Machine Detector Interface at the International Linear Collider

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Overview

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- Machine background:
  - SR for 2mrad
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    - Few words on MBKI
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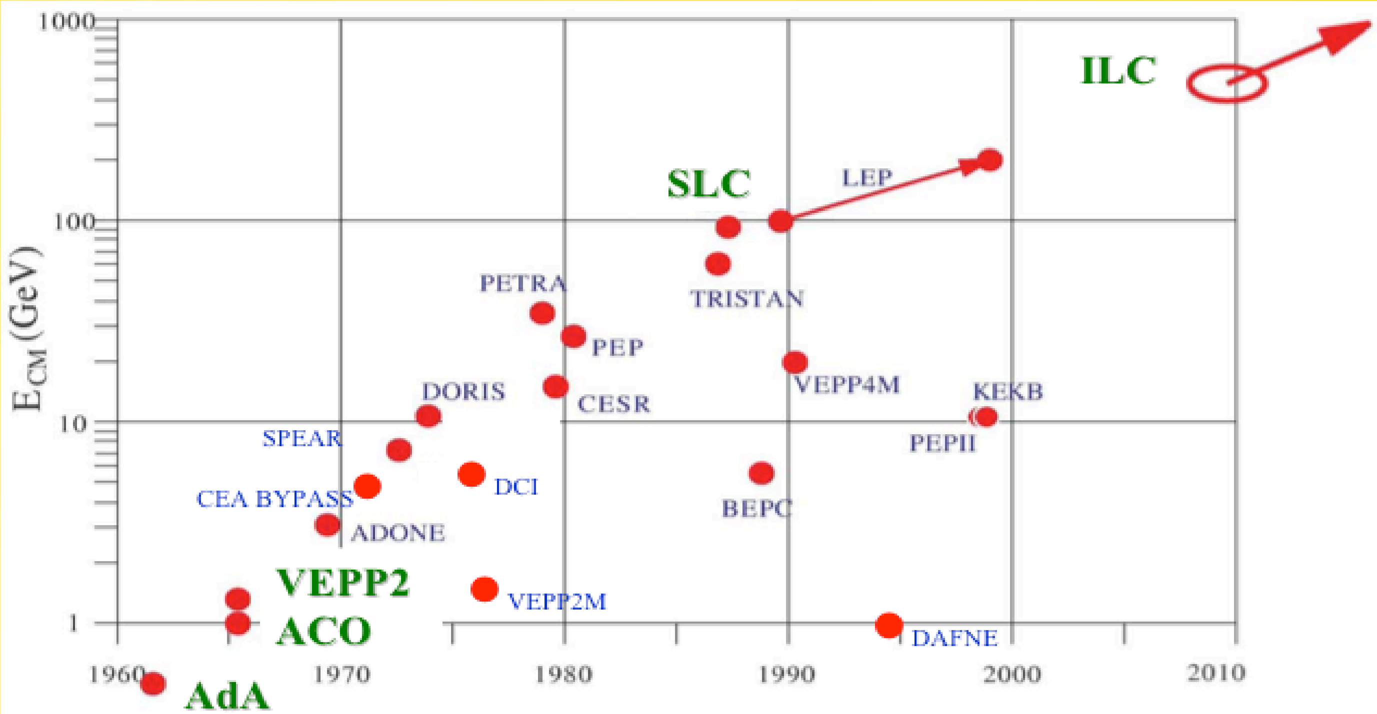
Introduction

Why e^+e^- linear collider ?

Linear vs circular:

- Synchrotron radiation:
  - $\Delta E \sim (E^4/m^4R)$ per turn
  - 2GeV per beam at LEP2 (200 GeV)
- Cost:
  - Circular : ~ E^2
  - Linear : ~ E

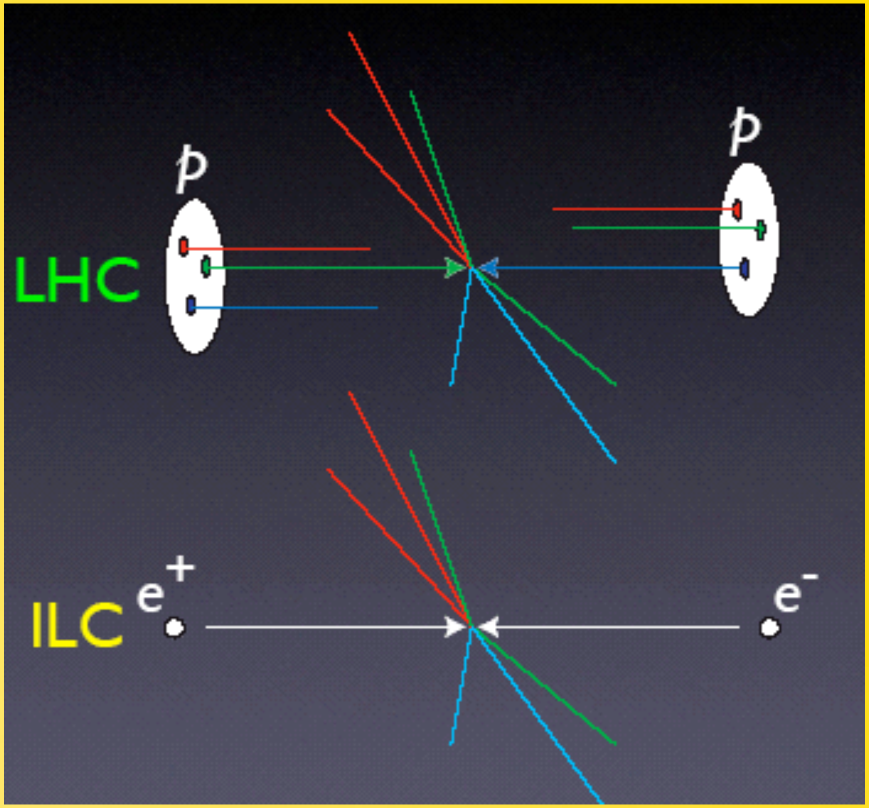
For those reasons, at very high energy it is preferable to accelerate electrons in a linear accelerator, rather than a circular accelerator



Why e^+e^- linear collider ?

e^+e^- collider

- Elementary particles
- Well defined :
  - Energy
  - Angular momentum
- Uses full center of mass energy
- Electron polarization
- No trigger



Physics goals

- There is one missing member of the Standard Model:

Higgs Particle

Masses are introduced by dynamical breaking of SU(2)xU(1) gauge symmetry → Higgs mechanism

- The Standard Model requires its existence !!
- Where is the Higgs?
- How it looks like ?
- The Standard Model tells us its properties except for its mass

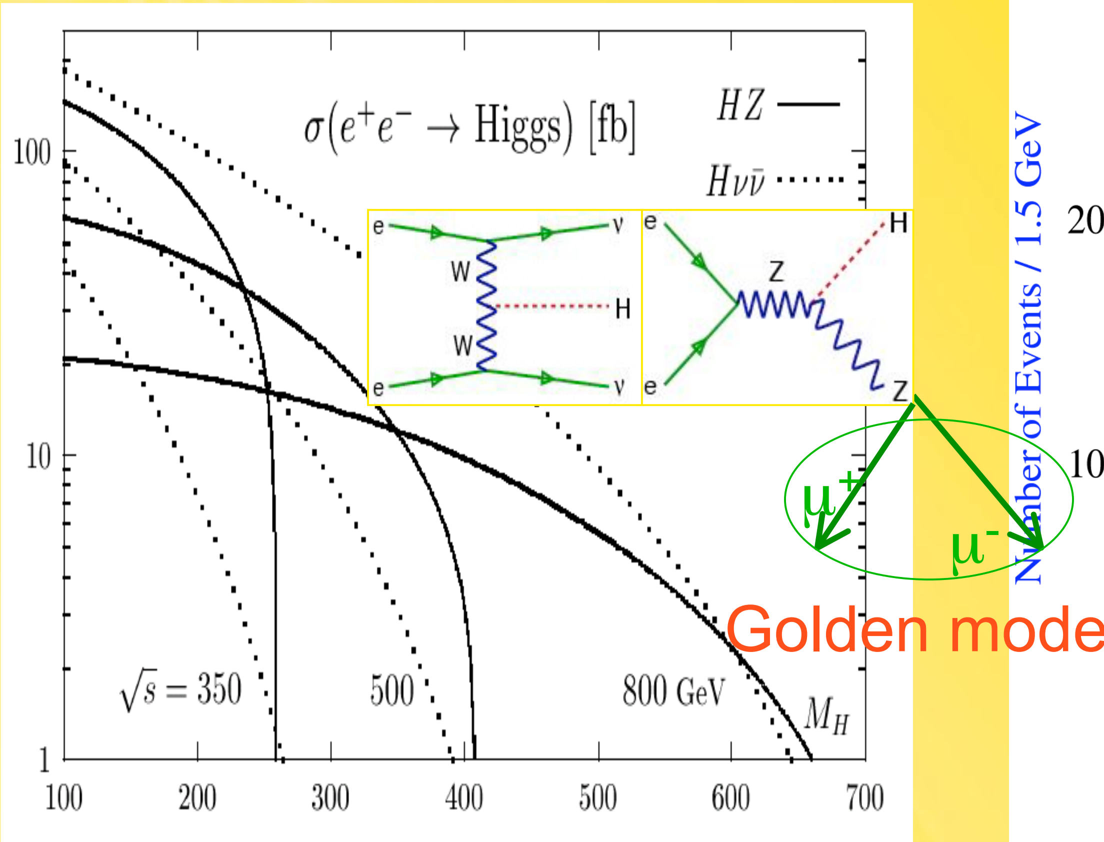
- Origin of the electroweak symmetry breaking: new physics at Terascale ?

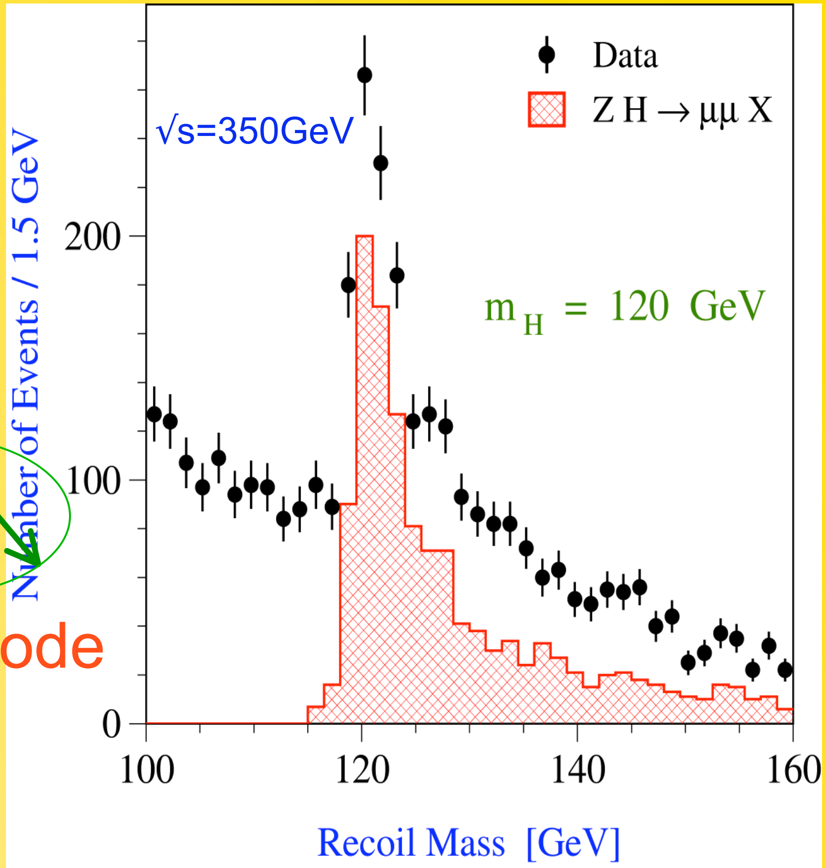
If Nature has chosen this mechanism, predictions from precision data indicate a light Higgs boson

114 ~ 200 GeV

Model Independent Higgs Reconstruction

Associate H^0Z^0 production, with $Z^0 \rightarrow ll$, allows to extract Higgs signal from recoil mass distribution, independent on H decay





S/B depend on P_t muon energy resolution $\delta P_t/P_t^2 \sim 2\times10^{-5}$

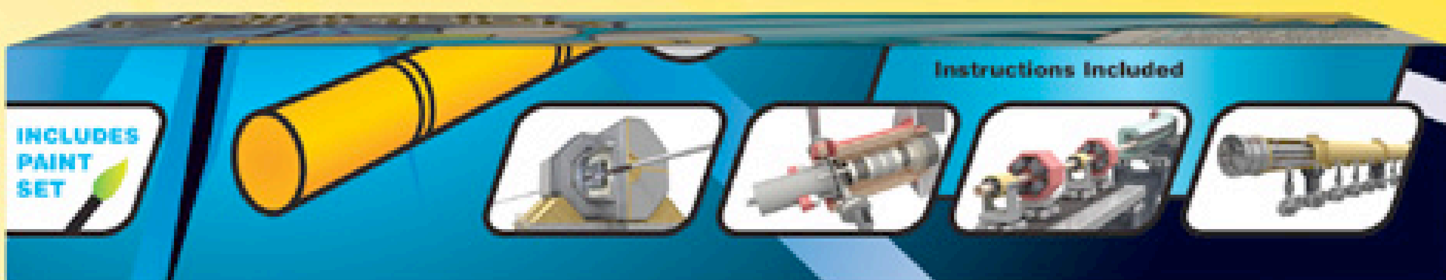
Philip Bambade & François Richard How to optimize the ILC energy for measuring ZH

ILC parameters goals

What do we need ?

