IP Instrumentation

Measurement of:

- **Luminosity (precise and fast)**
- **Energy**
- **Polarisation**

Wolfgang Lohmann,
DESY

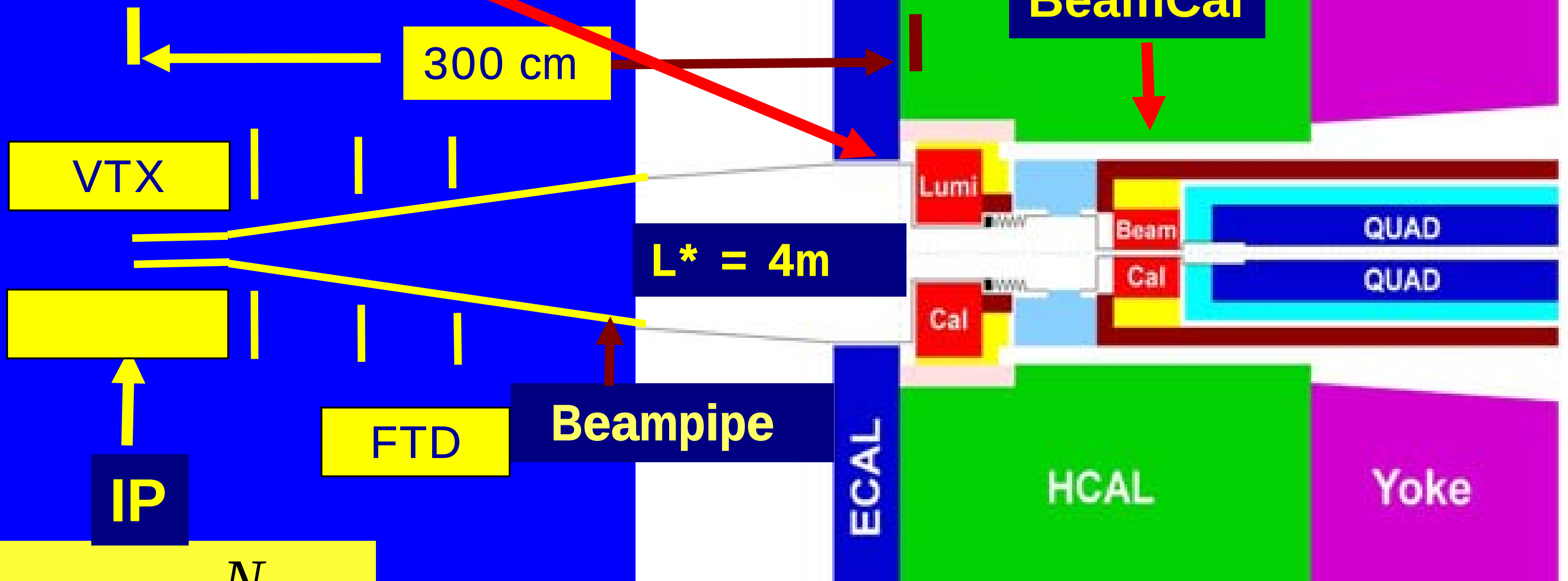
Precise Luminosity Measurement

Gauge process: Bhabha Scattering

$$e^+e^- \rightarrow e^+e^-$$

Device: LumiCal

$26 < \theta < 82$ mrad



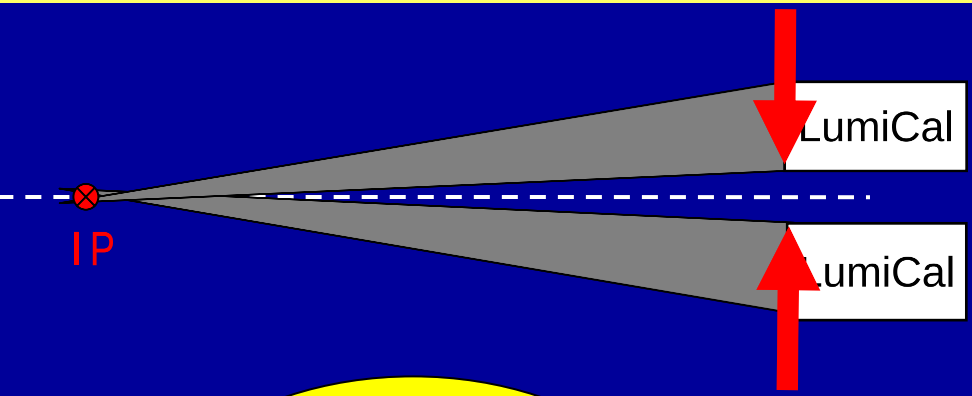
$$L = \frac{N_{LumCal} - N_{bgr}}{\varepsilon \ \sigma_{Bhabha}}$$

Accuracy (from Physics)
O(<10^{-3})

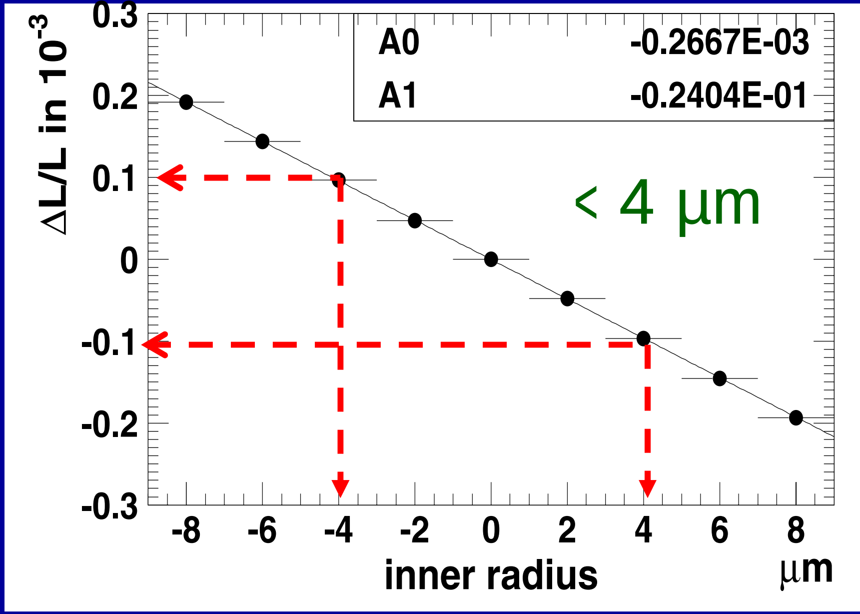
$(OPAL: \quad \Delta L / L = 3\times10^{-4}(stat) \oplus 5.4\times10^{-4}(theo))$

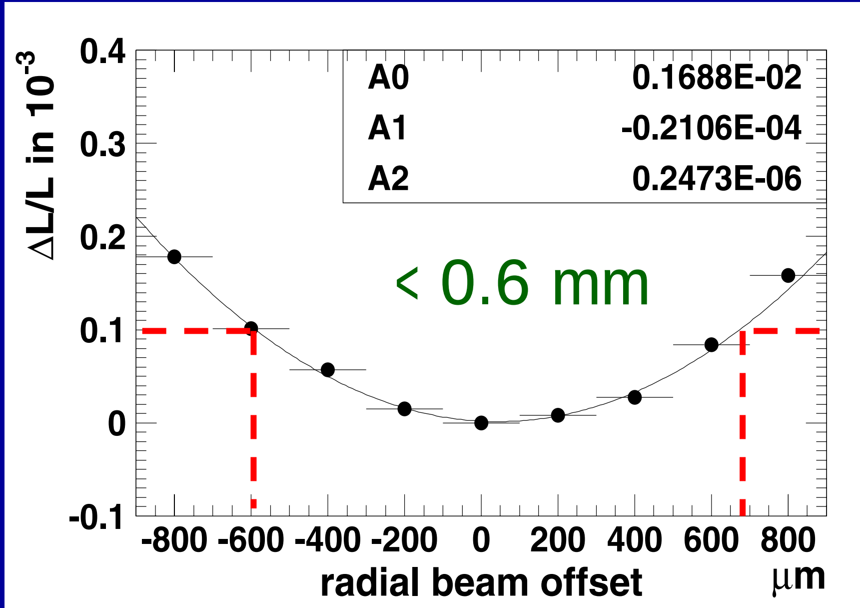
$(ALEPH: \Delta L / L = 6\times10^{-4}(stat) \oplus 6.1\times10^{-4}(theo))$

Requirements on the Mechanical Design



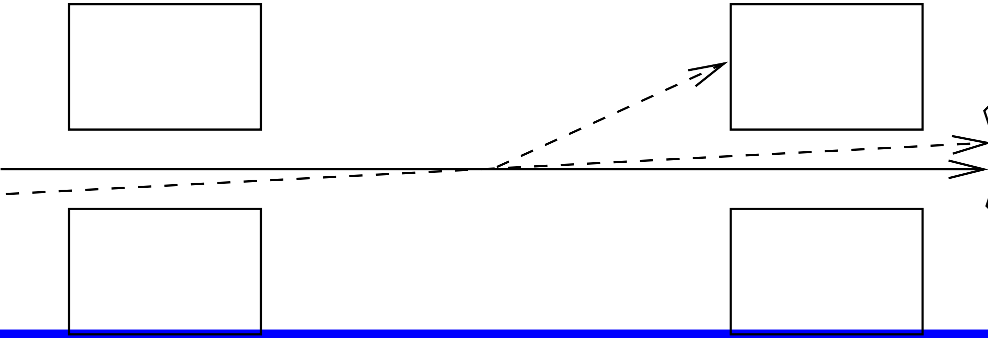
Requirements on Alignment and mechanical Precision (MC simulations, BHLUMI)

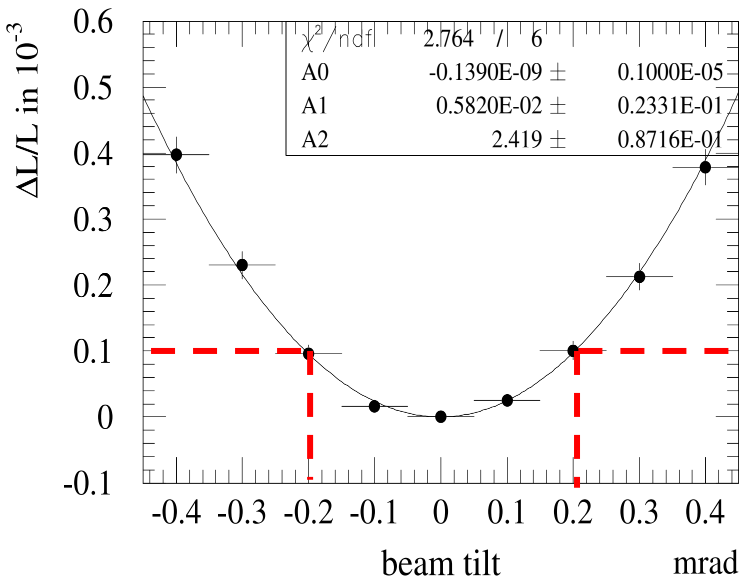




Inner Radius of Cal.:	**< 4 µm**
Distance between Cals.:	**< 100 µm**
Radial beam position:	**< 0.6 mm**

Beam Tilt

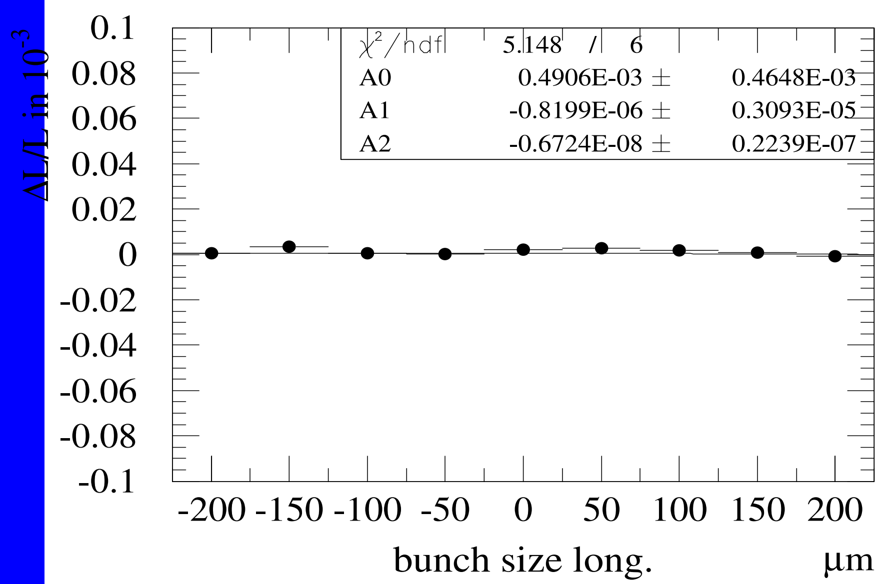




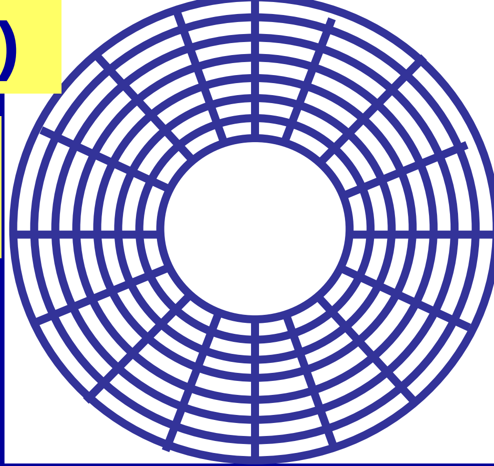
$$\frac{\Delta L}{L} \leq 10^{-4} \Rightarrow bmtilt \leq 0.2\,mrad$$

