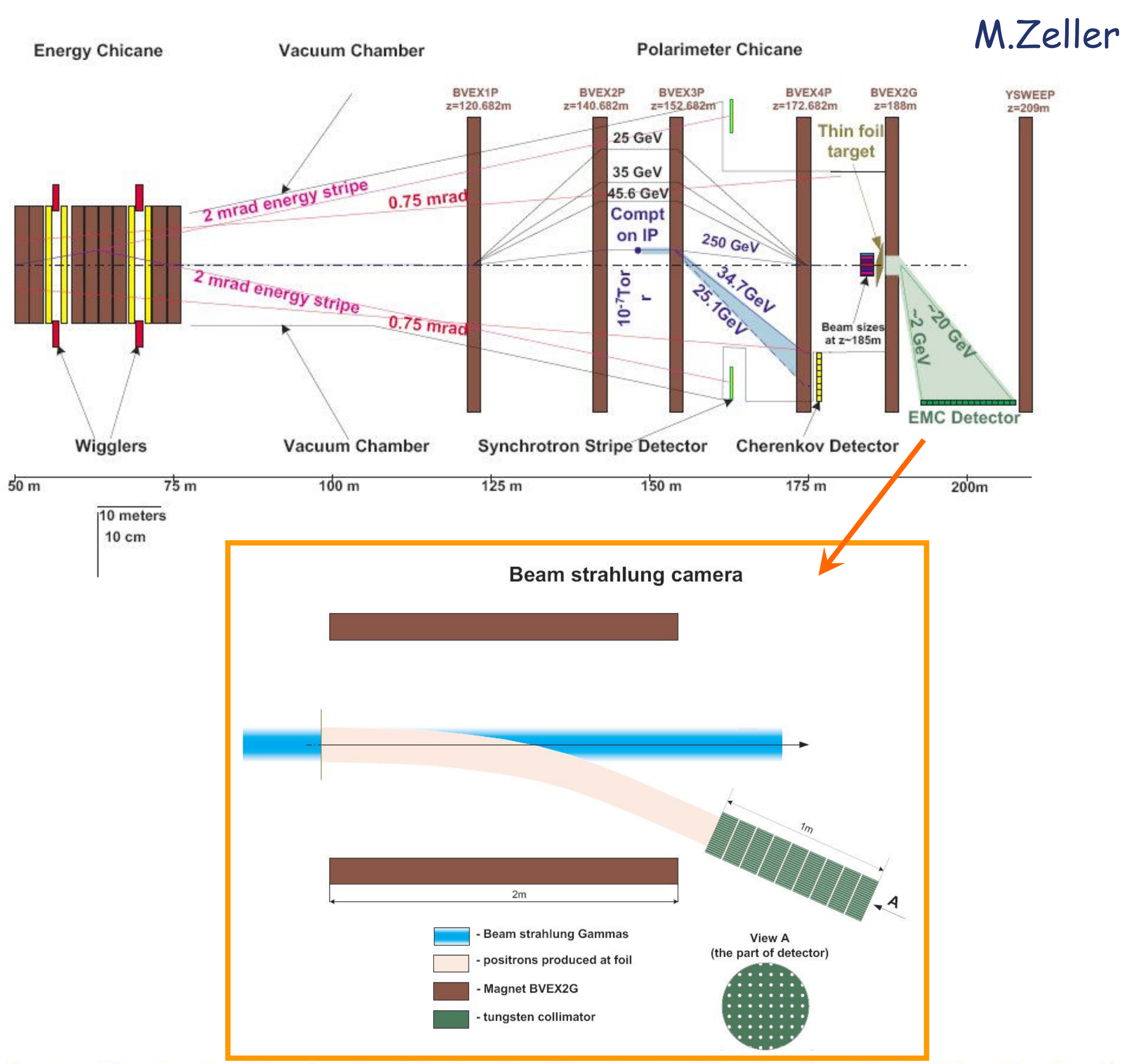
- Use as much information about the collision as possible!

➢ Define a robust signal proportional to the luminosity which can be fed to the feedback system!

➢ Investigate correlation to learn how we can improve the beamdiagnostics.

Diagram of the Energy Chicane and Polarimeter Chicane in the 14/20 mrad extraction line