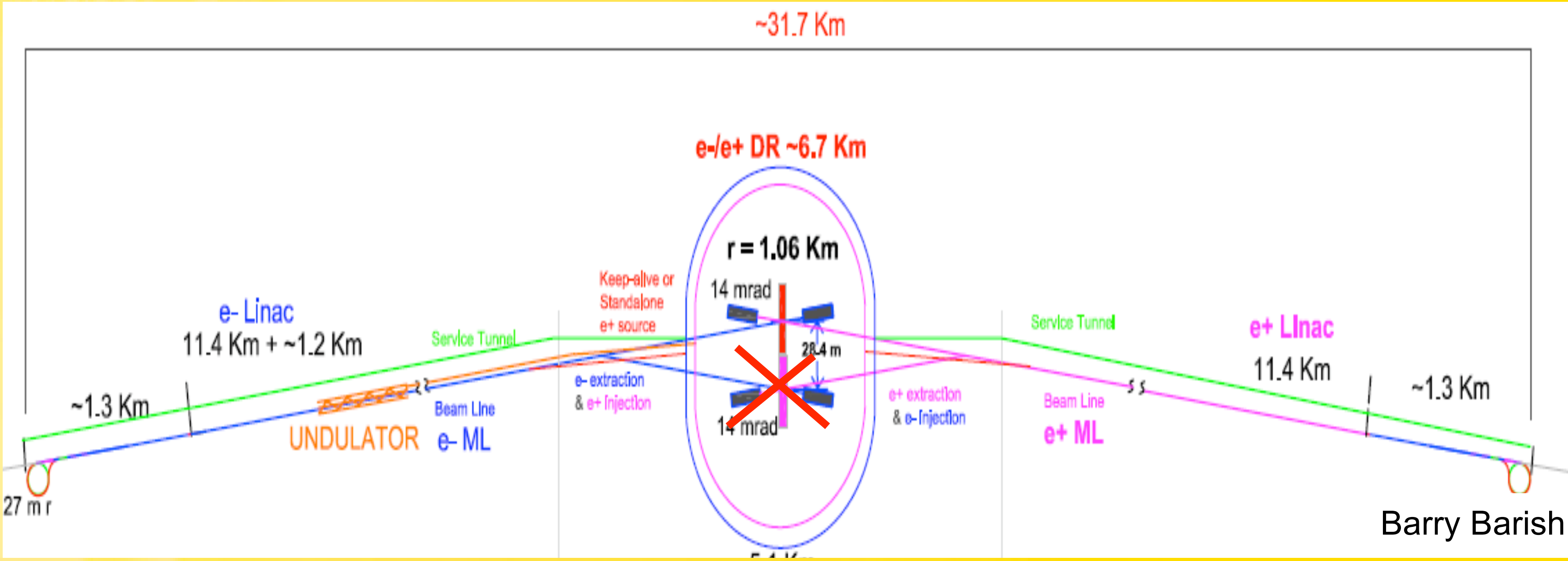
- $\sqrt{s}$ adjustable (ability to scan) from 200-500 GeV
- High Luminosity $\int \mathcal{L} dt = 500\ fb^{-1}$ in 4 years
- Energy stability and precision below 0.1%
- Controllable beam polarization
- Electron polarization of at least 80%
- Very sensitive detectors & trigger free
- The machine must be upgradeable to 1 TeV
- GigaZ option: 10^9 events at the Z pole with polarized beams
- e^-e^- option (PhD thesis Maria Alabau)

ILC project



ILC projects: e+e- linear collider

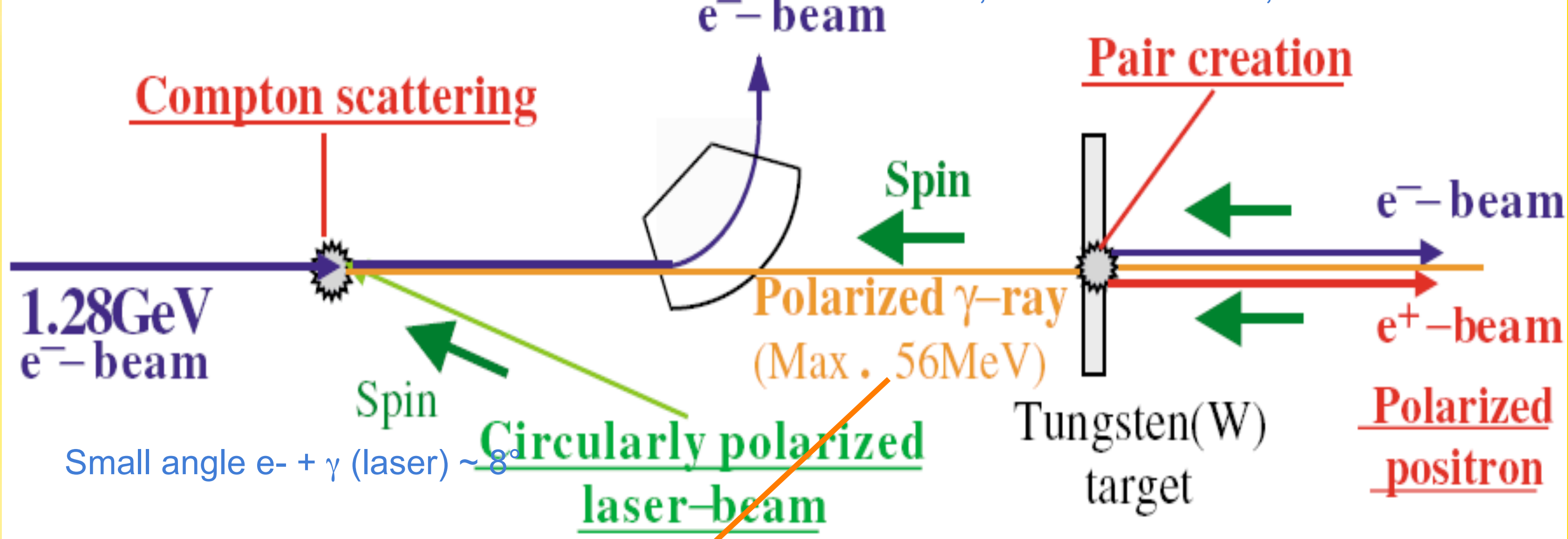
International Linear Collider (ILC) born in 2004:
World Wide collaboration around ONE Supraconducting LC
(from Tesla collaboration)

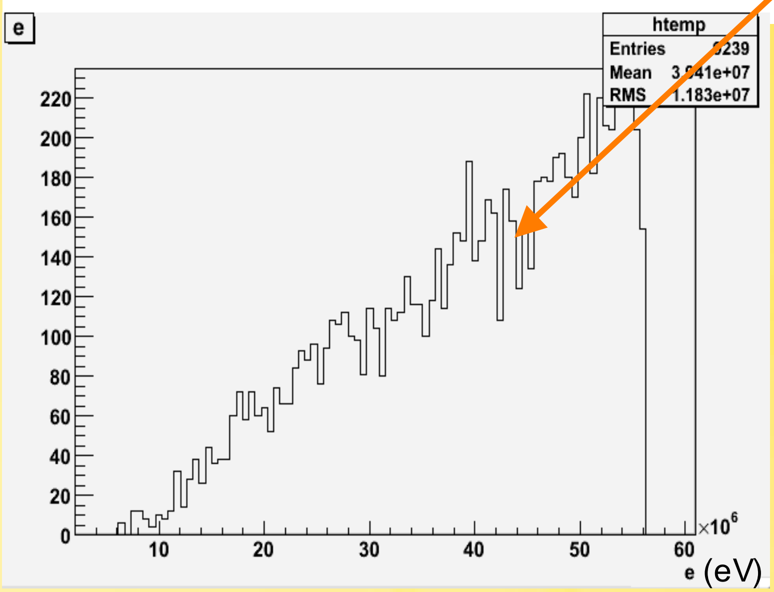


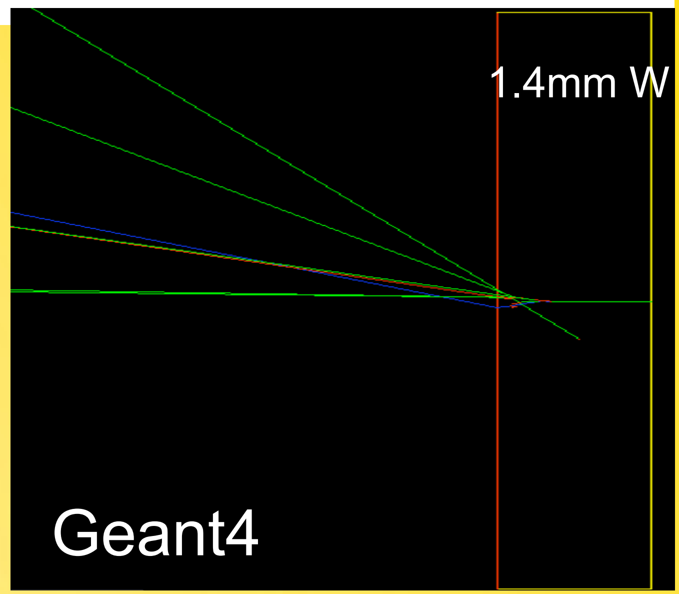
- 11km SC linacs operating at 31.5 MV/m for 500 GeV
- Centralized injector
  - Circular damping rings for electrons and positrons
  - Undulator-based positron source
- Dual tunnel configuration for safety and availability
- Single IR with 14 mrad crossing angle

Few words on polarized e+ alternative source

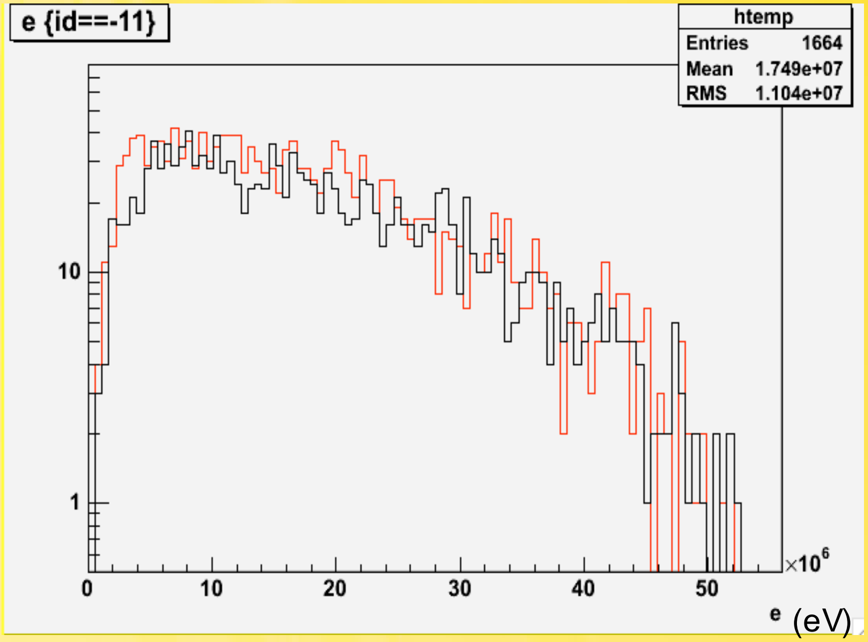
Alessandro Variola, Alessandro Vivoli, Robert Chehab