Beam Size

No effect



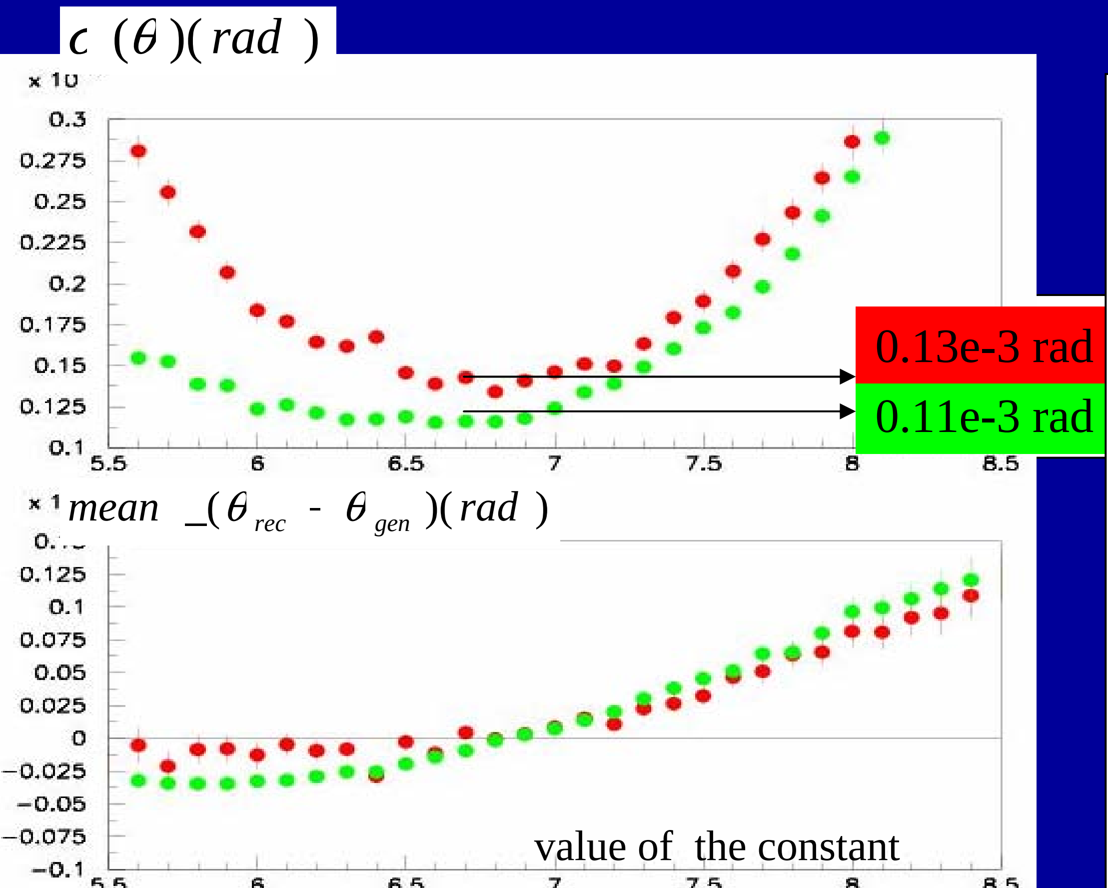
Performance Simulations for $e^+e^- \longrightarrow e^+e^-(\gamma)$

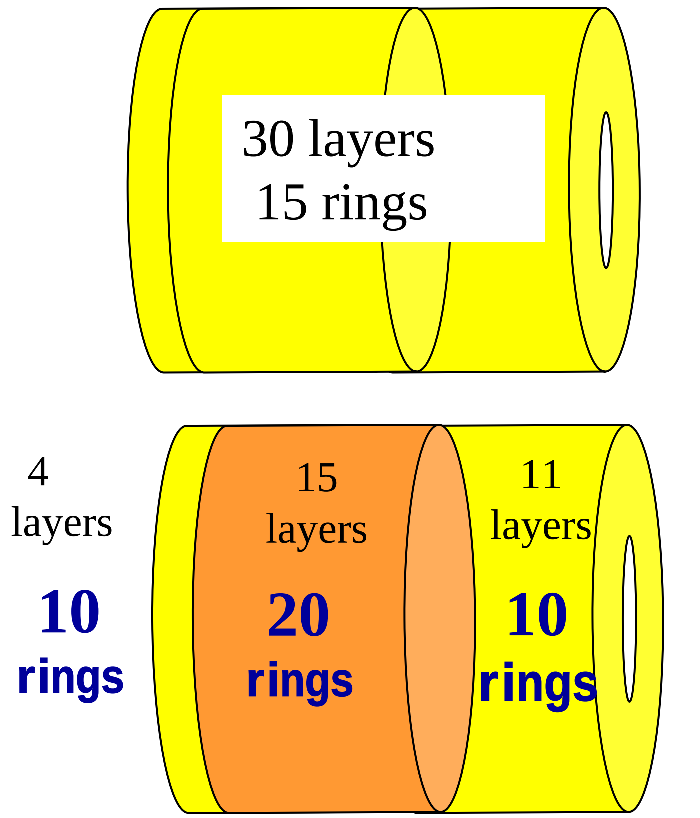


Simulation: Bhwide(Bhabha)+CIRCE(Beamstrahlung)+beamspread

Event selection: acceptance, energy balance, azimuthal and angular symmetry.

$$< X >= \frac{\sum X_i W_i}{\sum W_i} \qquad W_i = \max\{0,[const(E_{beam}) + \ln(\frac{E_i}{E_T})]\}$$

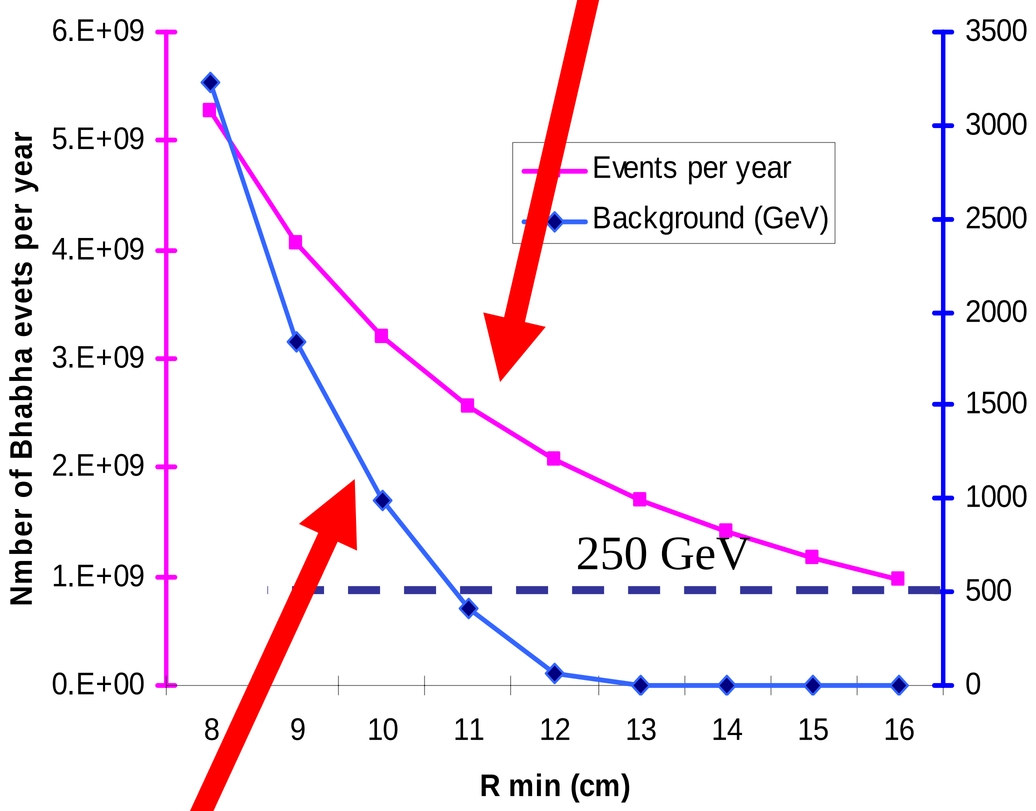




- More in the talks by Halina Abramowicz

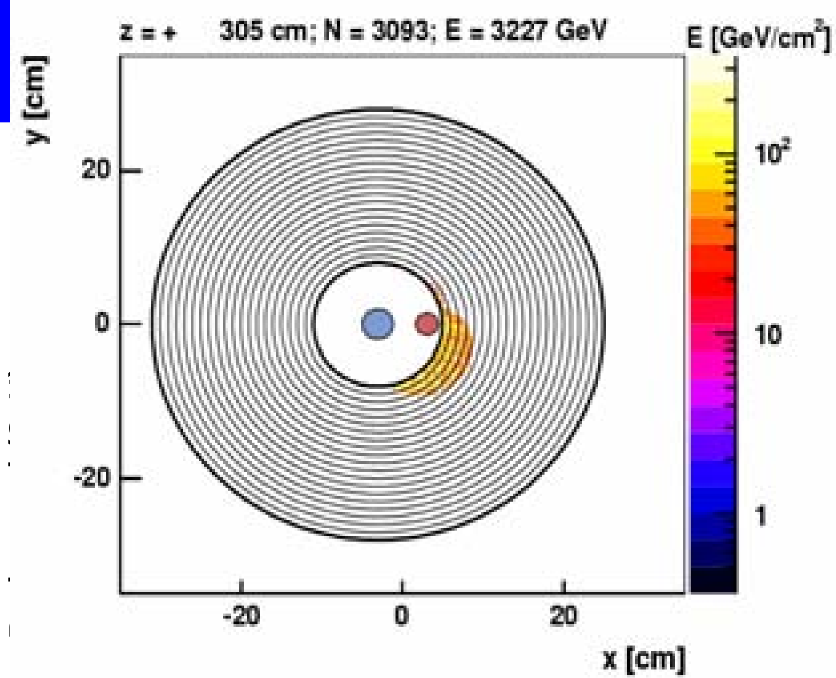
20 mrad crossing angle

Number of Bhabha events as a function of the inner Radius of LumiCal



Background from beamstrahlung

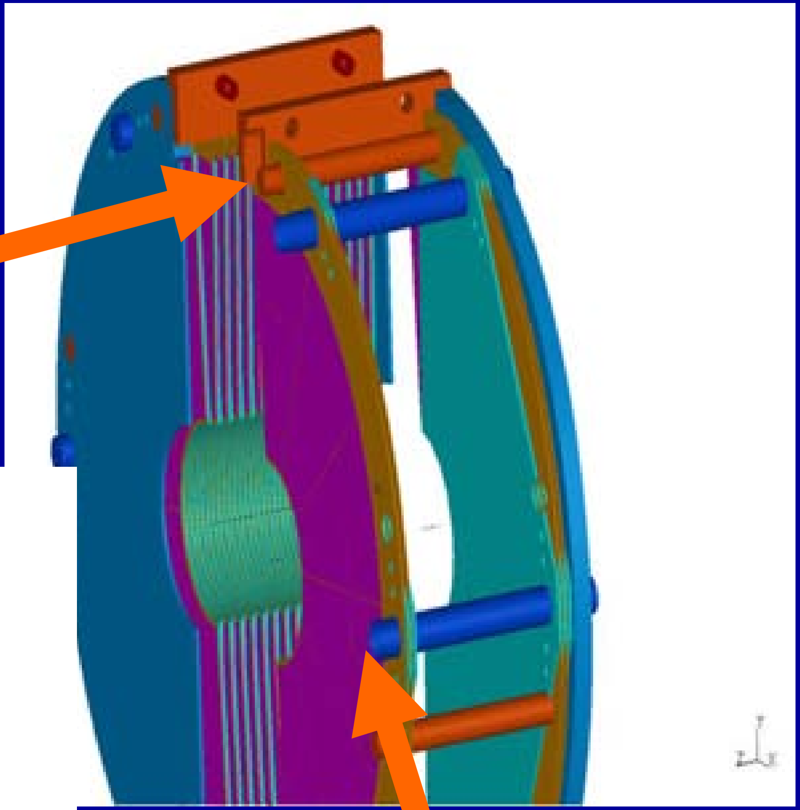
Beamstrahlung pair background using serpentine field