M.Zeller

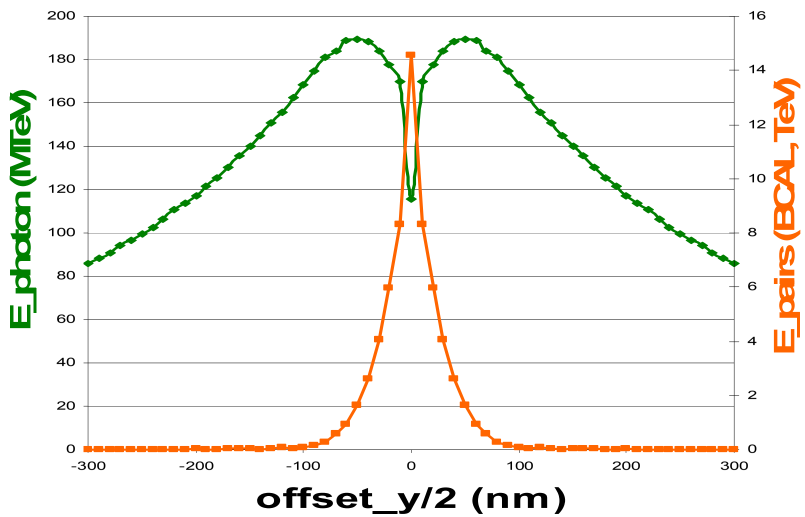


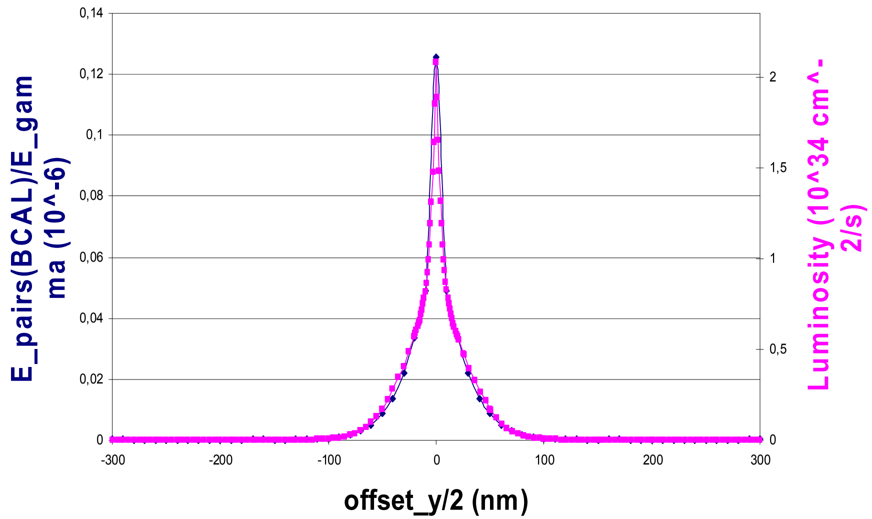
Fast Luminosity Monitoring

- 2 detectors essential for a fast luminosity feedback.
- BeamCal: physics reason: efficient low angle electron veto. Apart from this, BeamCal can:
  - **significantly improve L, e.g. by including the number of pairs hitting BeamCal in the feedback system**
  - **use more sophisticated algorithms to determine the parameters of the collision (beam sizes, emittances, offsets etc.)**
- The GamCal is a system measuring the energy of the beamstrahlung photons, located about 185m post IP.
  - **The beamstrahlung photon energy is a partly independent source of information about the collision.**
- Combining both measurements improves a luminosity feedback and help to distinguish beam parameter variations => example vertical offset

Vertical Offset (y-direction)

M.Ohlerich





complementary information from

1. total photon energy vs offset_y
2. BeamCal pair energy vs offset_y

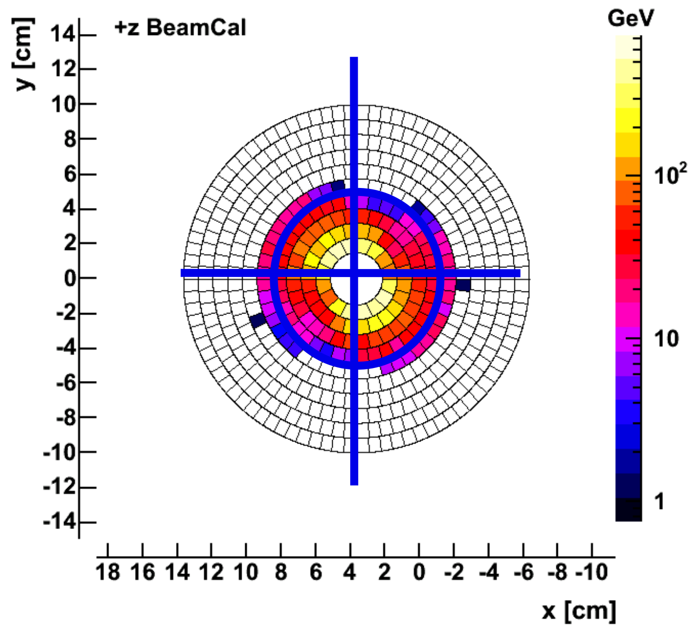
ratio of E_pairs/E_gam vs offset_y
is proportional to the luminosity

similar behaviour for
angle_y, waist_y, sigma_x, sigma_y, sigma_z

see also: EUROTeV-Memo-2006-011, LC-note in preparation

Beamparameter Reconstruction

- Define Observables (examples):
  - total energy
  - first radial moment
  - thrust value
  - angular spread
  - E(ring ≥ 4) / Etot
  - r-φ observables T1, T2
  - E / N
  - l/r, u/d, f/b asymmetries



			2mrad		14mrad antiDID	
Parameter	Unit	Nom.	μ	σ	μ	σ
σ_x	nm	655	653.42	1.95	653.89	2.27
σ_y	nm	5.7	5.208	0.371	5.395	0.229
σ_z	μm	300	300.75	4.56	299.83	4.11
ϵ_x	10^{-6}m rad	10	11.99	7.61	-	-
ϵ_y	10^{-9}m rad	40	40.41	1.29	40.72	1.19

Results from idealistic simulation and single parameter reconstruction. Correlations are an issue for multi-parameter Reconstruction.

Status of R&D

- The beam parameter reconstruction is investigated with a full Geant4 simulation.
  - **Investigate the possibility of using a reduced set of information (individual layers, clustering, digitization)**
- Radiation hard sensors are investigated
  - **Polycrystalline CVD diamonds, GaAs, radhard Si**
- Readout electronics are under develoment
- GamCal system is in the design phase