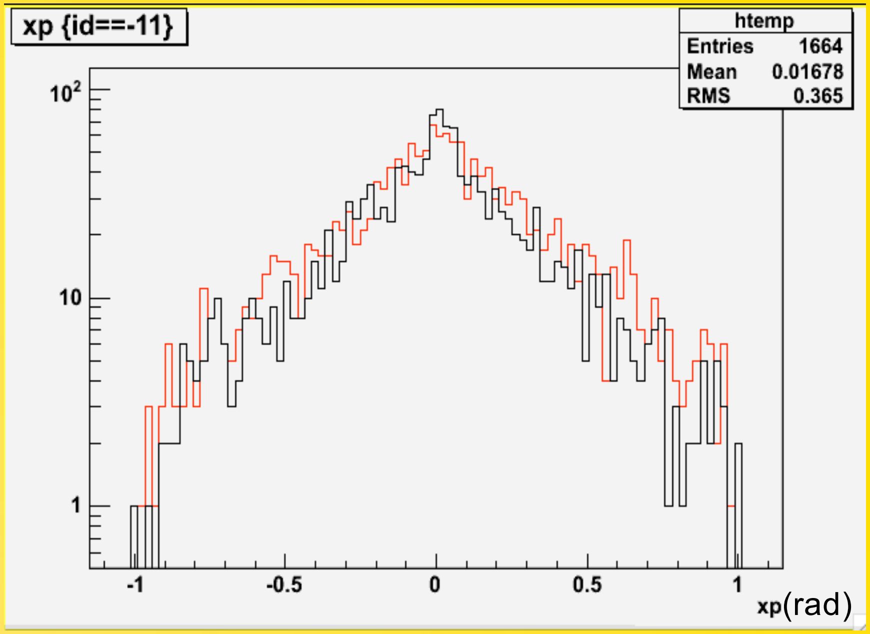


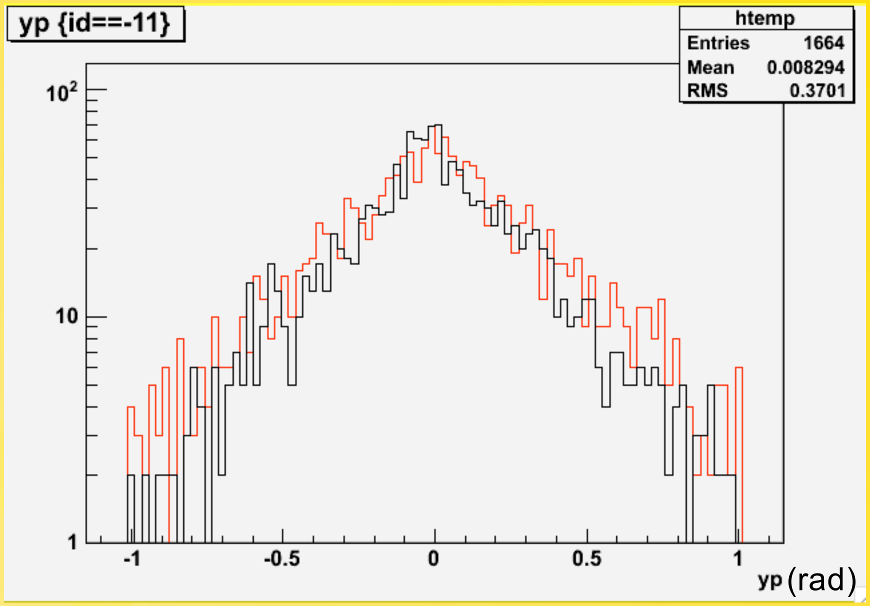




Geant4 vs EGS







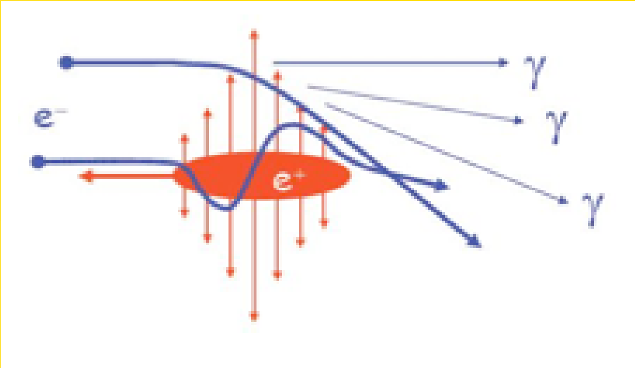
- Good agreement between both simulation
- Need to use the latest Geant4 simulation to incorporate the polarization

Nominal BDS Parameters @ 500GeV ecm

Length (linac exit to IP distance)/side	m	2226
Length of main (tune-up) extraction line	m	300
Max Energy/beam (with more magnets)	GeV	250
Distance from IP to first quad, L*	m	3.5
Crossing angle at the IP	mrad	14
Nominal beam size at IP, σ^*, x/y	nm	639/5.7
Nominal beam divergence at IP, θ^*, x/y	μrad	32/14
Nominal beta-function at IP, β^*, x/y	mm	20/0.4
Nominal bunch length, σ_z	μm	300
Nominal disruption parameters, x/y		0.17/19.4
Nominal bunch population, N		2.05×10^{10}
Beam power in each beam	MW	11.3
Preferred entrance train to train jitter	σ	< 0.5
Preferred entrance bunch to bunch jitter	σ	< 0.1
Typical nominal collimation depth, x/y		8–10/60
Vacuum pressure level, near/far from IP	nTorr	1/50
Number of bunches		2820
Frequency	Hz	5

Beamstrahlung

- Electrons of one bunch radiate against the coherent field of the other bunch
- Beamstrahlung is just another form of Synchrotron Radiation:
  - extremely high magnetic field B (10^5 T)
  - extremely short magnet length L ($\sim\sigma_z$)

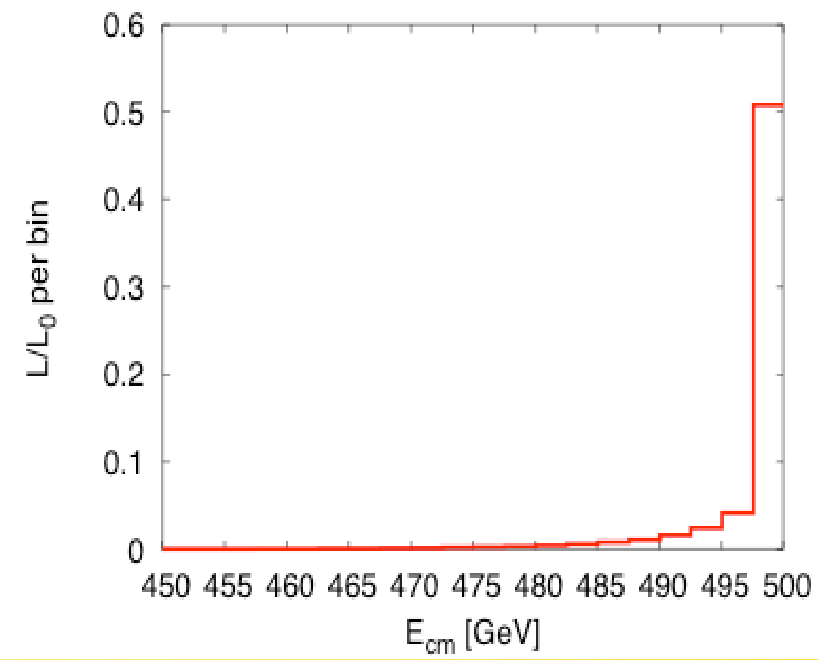


Energy loss of particle due to Beamstrahlung:

$$\Delta E \propto \Upsilon^2 \sigma_z \propto \frac{N}{(\sigma_x + \sigma_y)} \frac{N}{(\sigma_x + \sigma_y)\sigma_z}$$

(use flat beams)

- Hundreds of kW:
  Need to extract carefully the beamstrahlung photons from the Interaction Point to the dump



Other secondary production

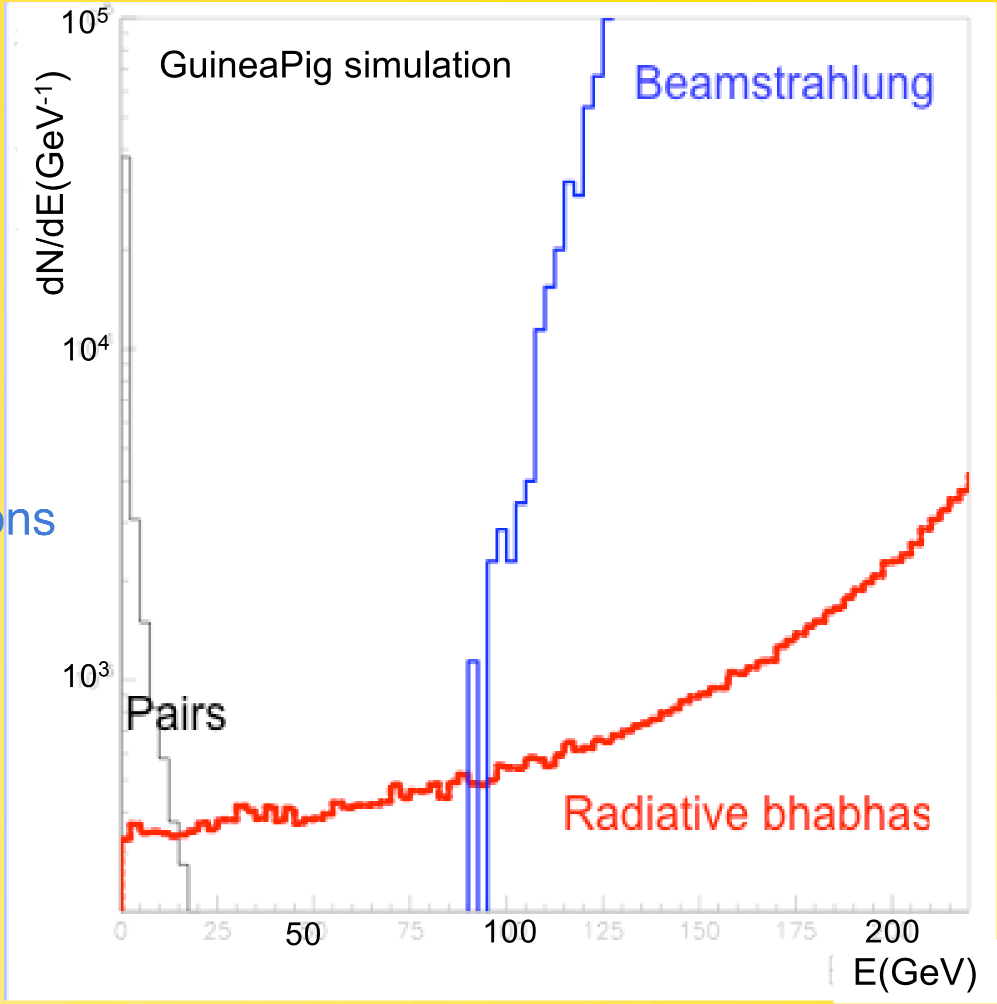
Bremsstrahlung

- Interaction of particle with individual particle of other beam
  - also called radiative Bhabha
  - Proportional to luminosity