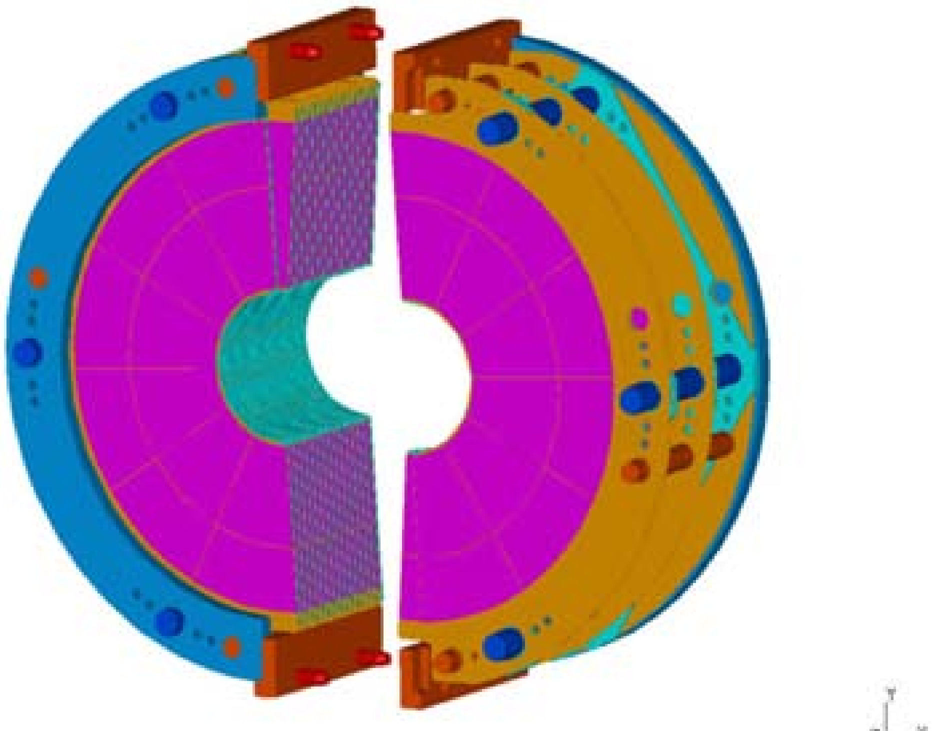


A design for 20 mrad crossing angle will be done (needs time)

Concept for the Mechanical Frame

Decouple sensor frame from absorber frame





Fast Lumi Measurement and Beam Diagnostics

Luminosity Monitor Studies for TESLA

Olivier NAPOLY
CEA, DSM/DAPNIA
CE-Saclay, F-91191 Gif-sur-Yvette Cedex, France

and

Daniel SCHULTE
CERN, PS/LP
CH-1211 Genève 23, Suisse

November 10, 1997

Use Electrons from Rad. Bhabha events

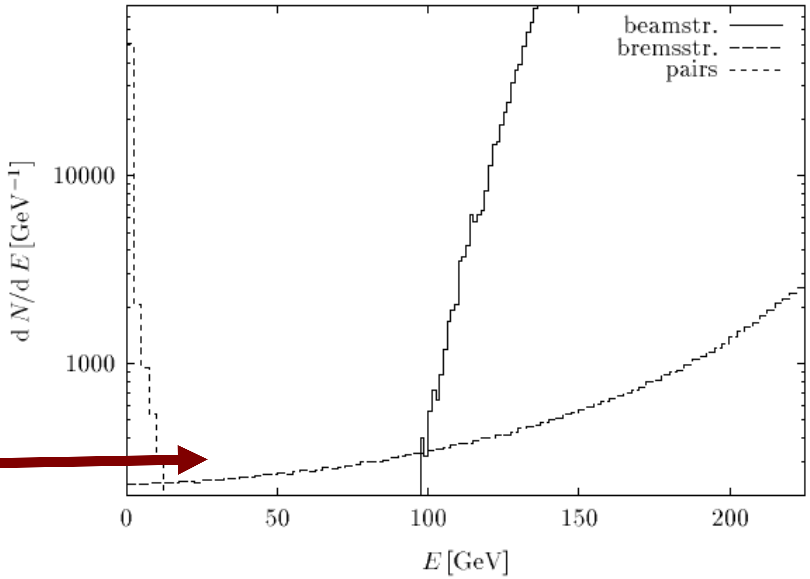


Figure 1: The energy spectrum of the particles due to pair production, bremsstrahlung and beamstrahlung for TESLA (500 GeV c.m.) parameters.

Fast Lumi Measurement and Beam Diagnostics

Trajectories of off momentum electrons in the first dublett

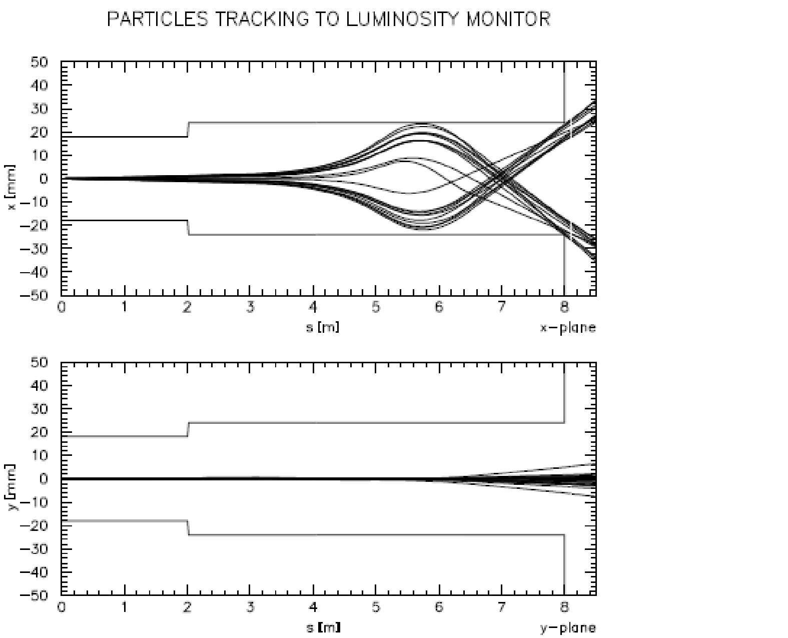


Figure 3: Trajectories from the IP hitting the luminosity monitor at 8.5 m

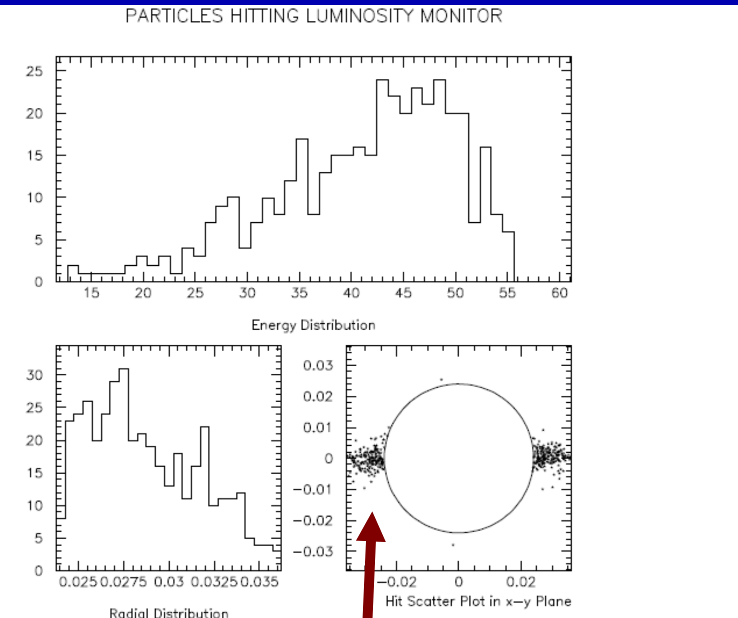
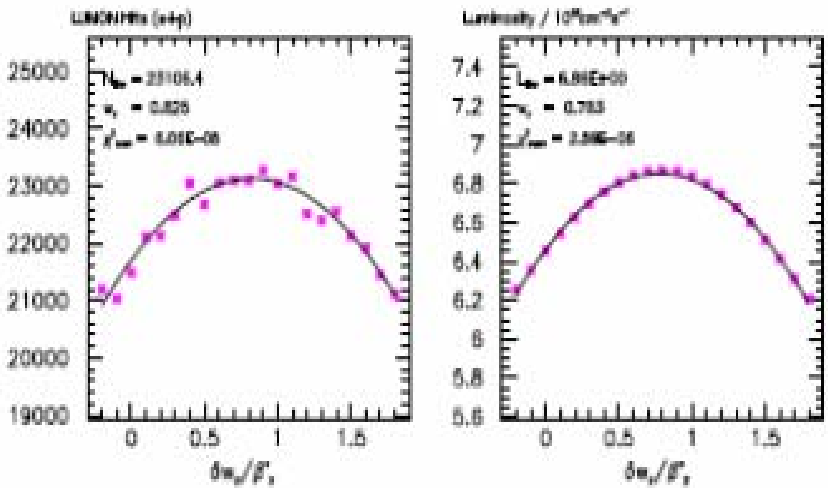


Figure 4: Energy and transverse distributions of the bremsstrahlung particles hitting the luminosity monitor for a single bunch crossing

Energy and spatial distributions

Needs a spectrometer there

Fast Lumi Measurement and Beam Diagnostics



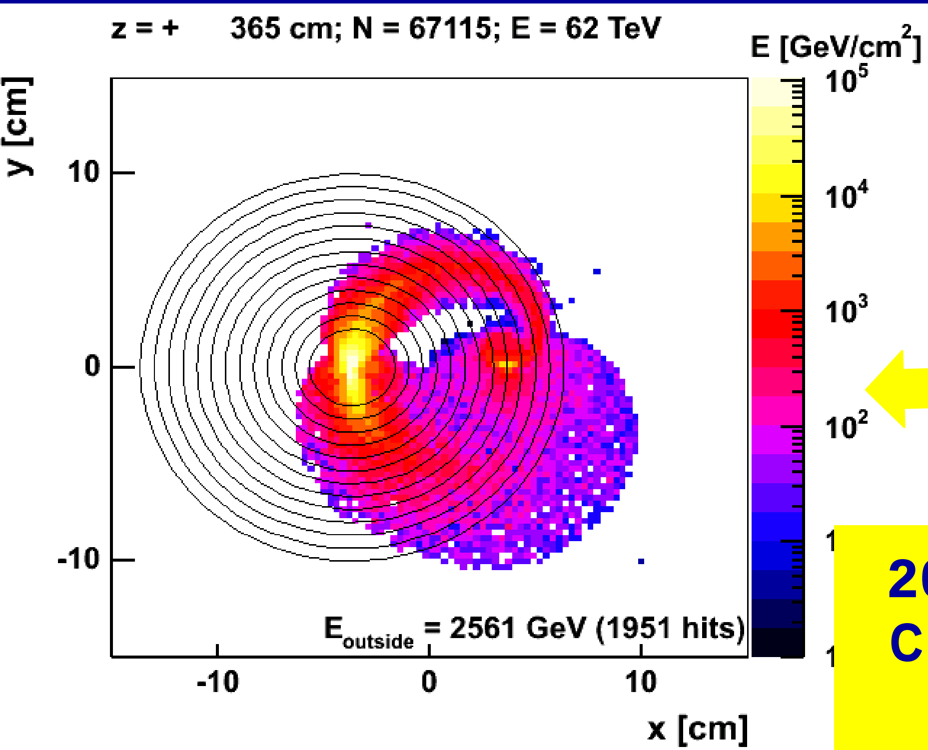
•Total hits in Lumi Cal and corresponding calculated Luminosity for an IP Beam Waist scan.

	Waist	Dispersion	Coupling
e^--hits	$2.0 \cdot 10^{-5}$	$2.3 \cdot 10^{-5}$	$3.1 \cdot 10^{-6}$
e^+-hits	$5.1 \cdot 10^{-4}$	$3.6 \cdot 10^{-4}$	$1.7 \cdot 10^{-5}$
$(e^- + e^+)$-hits	$1.7 \cdot 10^{-4}$	$4.8 \cdot 10^{-5}$	$1.5 \cdot 10^{-6}$
e^--energy	$2.3 \cdot 10^{-5}$	$5.4 \cdot 10^{-5}$	$2.6 \cdot 10^{-7}$
e^+-energy	$4.5 \cdot 10^{-4}$	$4.0 \cdot 10^{-4}$	$2.8 \cdot 10^{-5}$
$(e^- + e^+)$-energy	$1.6 \cdot 10^{-4}$	$3.6 \cdot 10^{-5}$	$8.3 \cdot 10^{-6}$

•Relative dL/L precision in determining optimal luminosity for various scans.

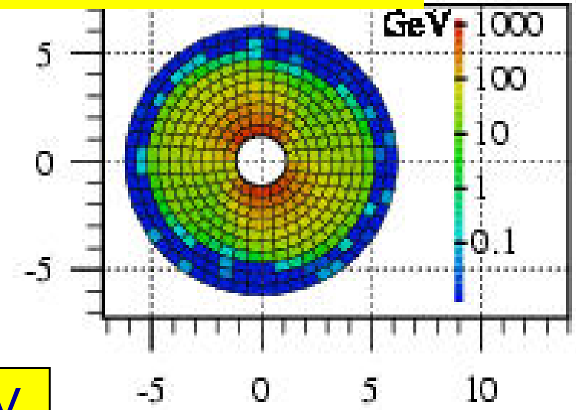
Beam Parameter Determination with BeamCal

- e^+e^- Pairs from Beamstrahlung are deflected into the BeamCal
- 15000 e^+e^- per BX ⟶ 10 – 20 TeV (10 MGy per year)
- direct Photons for θ < 200 μrad

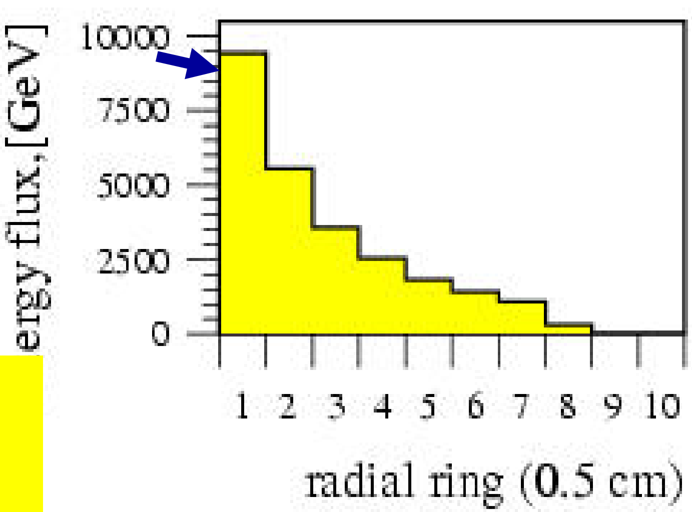


20 mrad Crossing angle

Zero (or 2 mrad) crossing angle



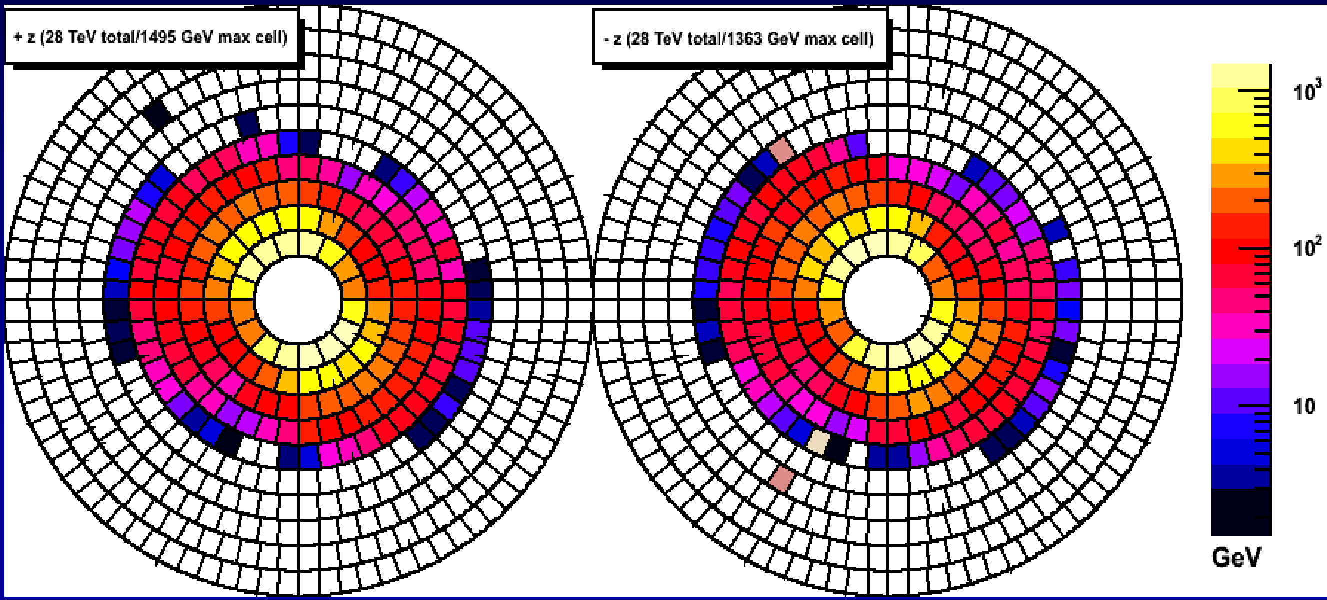
GeV



Beam Parameter Determination with BeamCal

Observables

total energy
first radial moment
thrust value
angular spread
L/R, U/D F/B
asymmetries



Quantity	Nominal Value	Precision
σx	553 nm	1.2 nm
σy	5.0 nm	0.1 nm
σz	300 μm	4.3 μm
Δy	0	0.4 nm

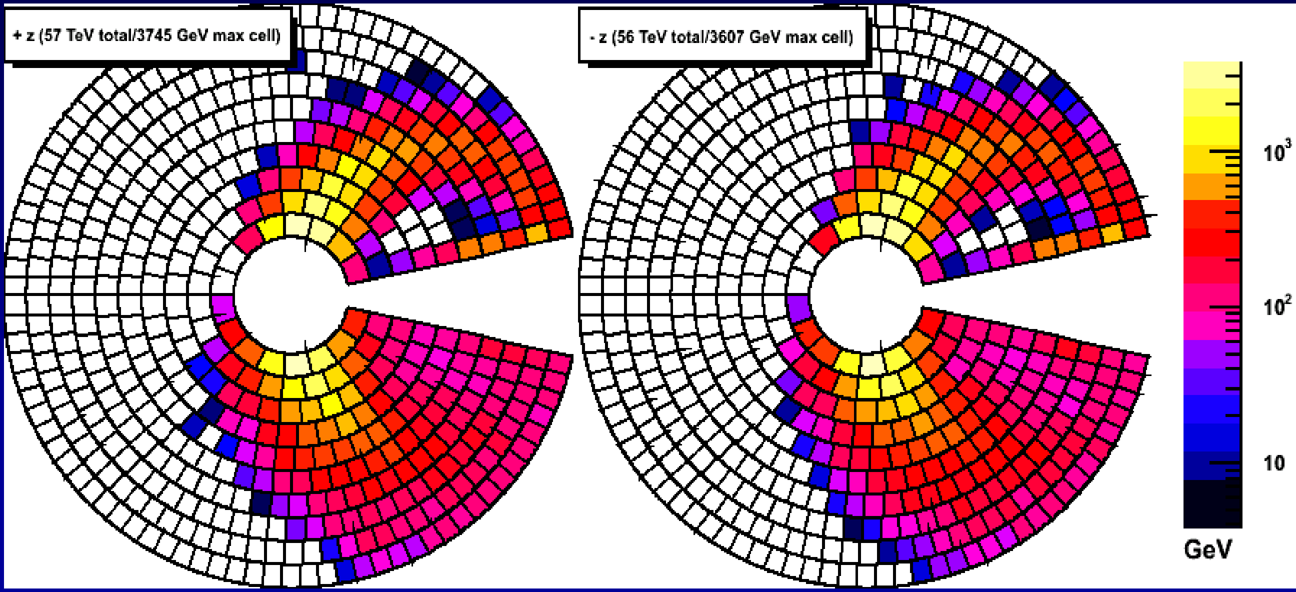
$\sqrt{s}$ = 500 GeV

zero or 2 mrad Crossing angle

Beam Parameter Determination with BeamCal

Observables

total energy
first radial moment
thrust value
angular spread
L/R, U/D F/B
asymmetries



Quantity	Nominal Value	Precision
σx	553 nm	4.8nm
σy	5.0 nm	0.1 nm
σz	300 μm	11.5 μm
Δy	0	2.0nm

20 mrad crossing angle

Also simultaneous determination of several beam parameter is feasible, but: Correlations! Analysis in preparation

PRELIMINARY!

Beam Parameter Determination with BeamCal

$$x = [x_1, x_2, \ldots. x_n]'$$

$$x^* = x_{Design}$$

$$f^n(x) = \text{observable n for x vector}$$

$$f^n(x^*) = \text{observable n for x}^* \text{ design vector}$$

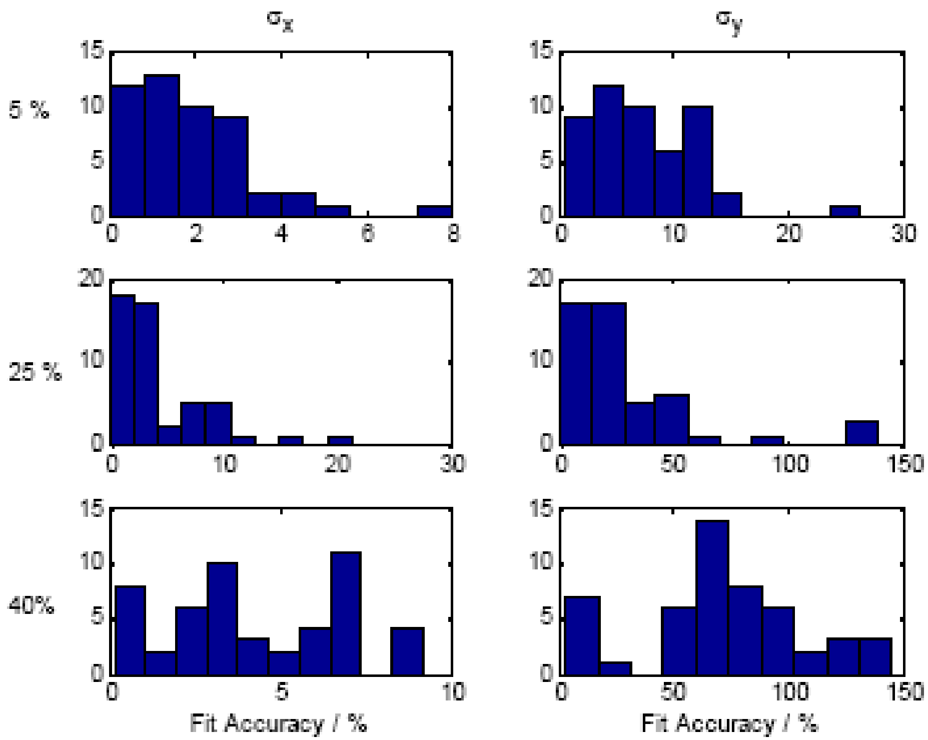
$$f^n(x) = f^n(x^*) + (x - x^*)' \, div.[f^n(x^*)] + \frac{1}{2}(x - x^*)' \widetilde{A}(x - x^*) + \ldots$$

$$\widetilde{A} = \begin{bmatrix} \frac{\partial^2 f}{\partial x_1^2} & \frac{\partial^2 f}{\partial x_1 \partial x_2} & . & \frac{\partial^2 f}{\partial x_1 \partial x_n} \\ \frac{\partial^2 f}{\partial x_2 \partial x_1} & . & . & . \\ . & . & . & . \\ \frac{\partial^2 f}{\partial x_n \partial x_1} & . & . & \frac{\partial^2 f}{\partial x_n^2} \end{bmatrix}$$

- Compute Taylor matrices through multiple GP runs varying beam params-> use Grid computing at QM to do in finite time (Generate full matrix elements for first and second order terms, and diagonal only elements up to 9th order).
- For parameter reconstruction: Solve x for given f(x) using multi-parameter fit. Unique solution not guaranteed- choice of fit technique is important.

Beam Parameter Determination with BeamCal

Test of Fitting With Realistic Observable Errors



Best Accuracy from lowest Fit Chi-Squared

2.8% 11.5%

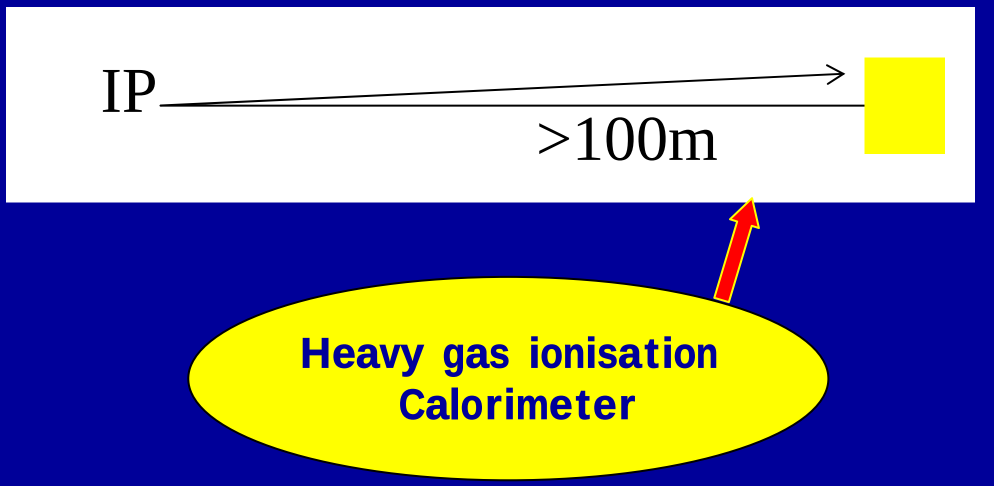
0.3% 0.9%

0.14% 2.7%

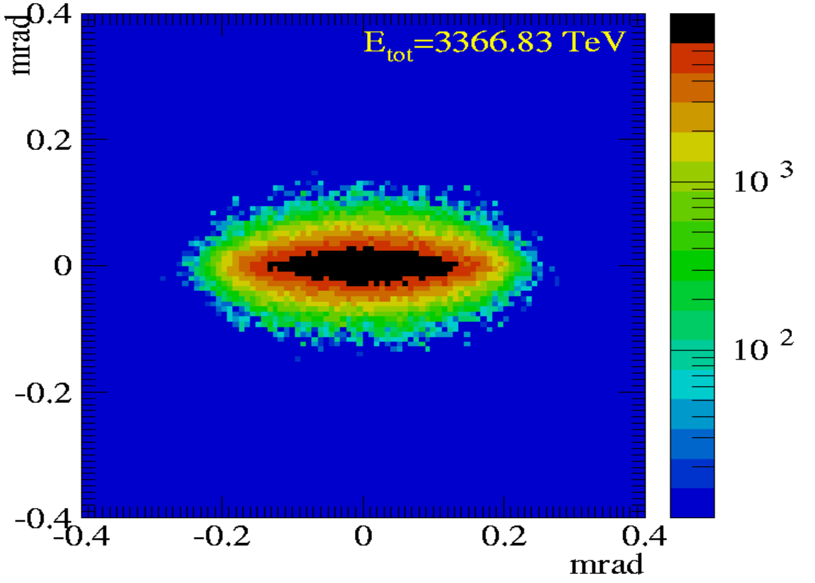
- Using Advanced Multi-Parameter non-linear fitting algorithm (Sequential Quadratic Programming Method) with 10-parameter fit (x ,y, x', y' and z IP sigmas).
- Fitter confused by errors, but averaging over 50 bunches, get above results by choosing best fit chi-squared.