Incoherent Pairs

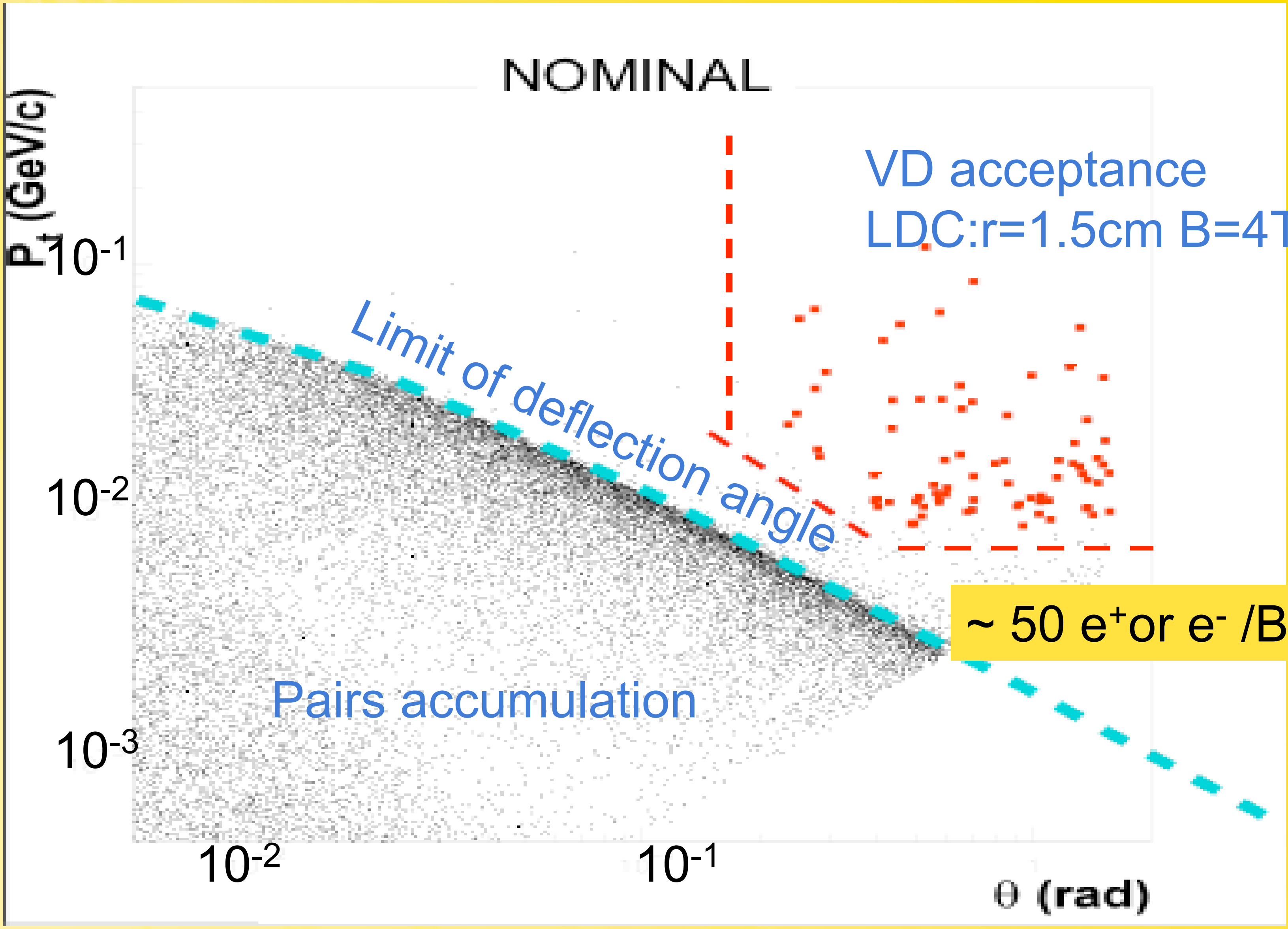
- Generated by Beamstrahlung photons

NB: Coherent pairs rate is very small below 1TeV
(generated by photon in the strong electromagnetic field of the opposite bunch)



Cécile Rimbault, Guy Le Meur, François Touze (GuineaPig++ version))

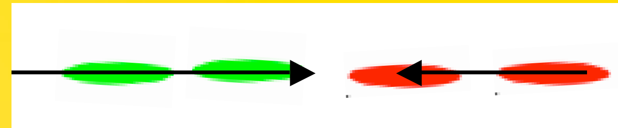
Pairs & microvertex detector



Cécile Rimbault

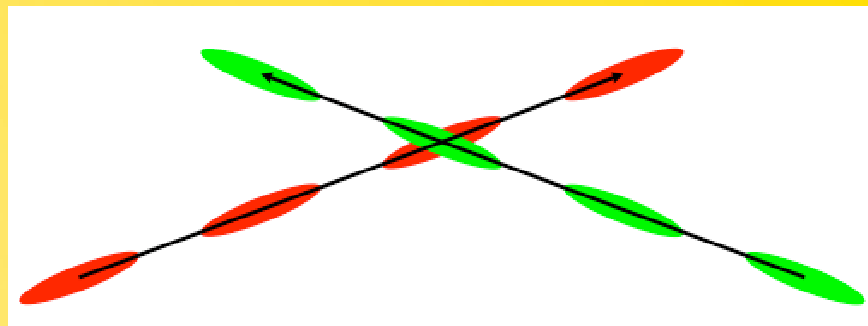
Luminosity and crossing angle

Luminosity, for head on collision $$\mathcal{L} = \frac{N^2 f_r n_b}{4\pi\sigma_x\sigma_y}$$

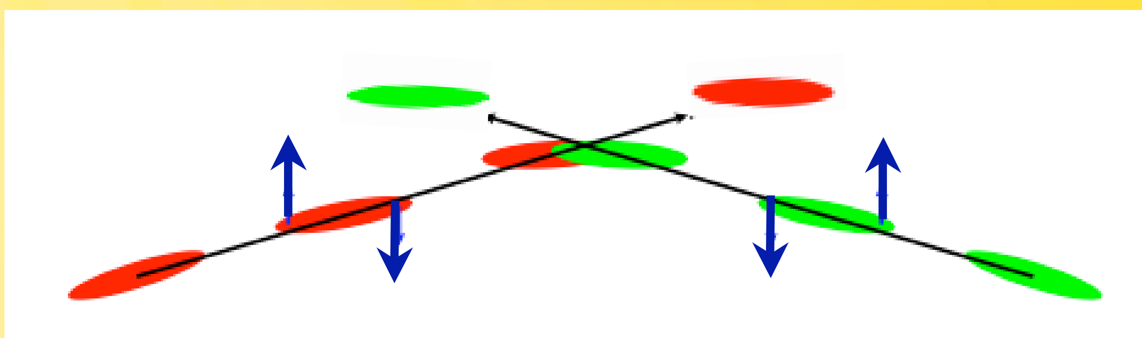


The crossing angle θ_c can lead to a reduction of luminosity

$$\frac{L}{L_0} = \frac{1}{\sqrt{1 + \left(\frac{\sigma_z}{\sigma_x}\tan\frac{\theta_c}{2}\right)^2}}$$

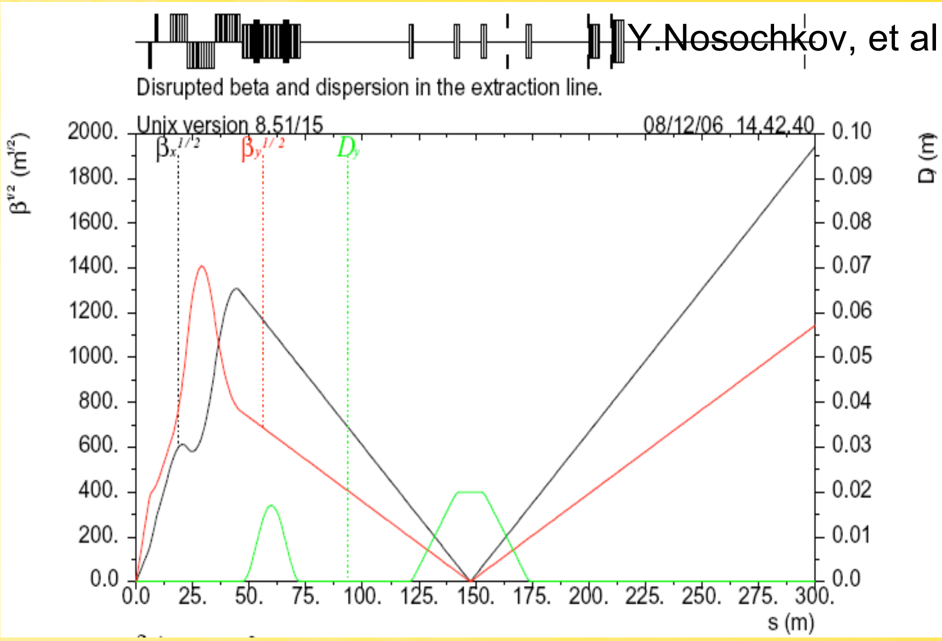


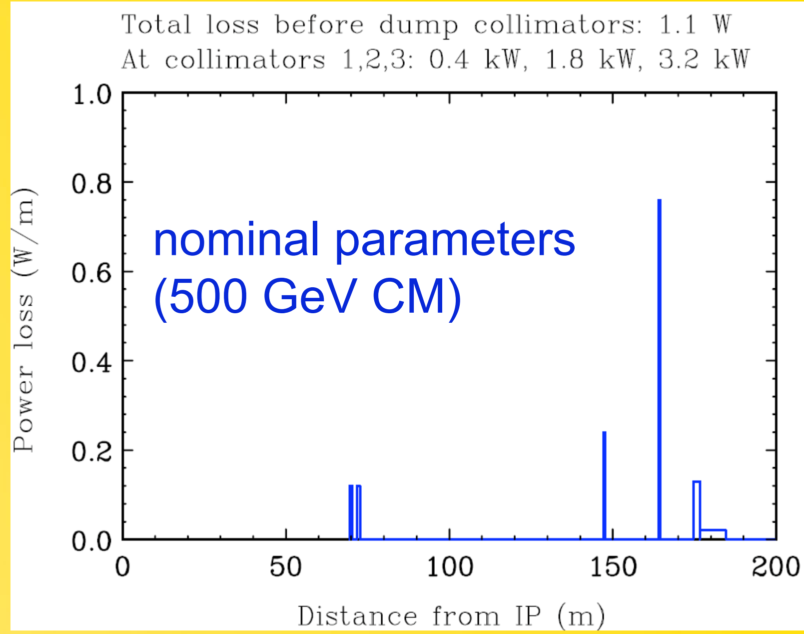
This can be avoided using the “crab crossing” scheme