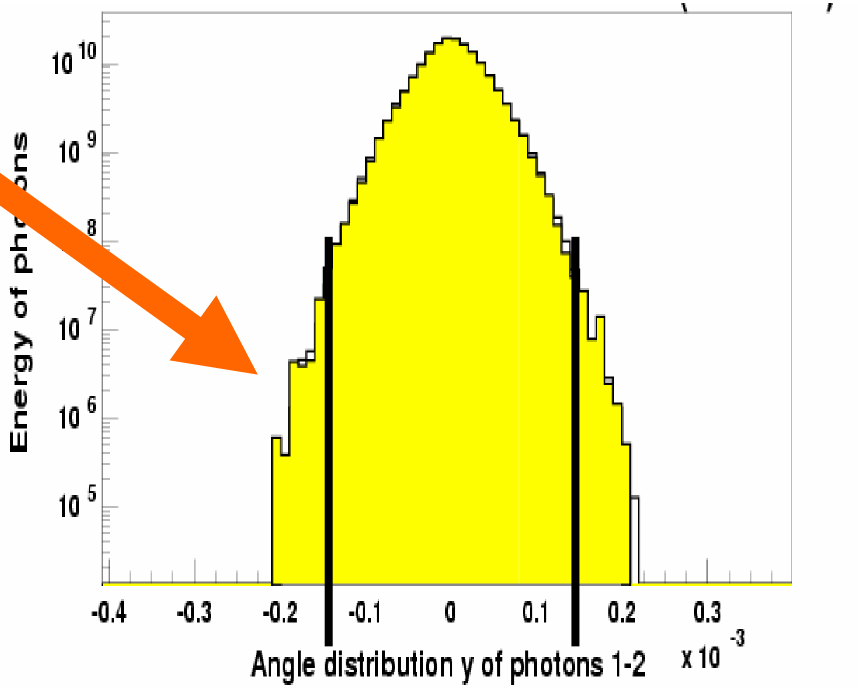
and with PhotoCal

Photons from Beamstrahlung



L/R, U/D F/B asymmetries of energy in the angular tails



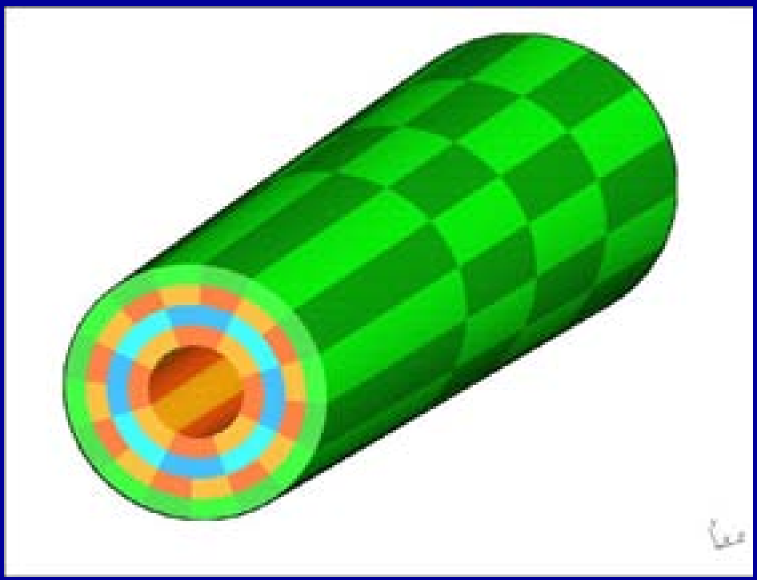


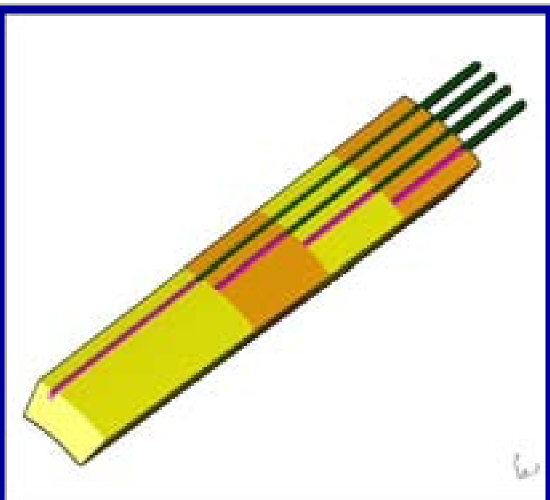
Quantity	Nominal Value	Precision
σx	553 nm	4.2 nm
σz	300 µm	7.5 µm
Δy	0	0.2 nm

Technologies for the BeamCal:

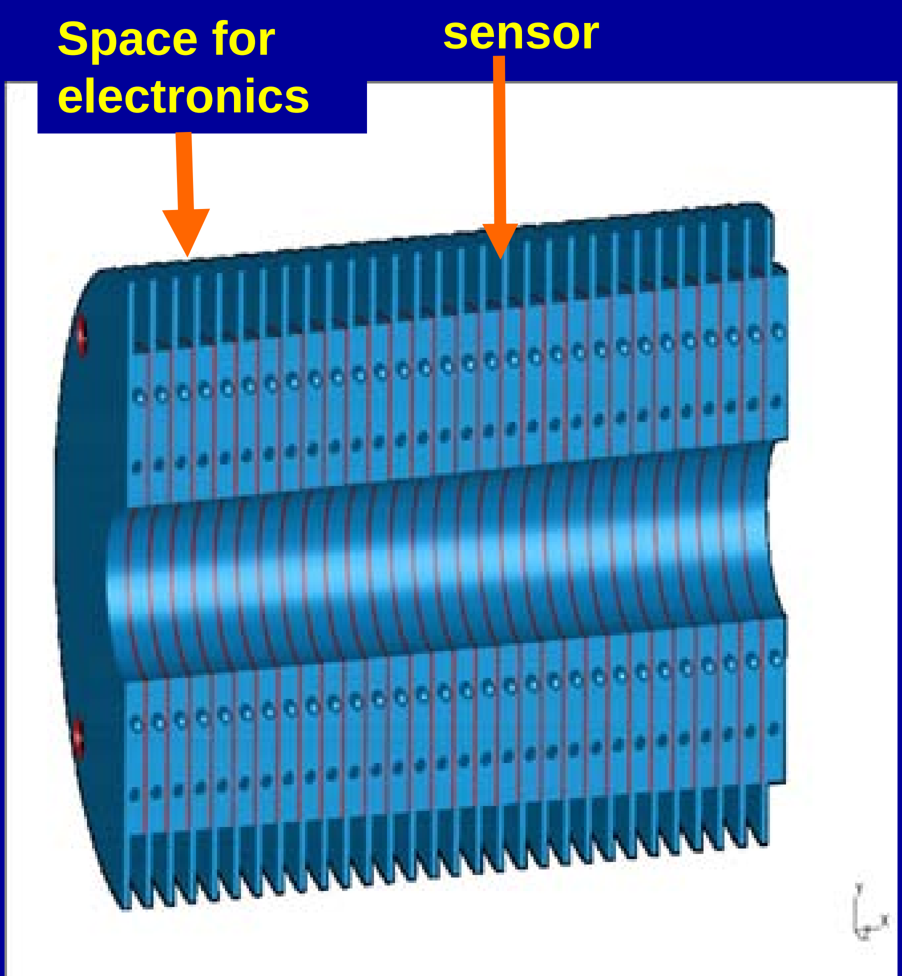
- Radiation Hard
- Fast
- Compact

Heavy crystals





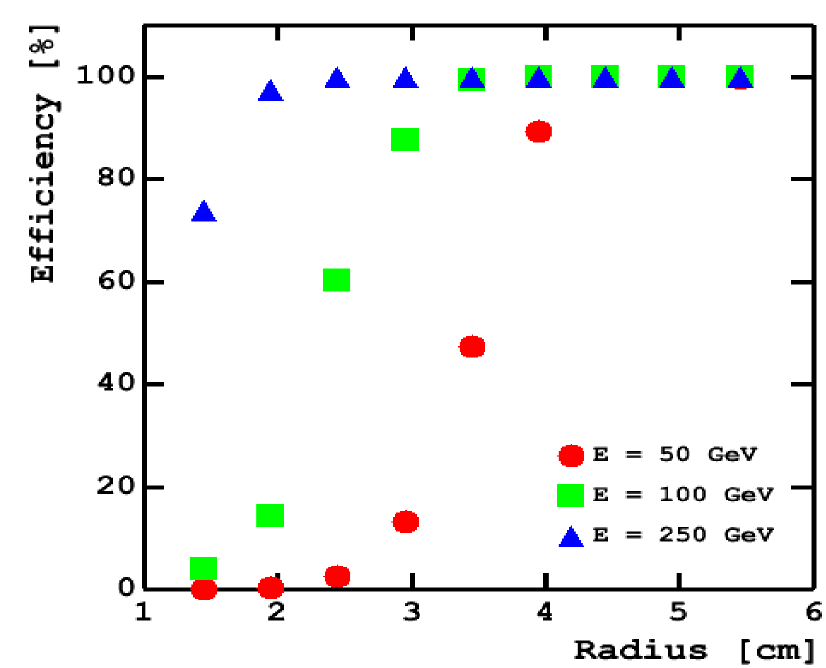
W-Diamond sandwich



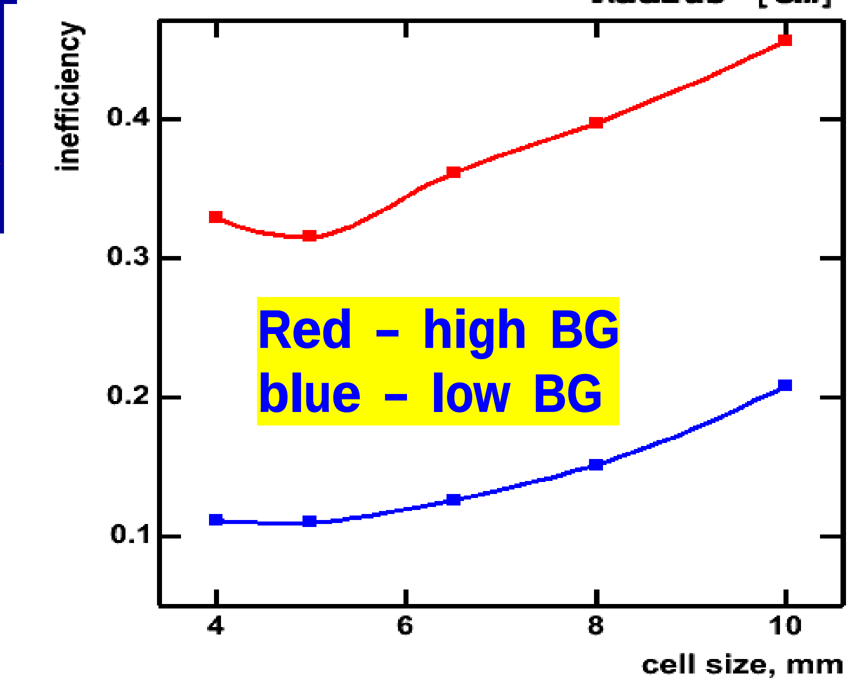
Detection of High Energy Electrons and Photons (Detector Hermeticity)

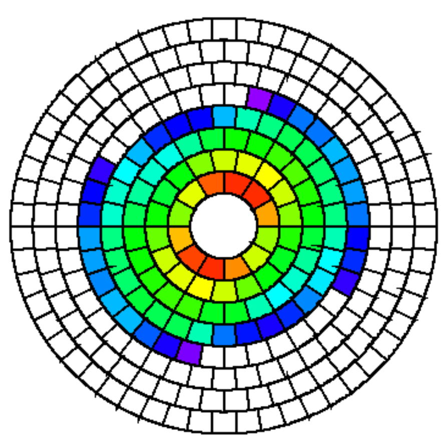
√s = 500 GeV

Single Electrons of 50, 100 and 250 GeV, detection efficiency as a function of R (‘high background region’) (talk by V. Drugakov and P. Bambade)



Detection efficiency as a function of the pad-size (Talk by A. Elagin)

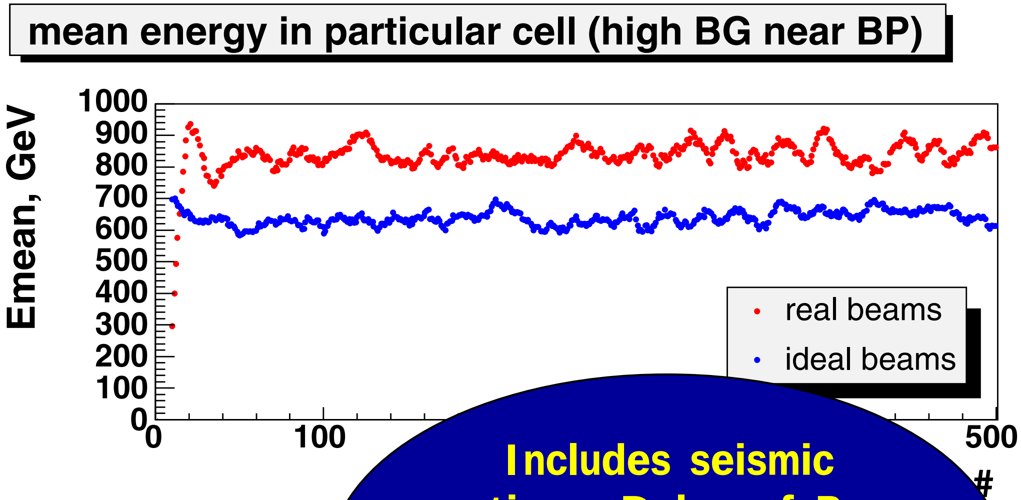


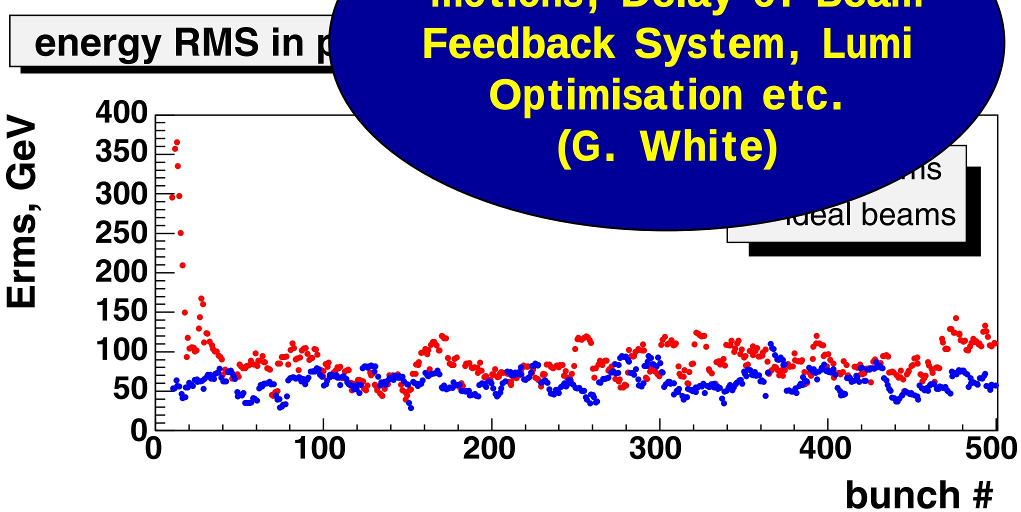


Message: Electrons can be detected!

Detection of High Energy Electrons and Photons

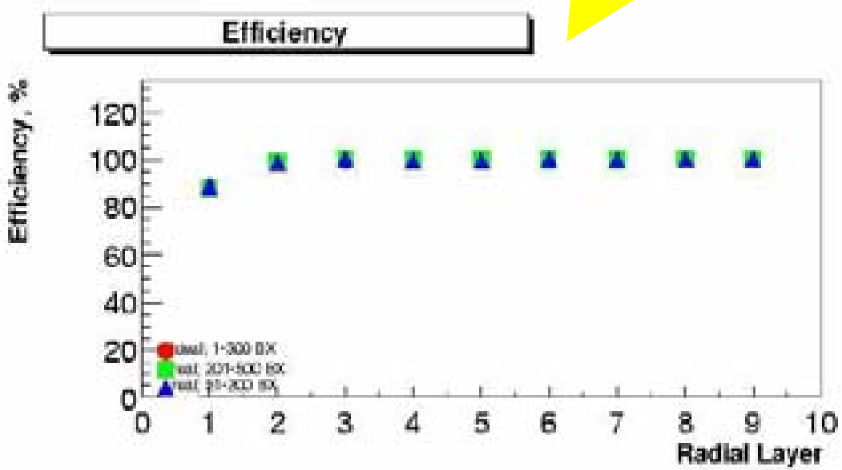
Realistic beam simulation
$\sqrt{s}$ = 500 GeV

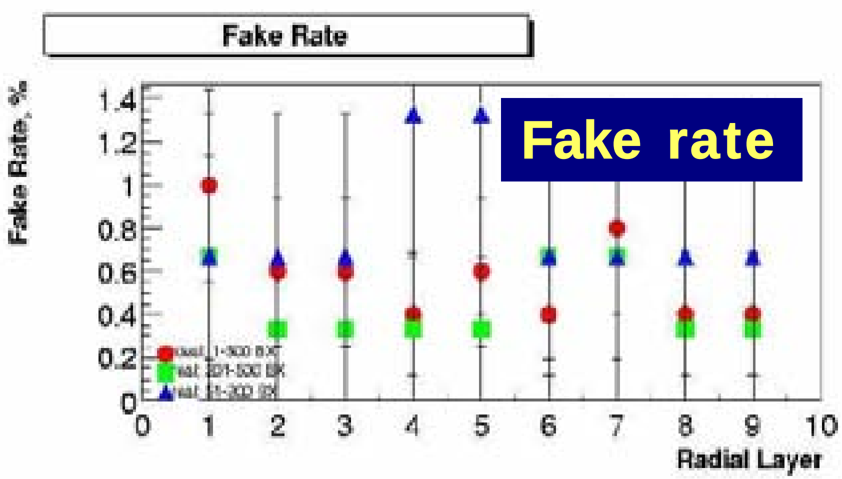




Includes seismic motions, Delay of Beam Feedback System, Lumi Optimisation etc.
(G. White)

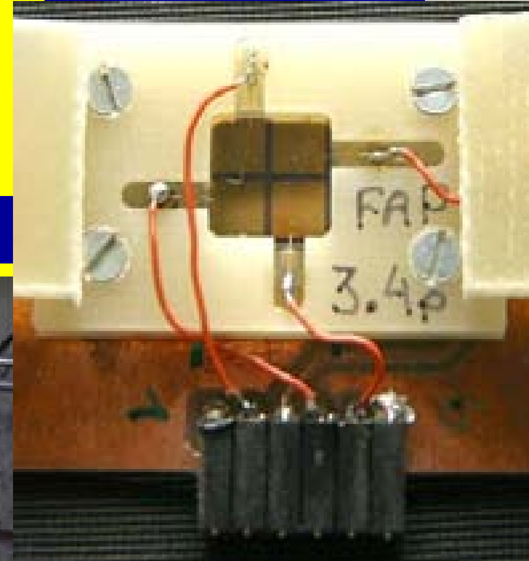
Efficiency to identify energetic electrons and photons (E > 200 GeV)

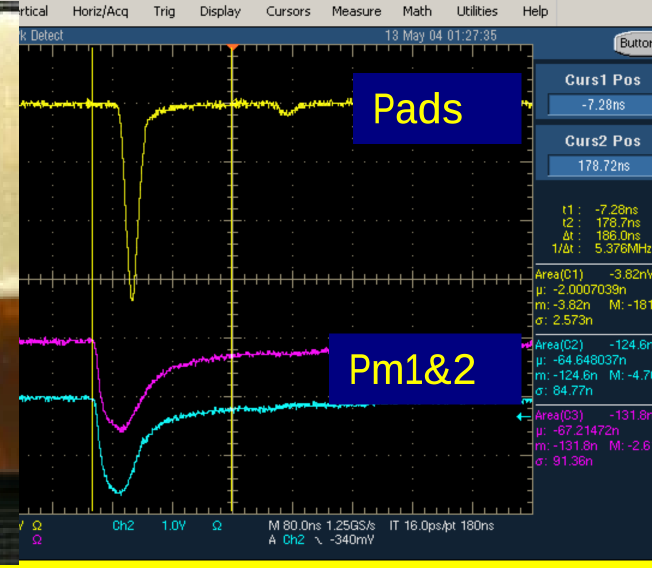


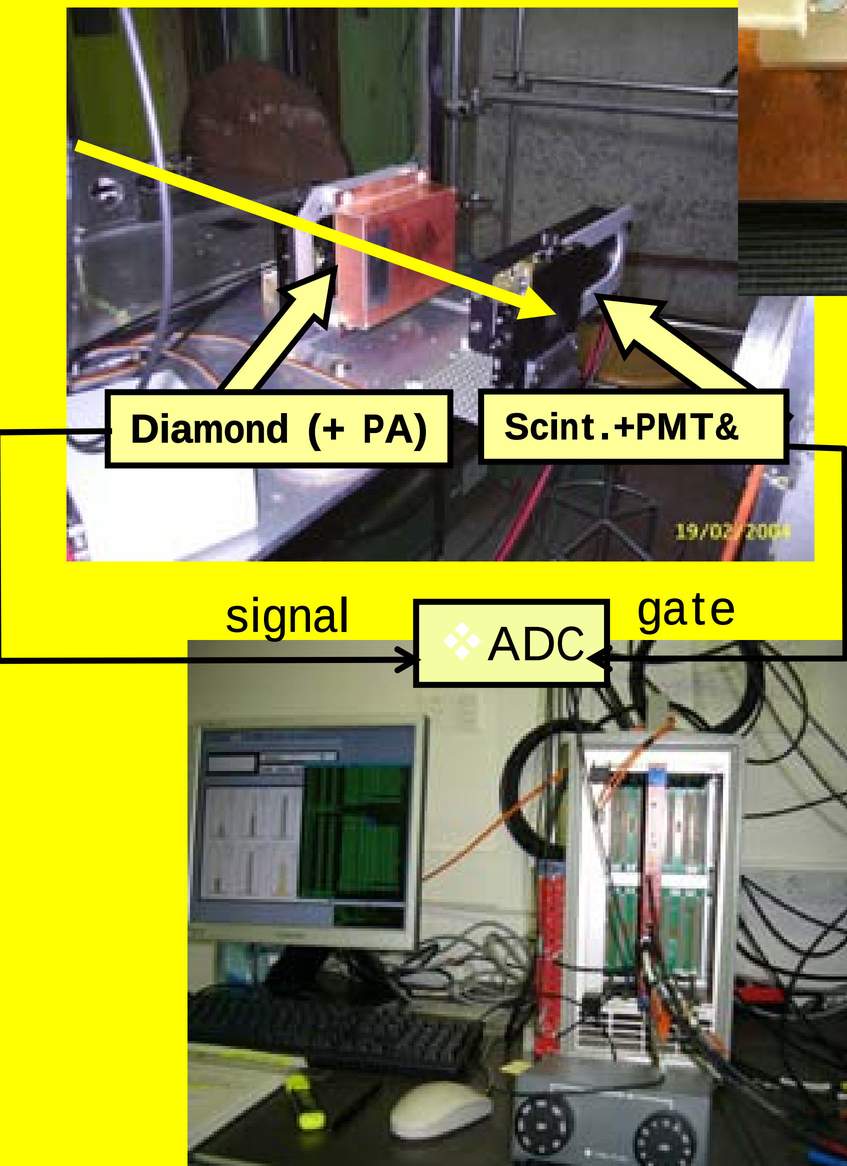


Fake rate

Sensor prototyping, Diamonds







May,August/2004 test beams

CERN PS Hadron beam – 3,5 GeV

2 operation modes:

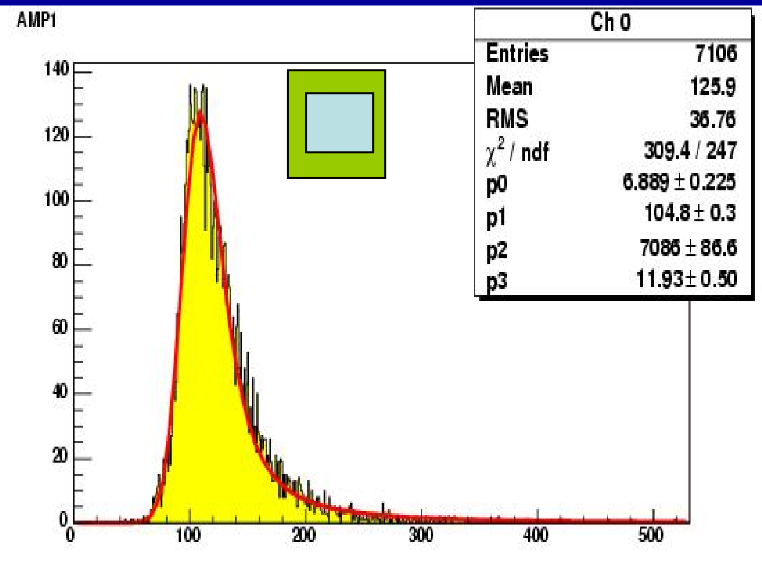
- Slow extraction ~10^5-10^6 / s
- fast extraction ~10^5-10^7 / ~10ns
  (Wide range intensities)