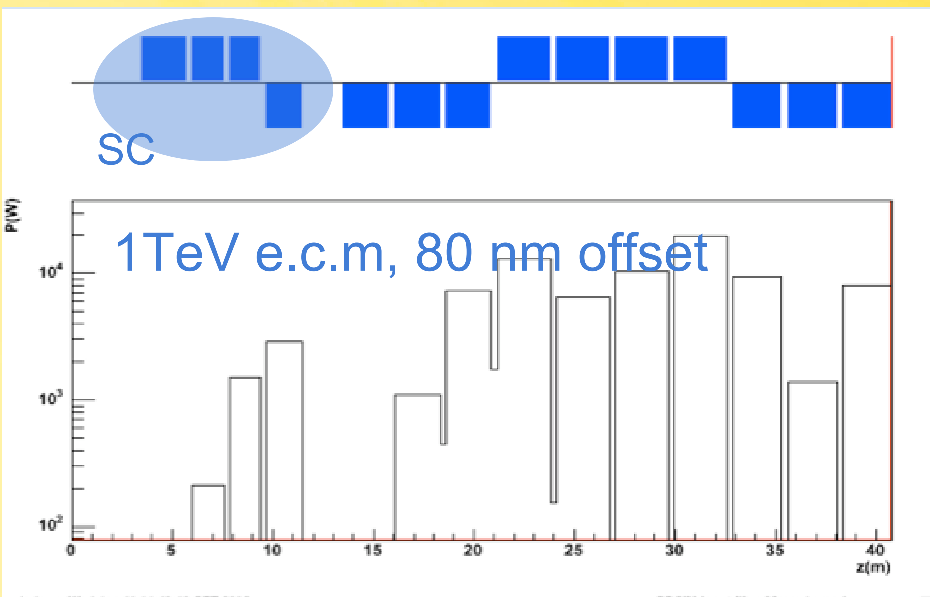


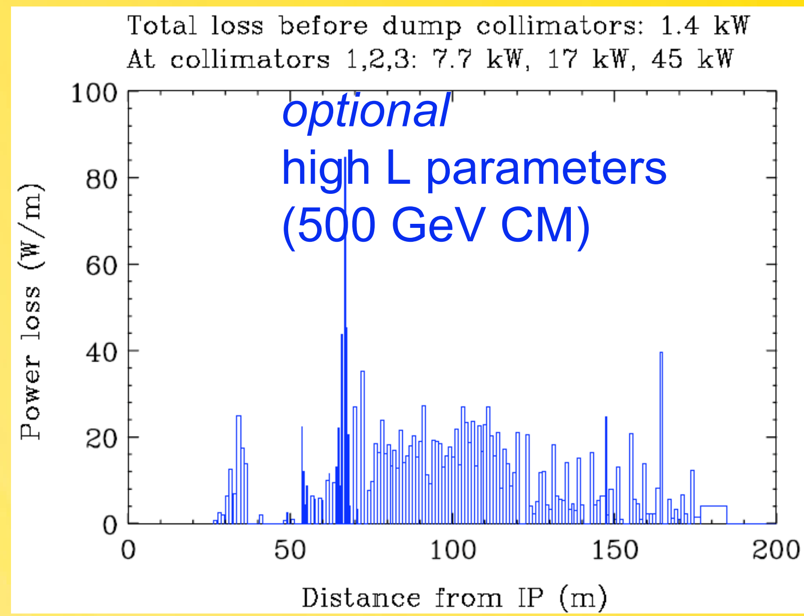
14mrad extraction line

~1W for 200m from IP (nominal parameters)









Machine background

Purpose

In spite of all the attention put into the design of the extraction line, the losses of some :

- disrupted beam particles,
- or synchrotron radiation photons

are unavoidable

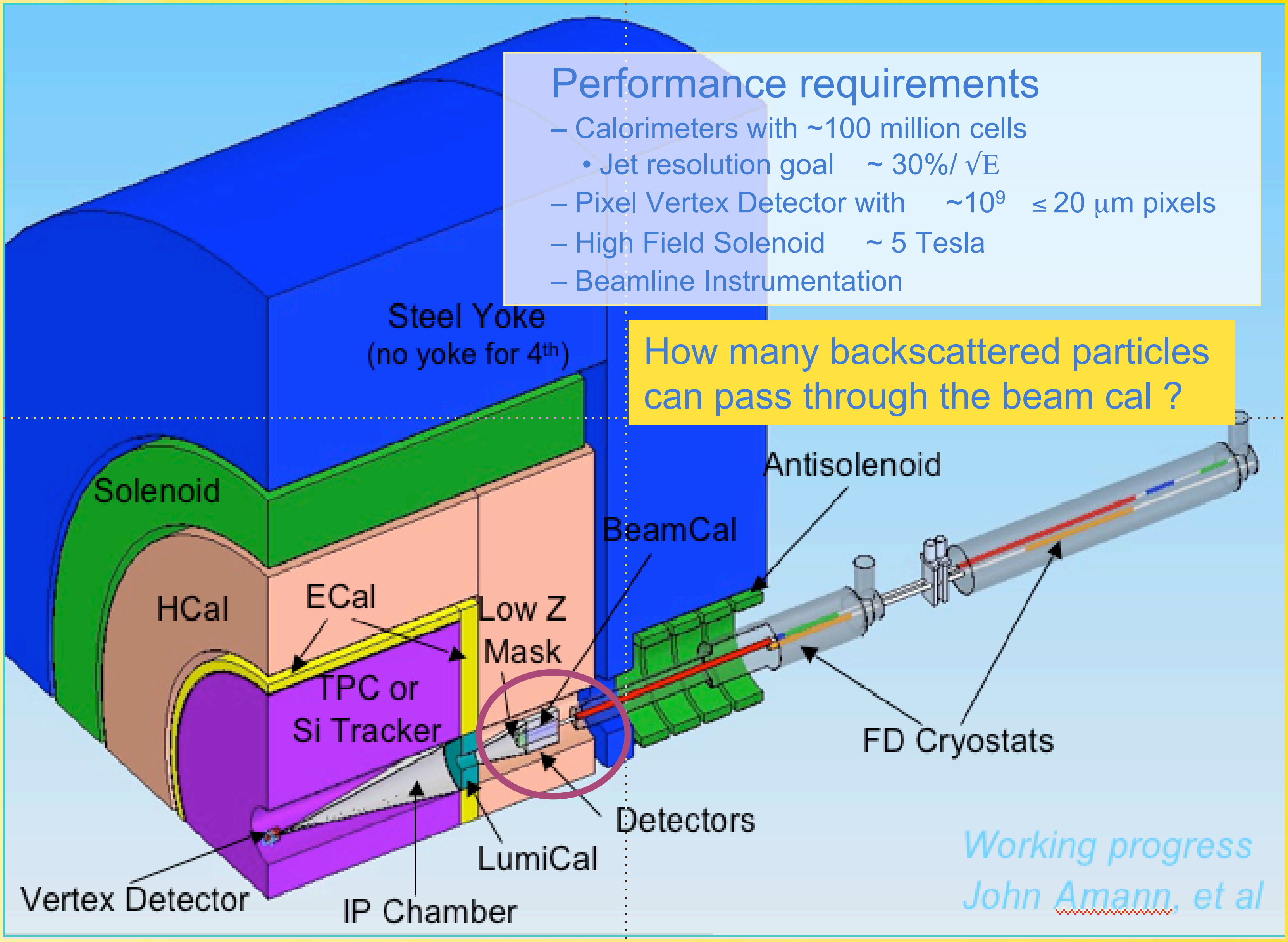
background sources at the IP

(several other sources: beamstrahlung, e^+e^- pairs, radiative Bhabhas, backscattered particles from the dump …)

We would like to quantify the number of such backscattered particles, for the different extraction lines and different concept detectors

Main tool BDSIM simulation (based on Geant4)

Generic Detector



Performance requirements

- Calorimeters with ~100 million cells
  - Jet resolution goal ~ 30%/ √E
- Pixel Vertex Detector with ~10^9 ≤ 20 μm pixels
- High Field Solenoid ~ 5 Tesla
- Beamline Instrumentation

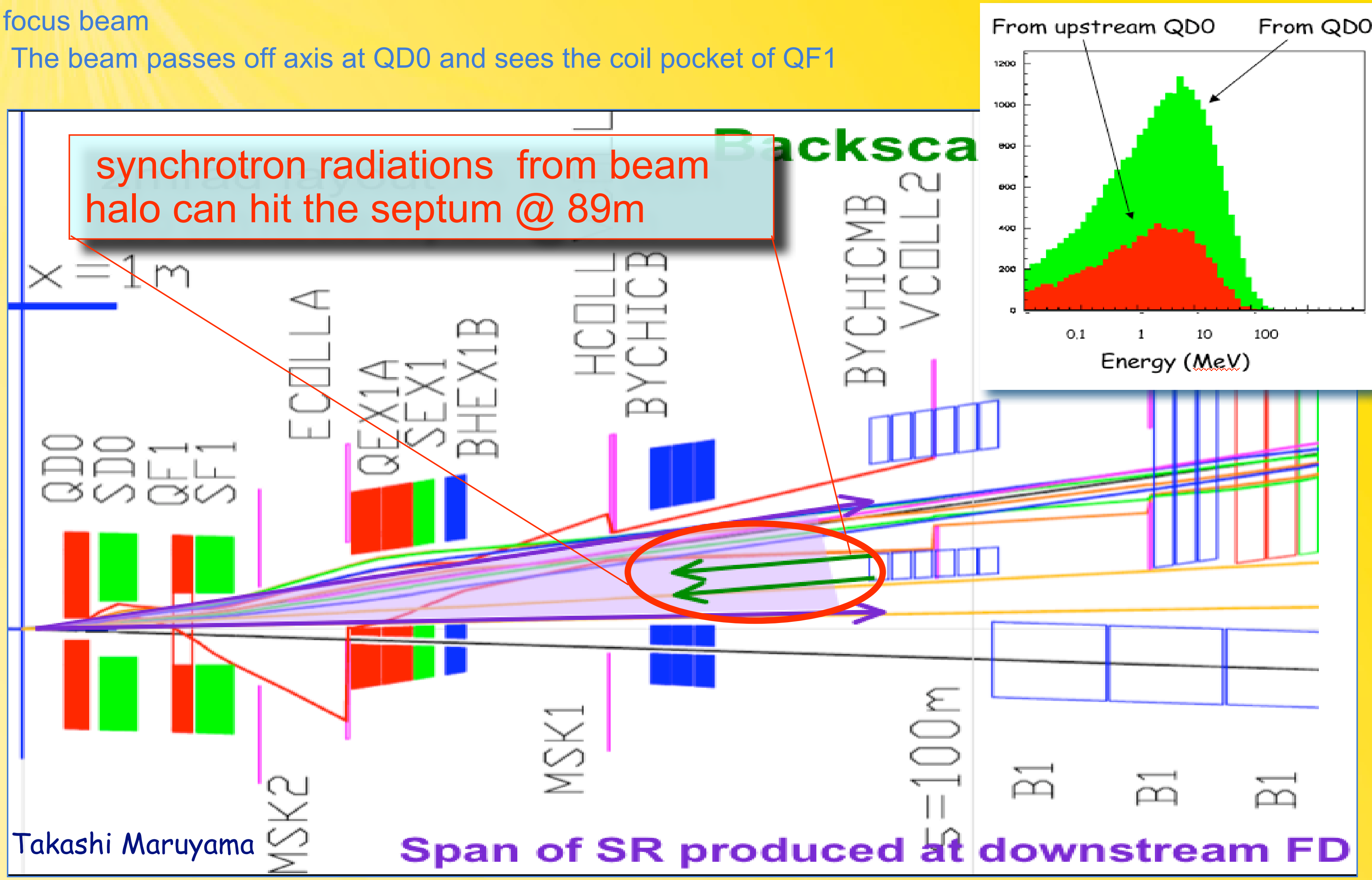
How many backscattered particles can pass through the beam cal ?

Working progress
John Amann, et al

SR: small crossing angle (2mrad)

In the 2mrad scheme, the beam goes off axis through the first magnets of the incoming final focus beam