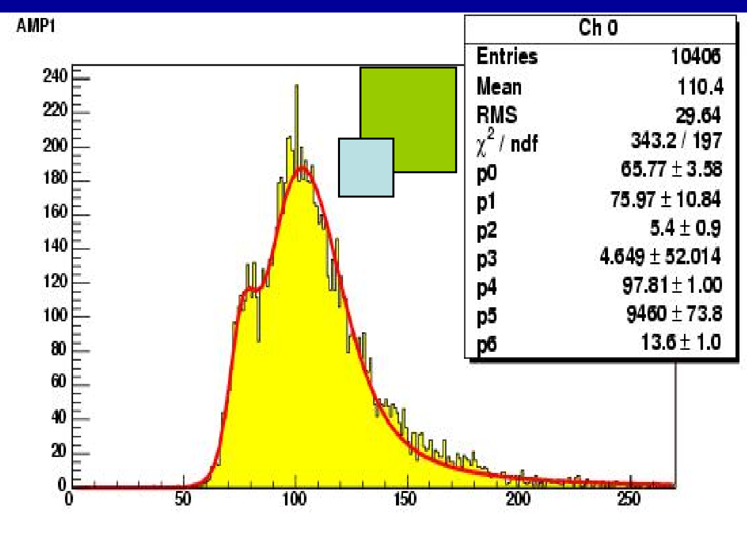
Diamond samples (CVD):

- Freiburg
- GPI (Moscow)
- Element6

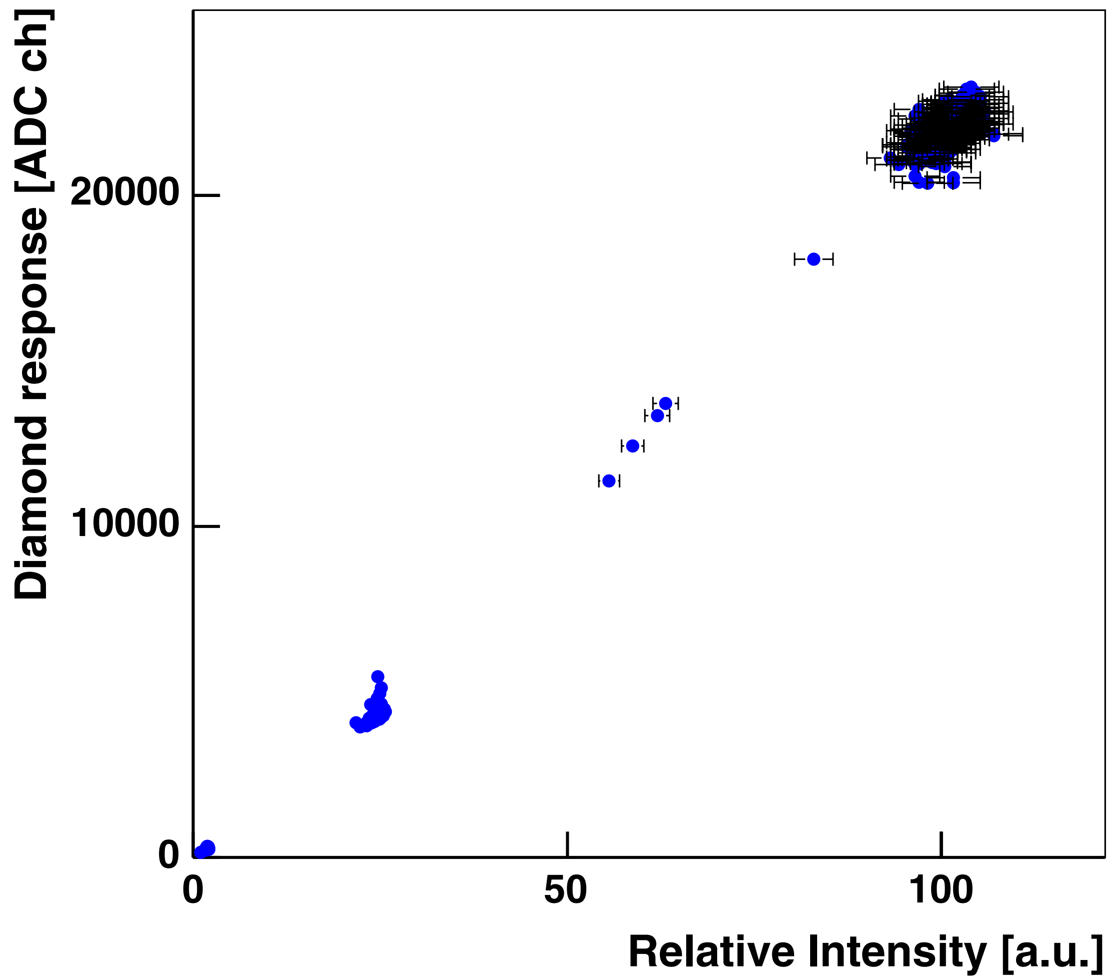
Diamond Sensor Performance

Response to mip

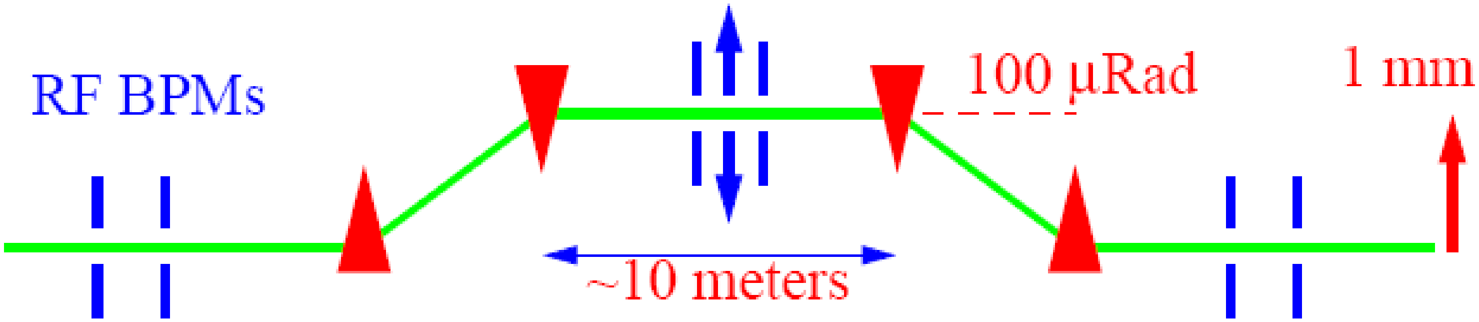




Linearity Studies with High Intensities (PS fast beam extraction) 10^5 particles/10 ns

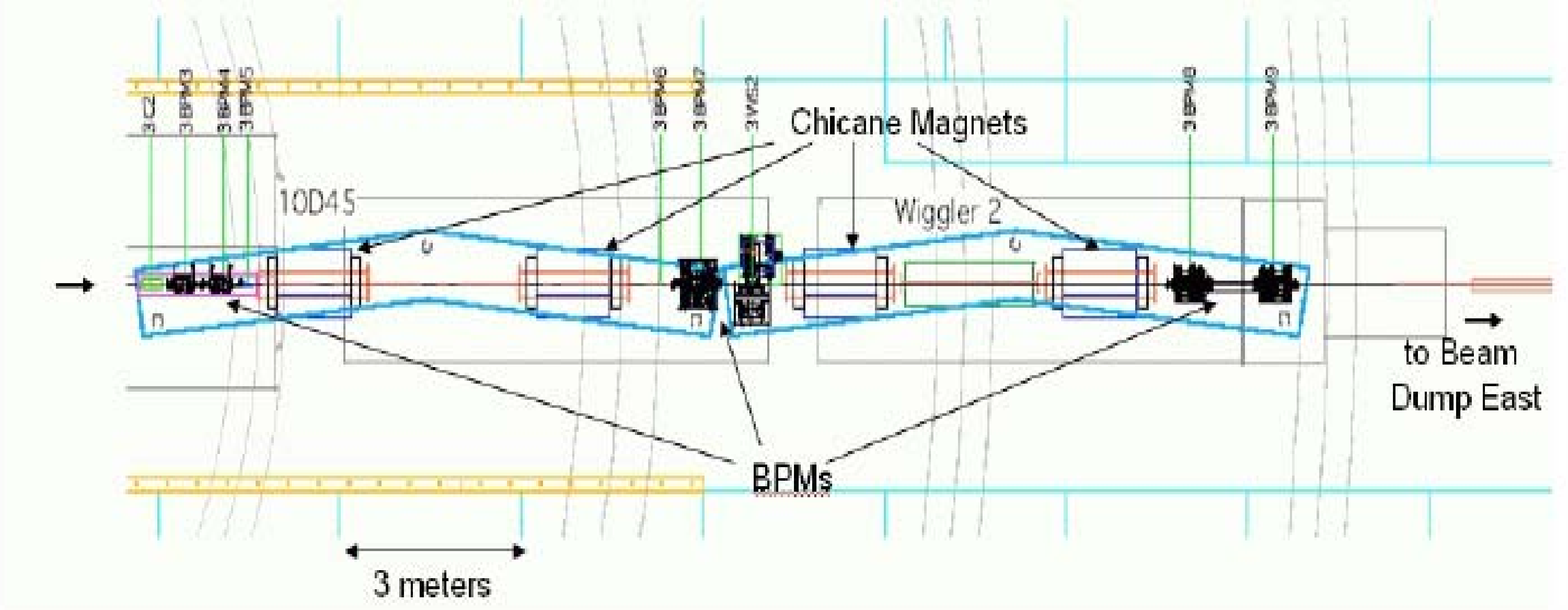


Upstream momentum spectrometer



- Bends ~ 100 μRad, lengths 10 m, 1 mm bump
- Need 100 nm (or better) resolution and accuracy
- Move BPMs to the beam (keep same relative position)
- Calibrate alignment by ramping chicane (bipolar best)

ESA Test Beam Plans for 2005/2006



$2x10^{10}$ electrons per bunch @ 28.5 GeV (ILC buch charge and length)

Compare different measurments (this spectrometer, A- line BPMs, Synchrotron spectrometer)

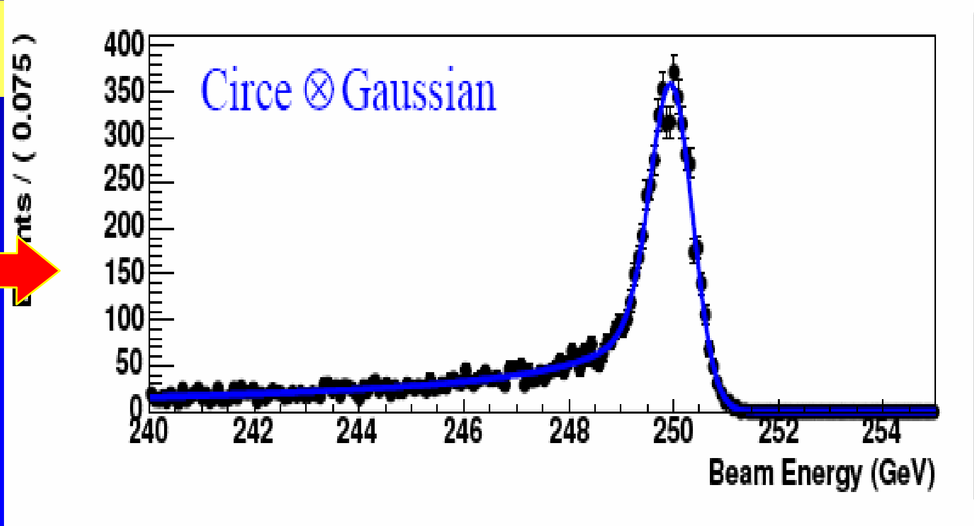
Accuracy goal: < 100 ppm

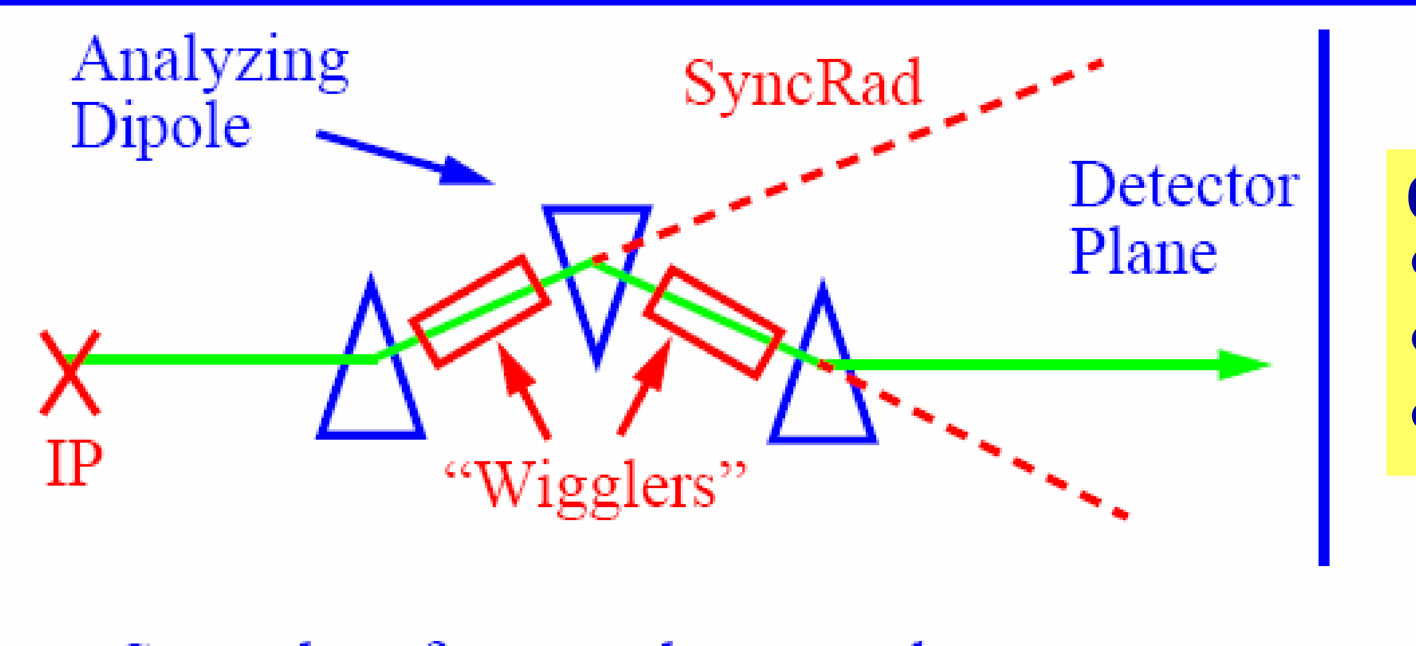
Proof of principle!

Energy Measurement

Downstream SR spectrometer

Energy spectrum After bunch crossing





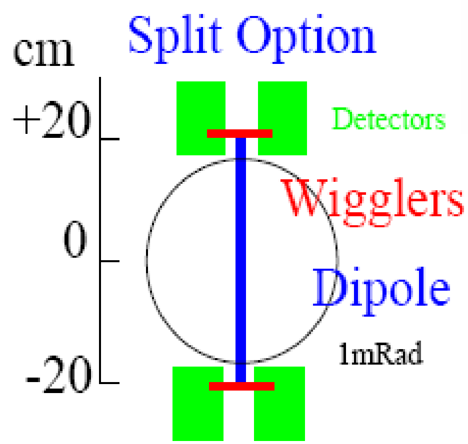
Goals:

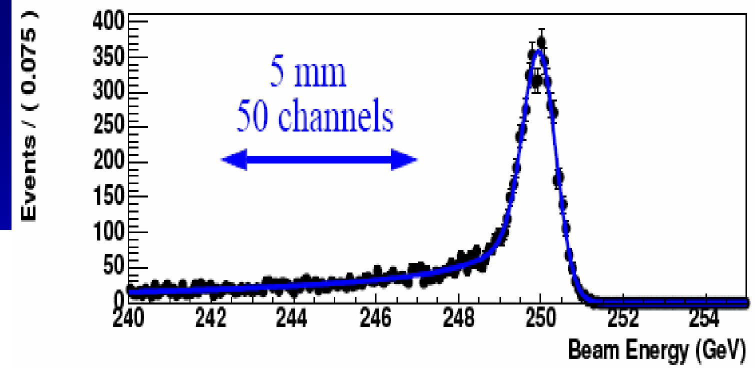
- **peak position,**
- **width,**
- **tail**

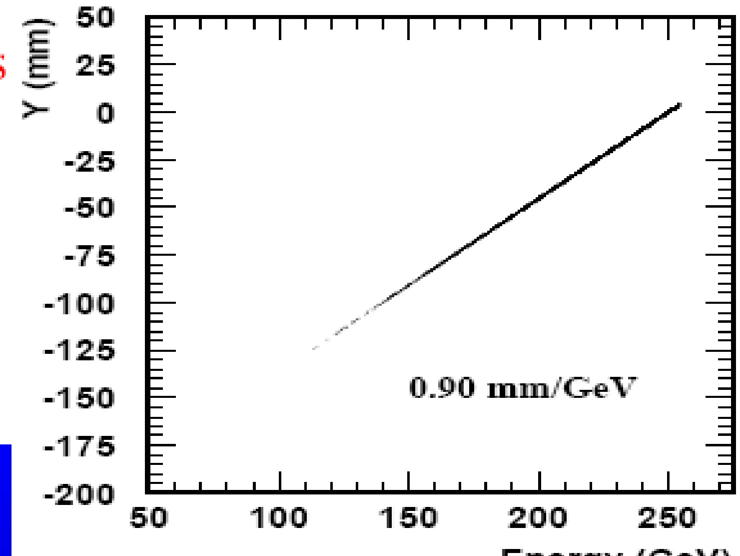
Downstream SR spectrometer

Detector Plane

- L ~ 100m, > 2 mRad bend
- large λ wiggler - SR "tee"
- detector ~ 100 µm pitch
- Δy = 40 cm
  40 µm precision required
- < 125 MeV/100 µm
  for 250 GeV beam
- Single arm gives energy spread

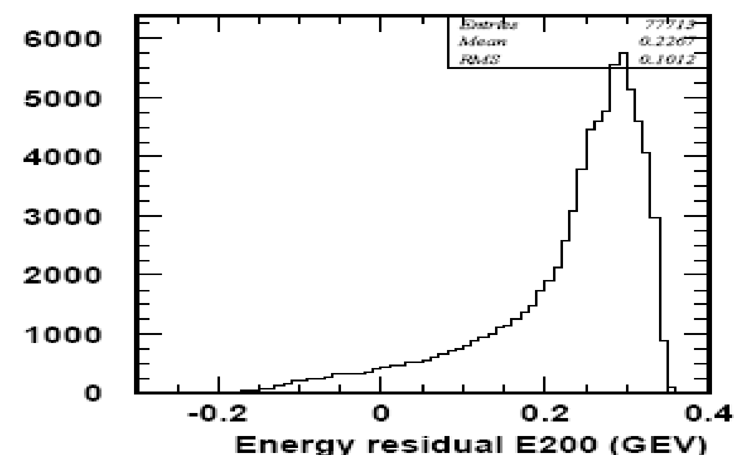




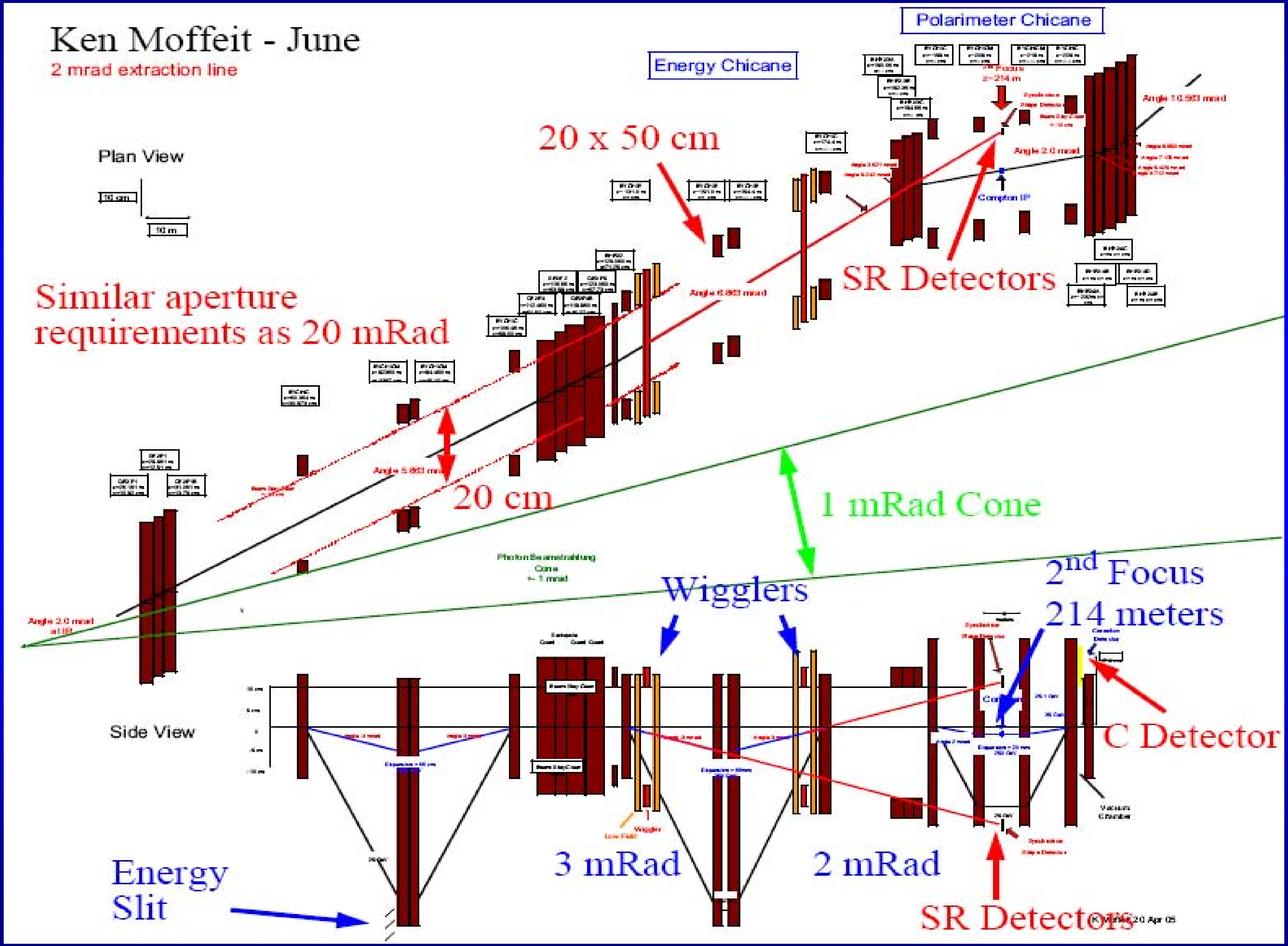


Beam Energy mapped to y position on detector plane
Order 1 GeV/mm sampled at 100 µm pitch

Use quartz fibers: low efficiency, but rad hard and some background tolerance. Large dynamic range with MAPMTs. 64 channels/PMT.

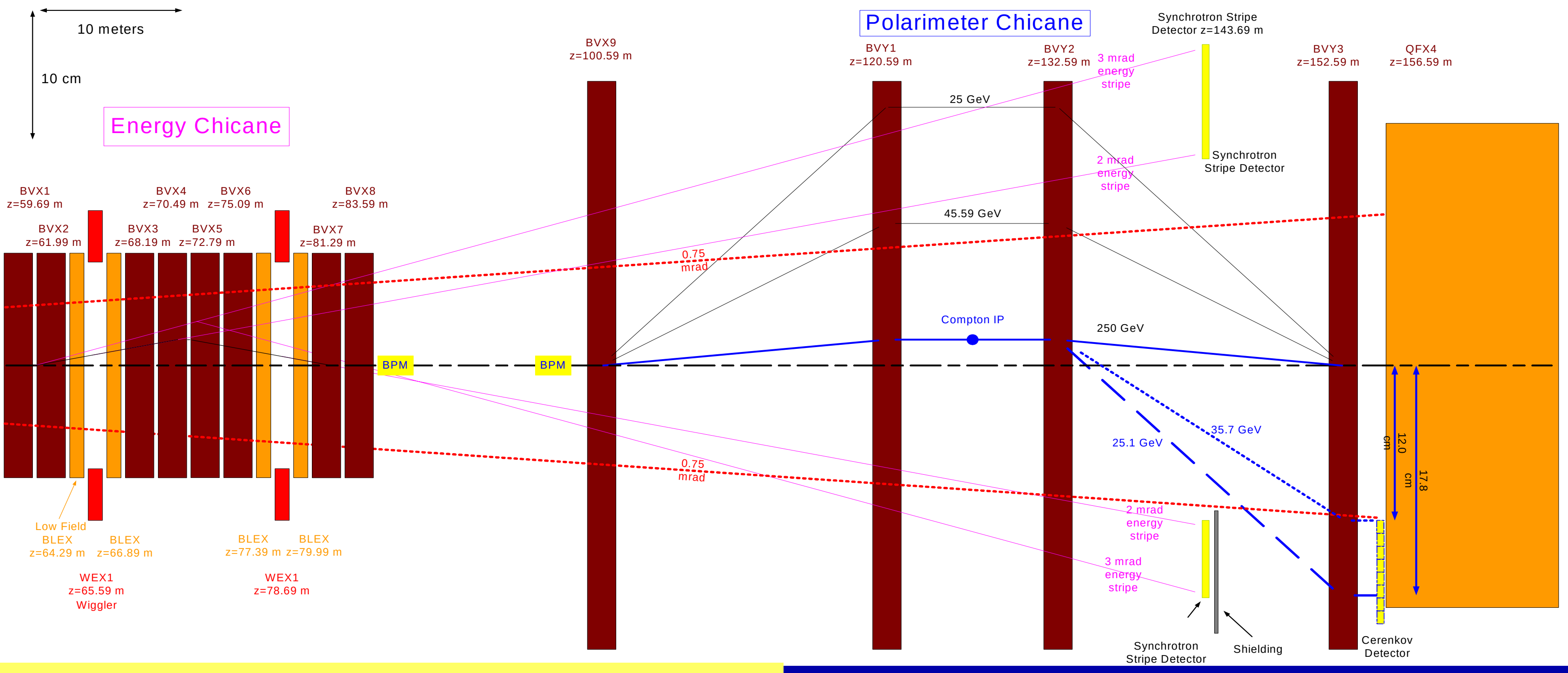


Downstream SR spectrometer



Polarimetry

Upstream polarimeter



+ Downstream polarimeter

Document on polarimetry design in Feb 2006

The needs from Detector and Machine side are different. Lets find solutions