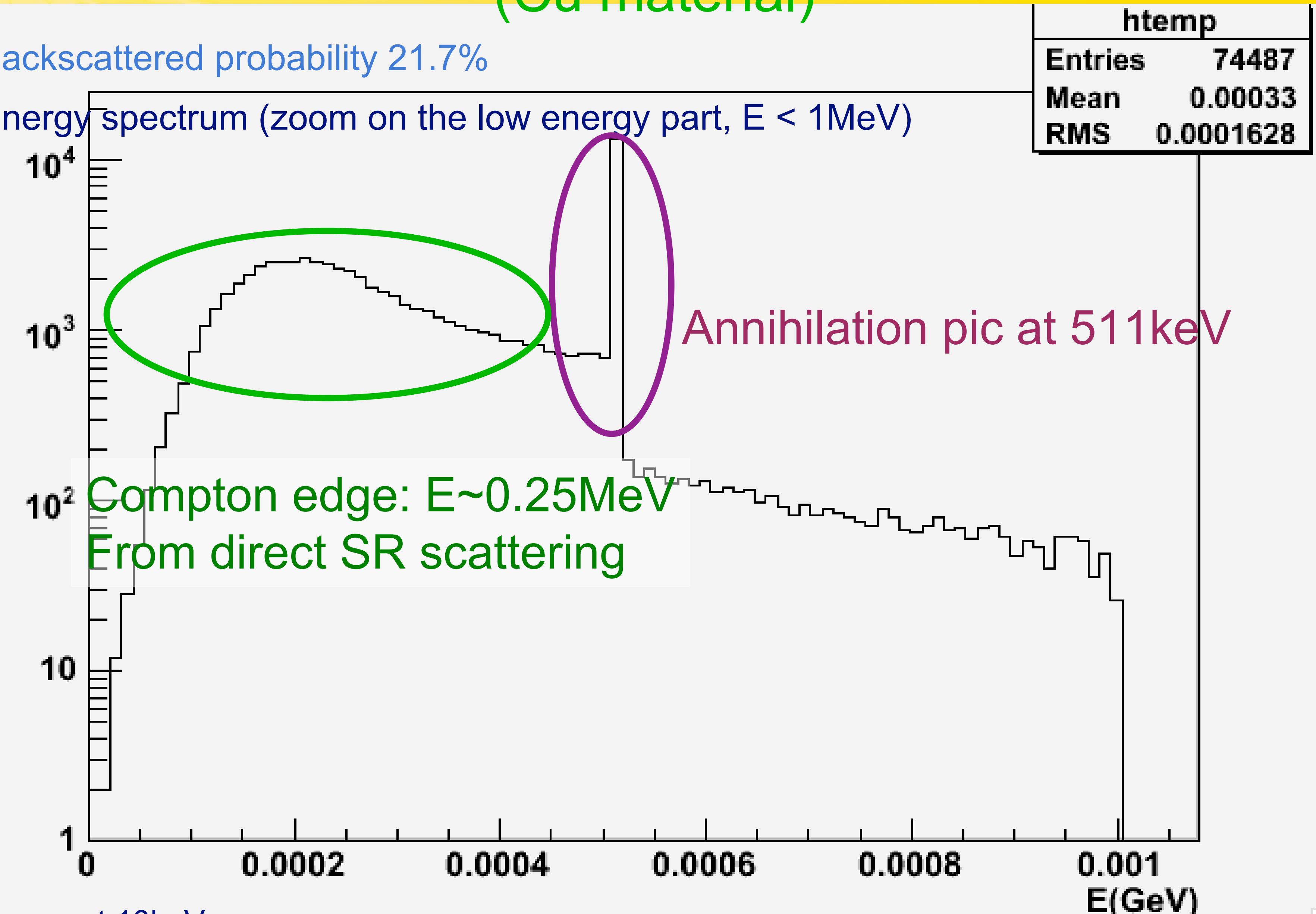
The beam passes off axis at QD0 and sees the coil pocket of QF1



Backscattered photon energy from SR
(Cu material)

Backscattered probability 21.7%

Energy spectrum (zoom on the low energy part, E < 1MeV)

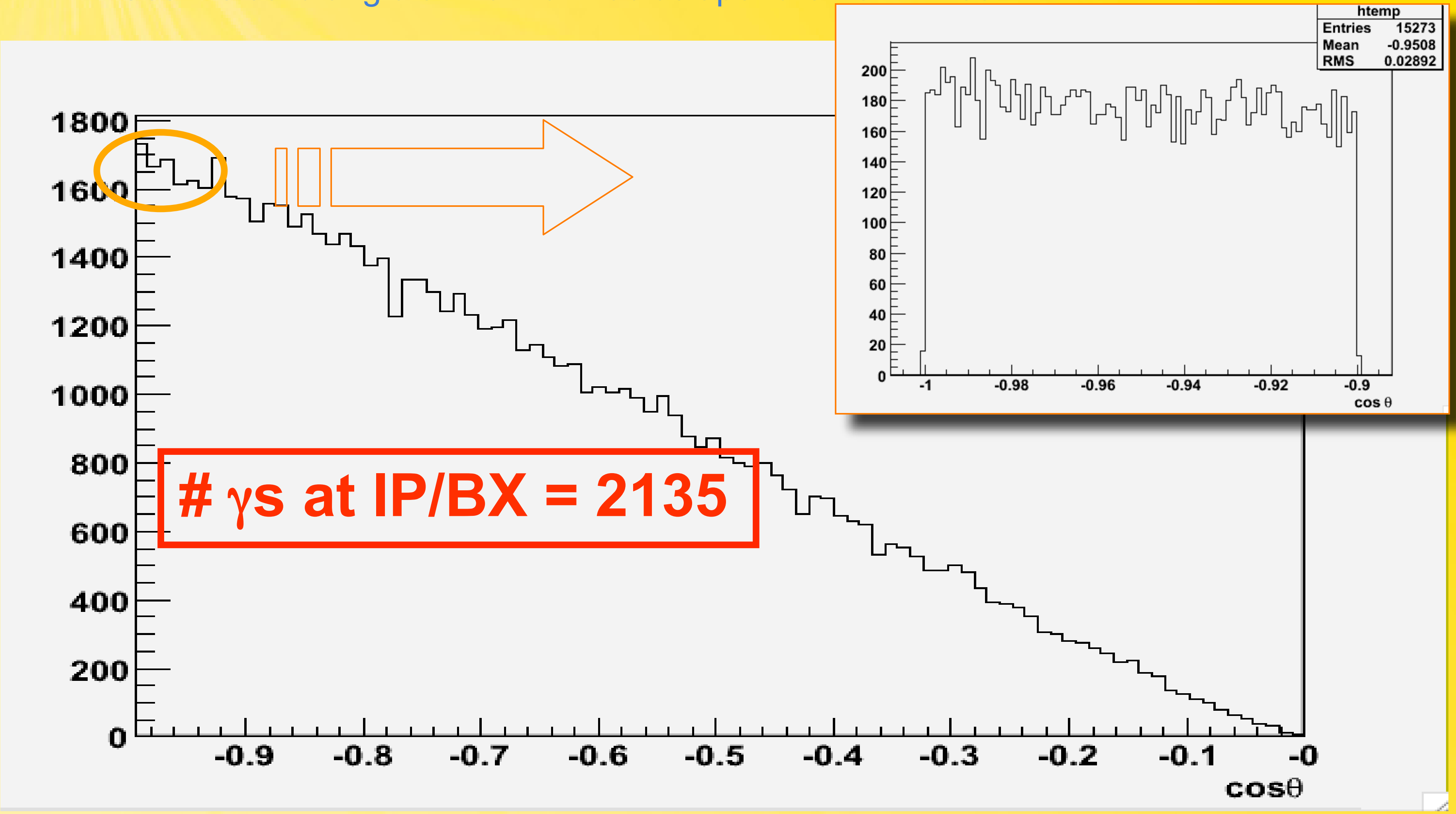


Energy cut 10keV …

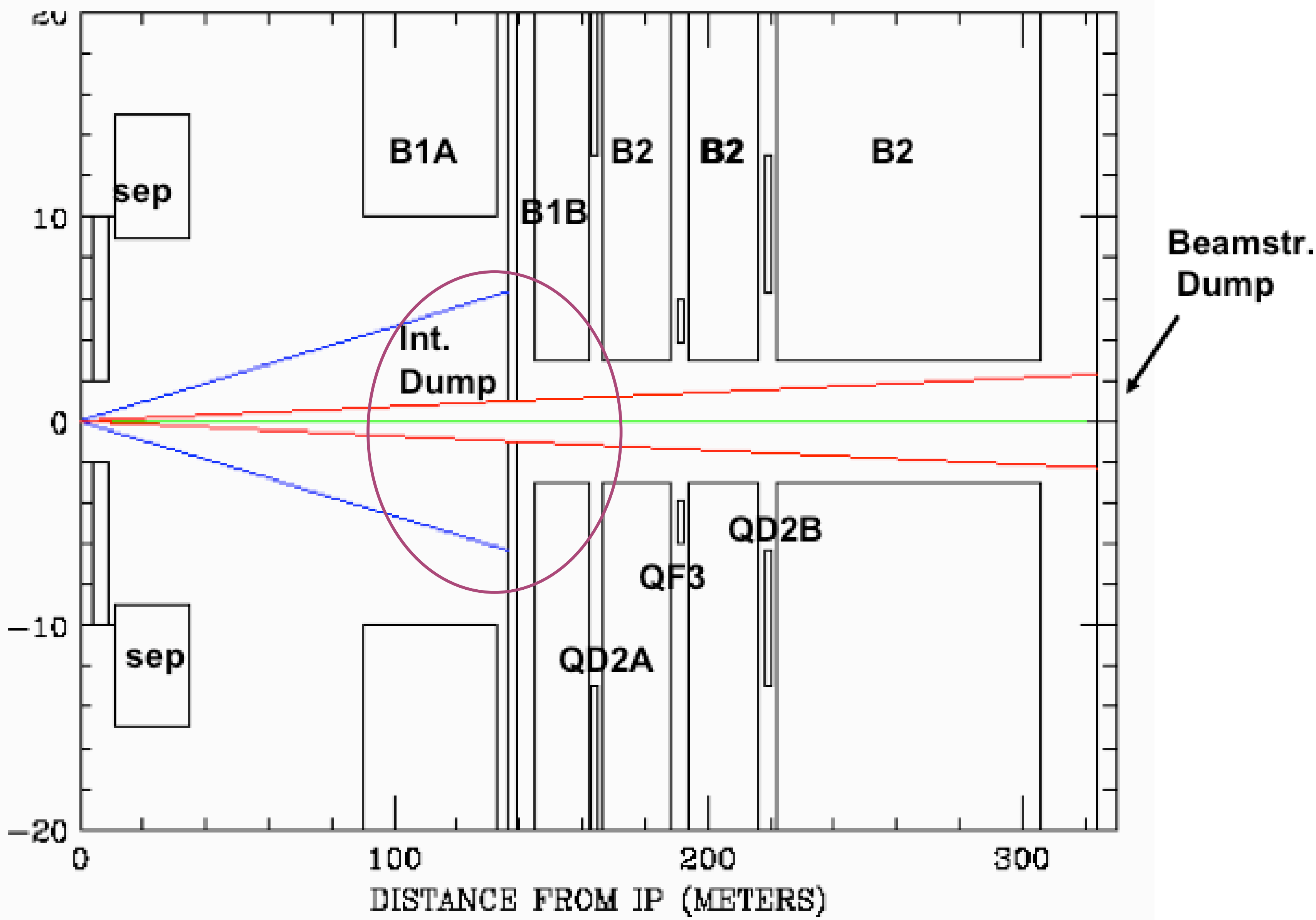
Backscattered photon

To estimate the photon flux within 2 cm BeamCal aperture.

- Find the backscattering rate in -1 < cosθ < -0.9, almost flat region
- Use the solid angle of the 2 cm radius aperture from z= 89m



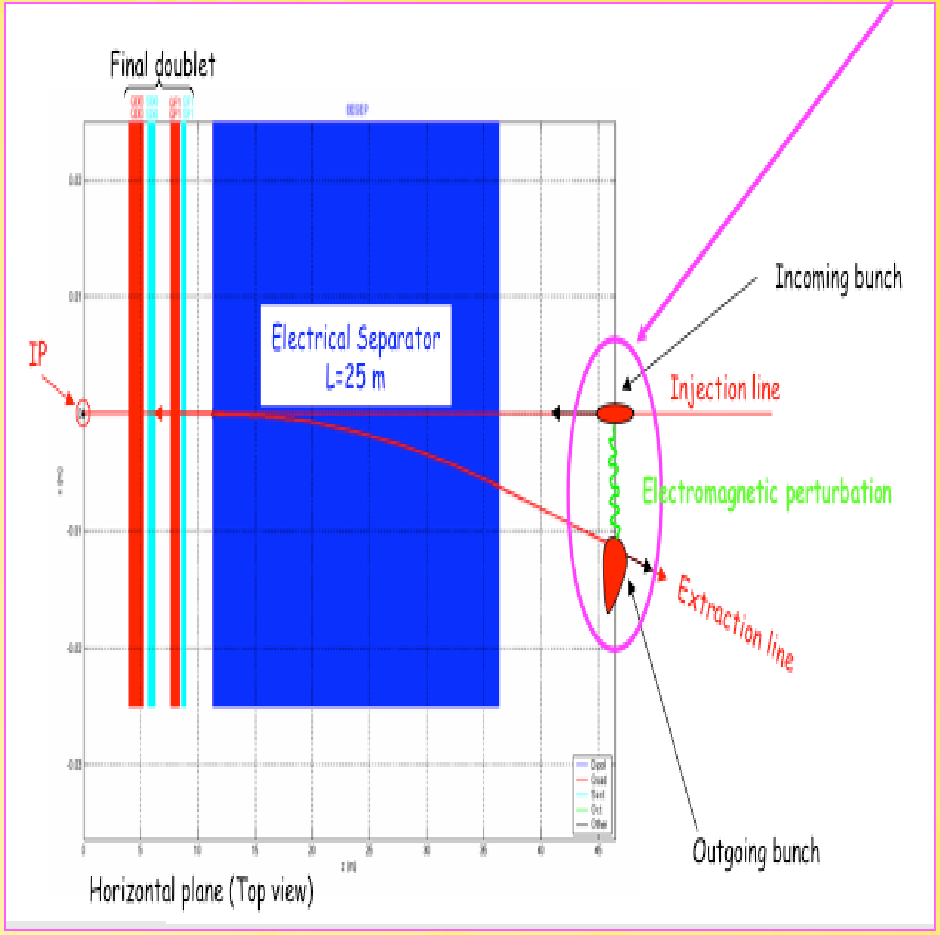
Head On

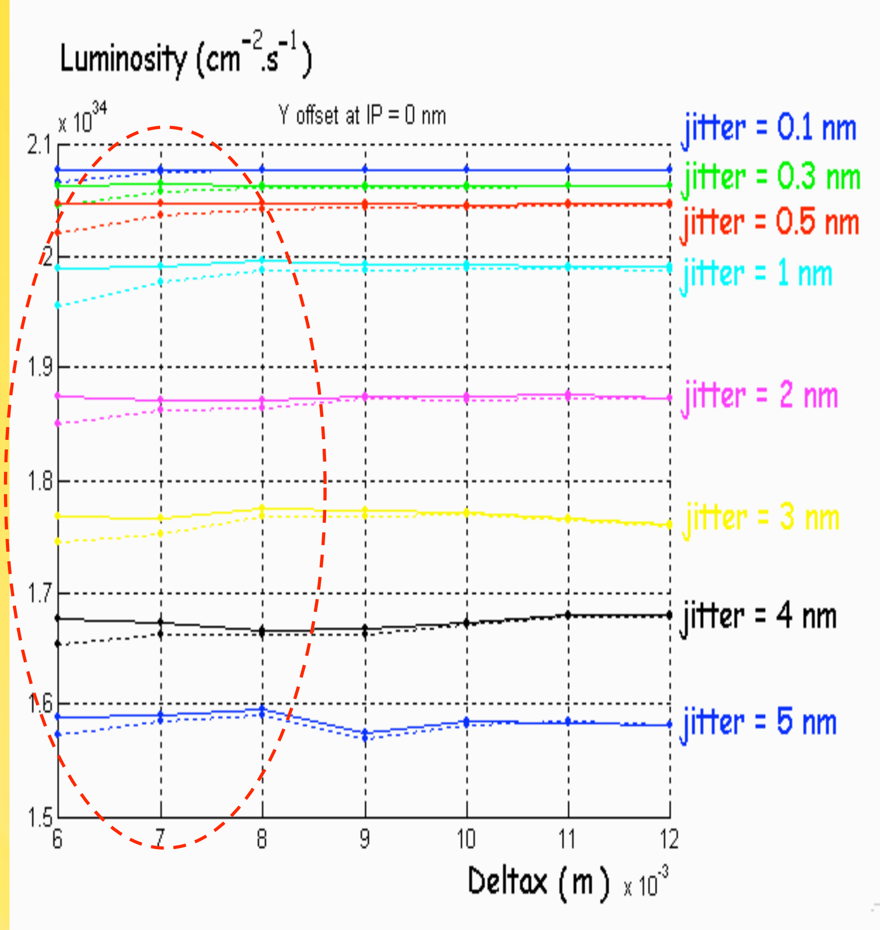


sep
B1A
B2
B2
B2
B1B
10
Beamstr.
Dump
Int.
Dump
0
QD2B
QF3
−10
sep
QD2A
−20
0
100
200
300
DISTANCE FROM IP (METERS)

Multi bunch kink instability

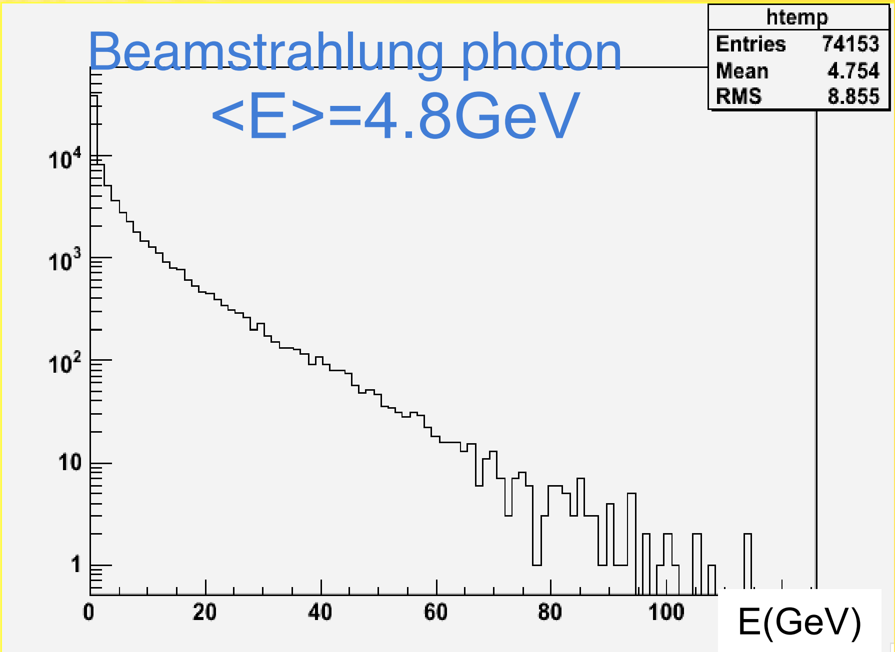
Residual random motion (jitter) not corrected by the feedback loop can reduce the luminosity in any IR arrangement. In the head-on scheme, the kick from the (first) Parasitic crossing can amplify this reduction. Must ensure that this amplification is negligible by making the horizontal separation large enough.

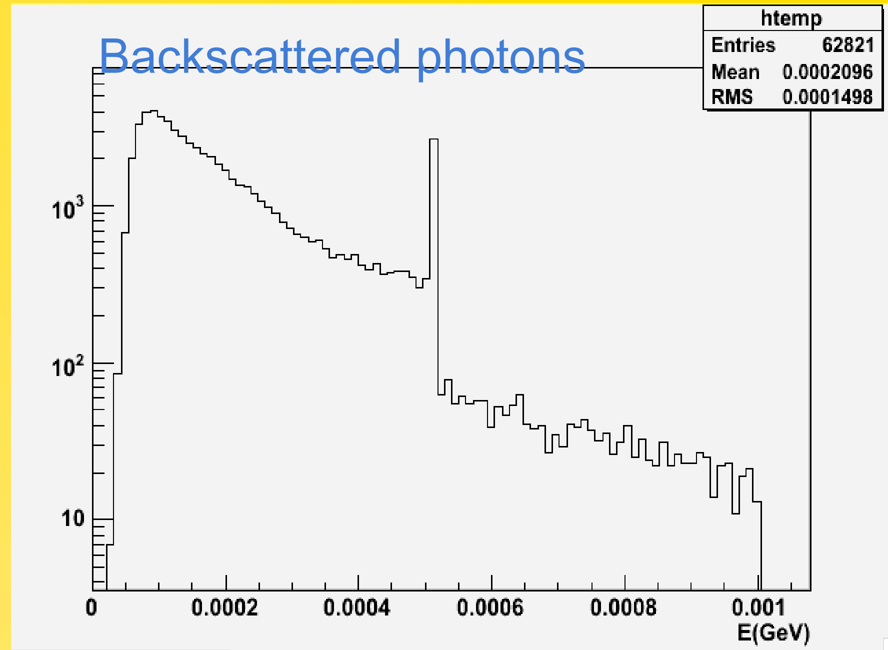


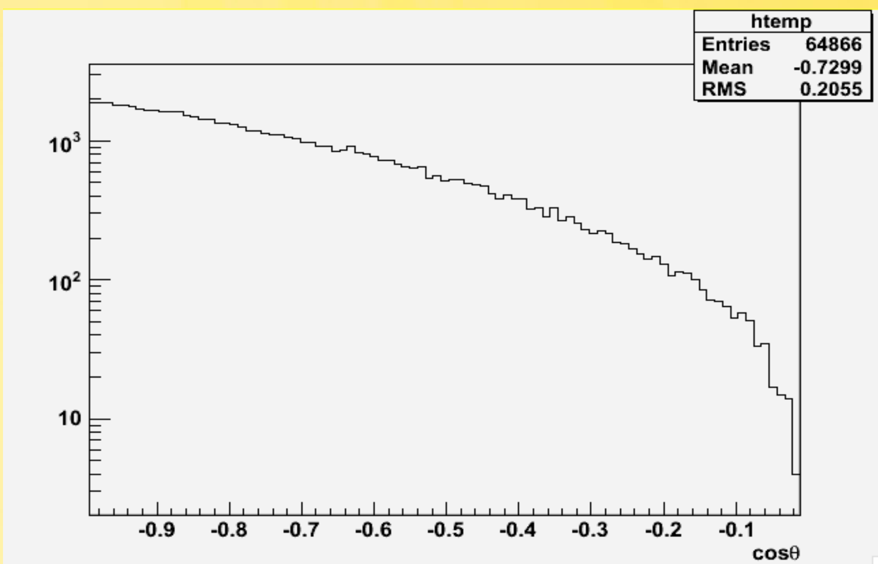


Julien Brossard

Backscattered photons from Beamstrahlung @ Inter. dump

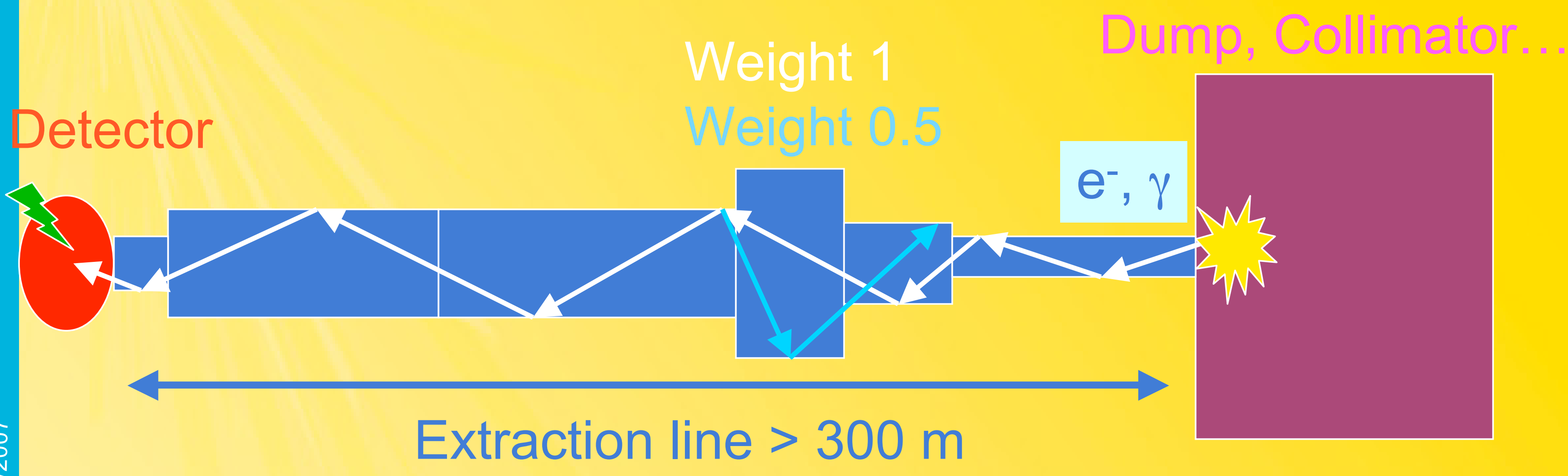






160 backscattered photon/BX

Prospects



- Very few invent in Detector event for huge statistic
- Event biasing method class already exist in Geant4 (for hadronic process)
Biasing secondary production in terms of particle type, momentum distribution, cross-section …
- Need to implement it in BDSIM simulation
- Collaboration with Marc Verderi from LLR (ANR ATF2)

Conclusion

- Incorporate the polarization inside the simulation of e^+ source
- For the different crossing angle scheme study the backscattered particles (even if there is no beam loss for 14mrad we need to study the secondary from collimator and dump)
- Need to simulate the behavior of backscattared particles in the detector(s) using specific tools: Mokka and Marlin
- Implement the event biasing method
- Simulation of secondary generated along the extraction line is very CPU time consuming
  All the simulations is done using the grid

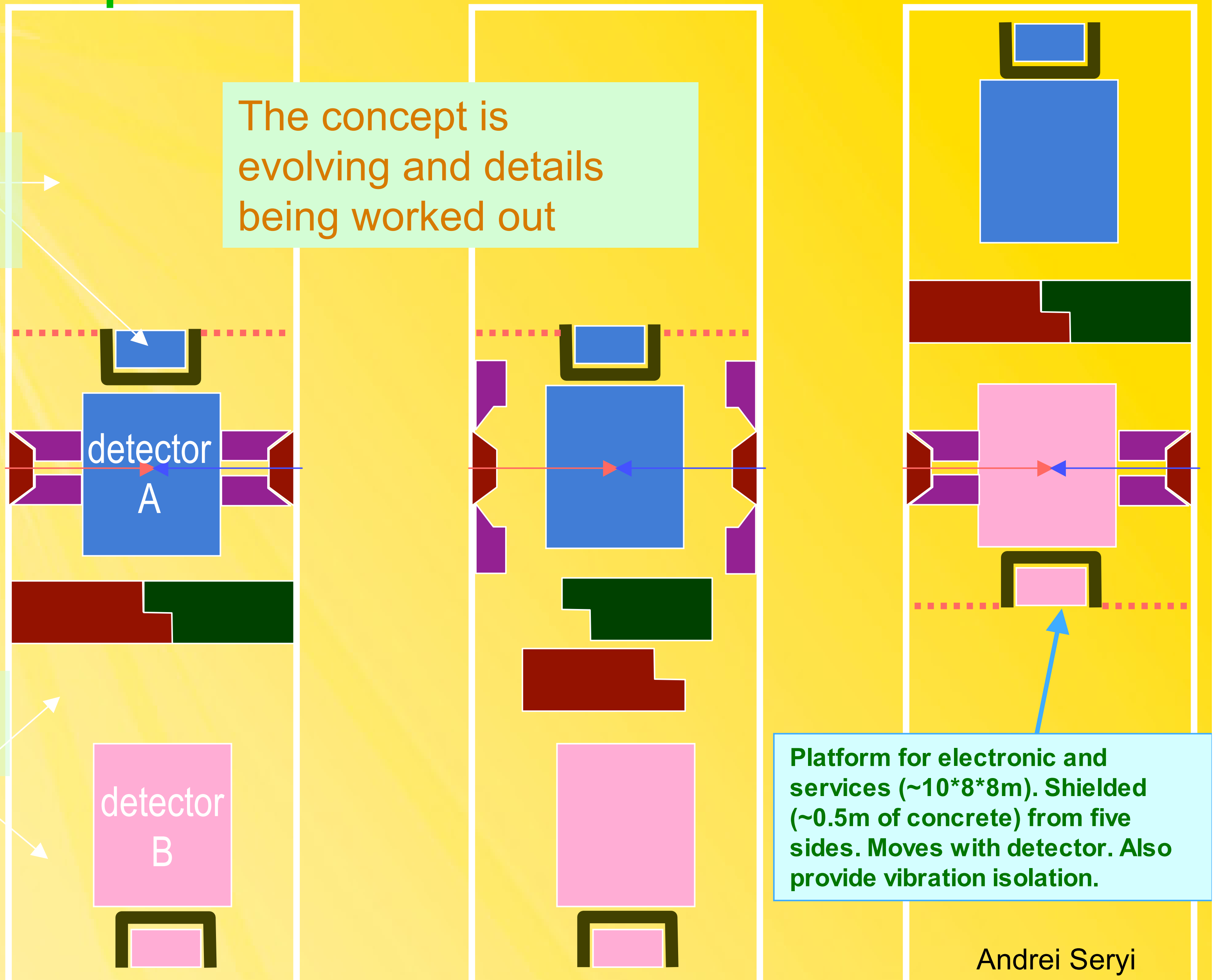
thanks to grid.support@lal.in2p3.fr and Charles Loomis

Extra Slides

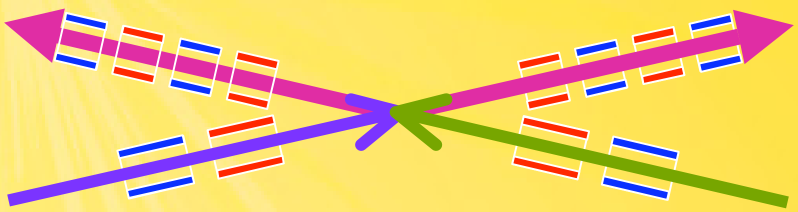
Concept of IR hall with two detectors

may be accessible during run

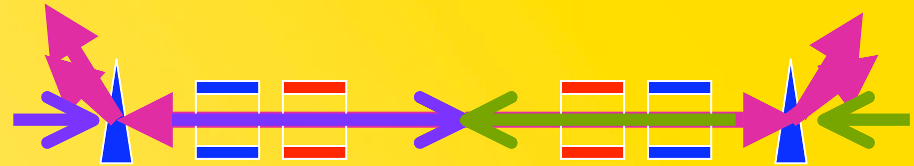
accessible during run



Choice of crossing angle influence



- Incoming and outgoing beam are independent
- Disrupted beam with large energy spread captured by alternating focusing, no need to bend the beam after collision => easier to minimize beam losses
- Require compact SC quads and crab cavity
- The exit hole un-instrumented => loss of detector hermeticity (-)
- Low energy pairs spread by solenoid field => somewhat larger background

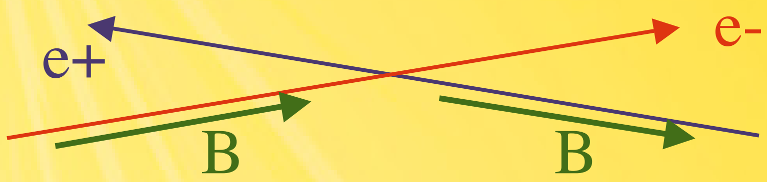


- No extra exit hole => somewhat better detector hermeticity (+)
- Low energy pairs spread less => somewhat better background (+)
- Require electrostatic separator with B-field or RF-kicker
- Incoming and outgoing magnets shared => difficult optics, collimation apertures set by outgoing beam (-)
- Need to bend disrupted beam with large energy spread => beam loss, especially at high energy, MPS (-)

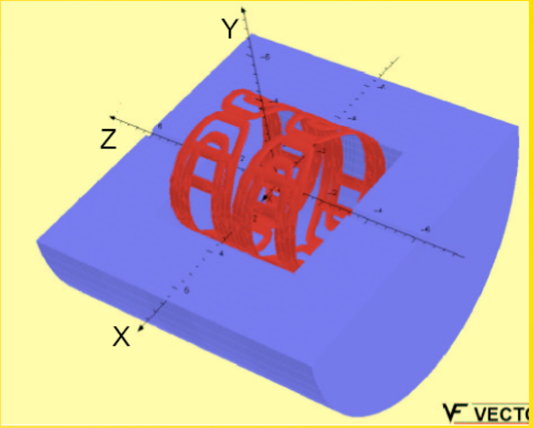
Andrei Seryi

DID and anti-DID

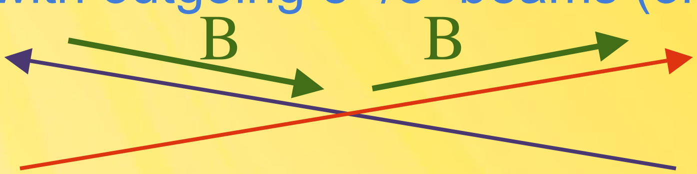
- Detector Integrated Dipole field has been suggested to correct for unwanted machine effects in the crossing angle case
- Align B with incoming e+/e- beams (on av.) : **DID**



  - Solves SR emittance growth.
  - ×2 Bt for outgoing beams
    → Worse pair background



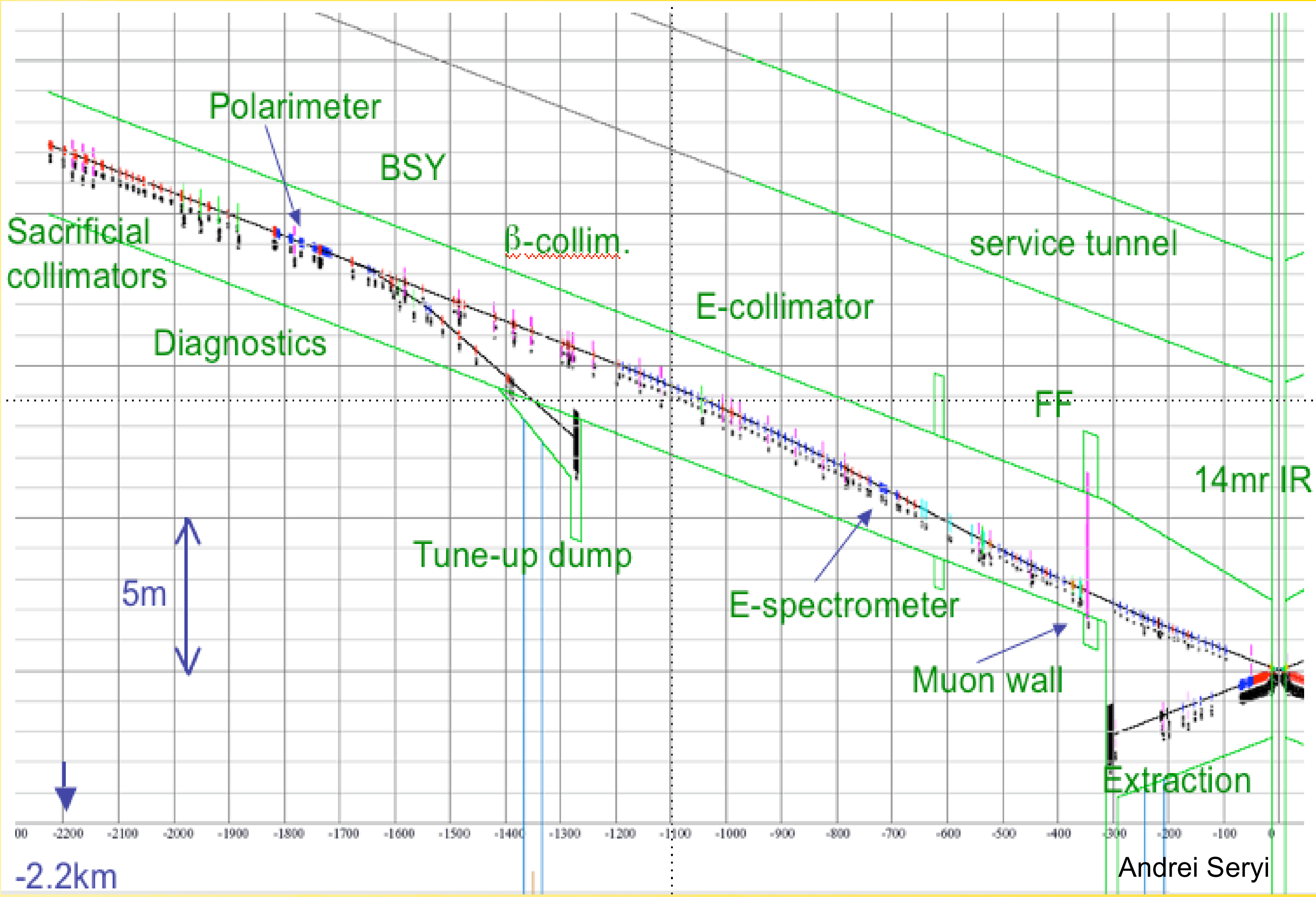
- Align B with outgoing e+/e- beams (on av.) : **antiDID**



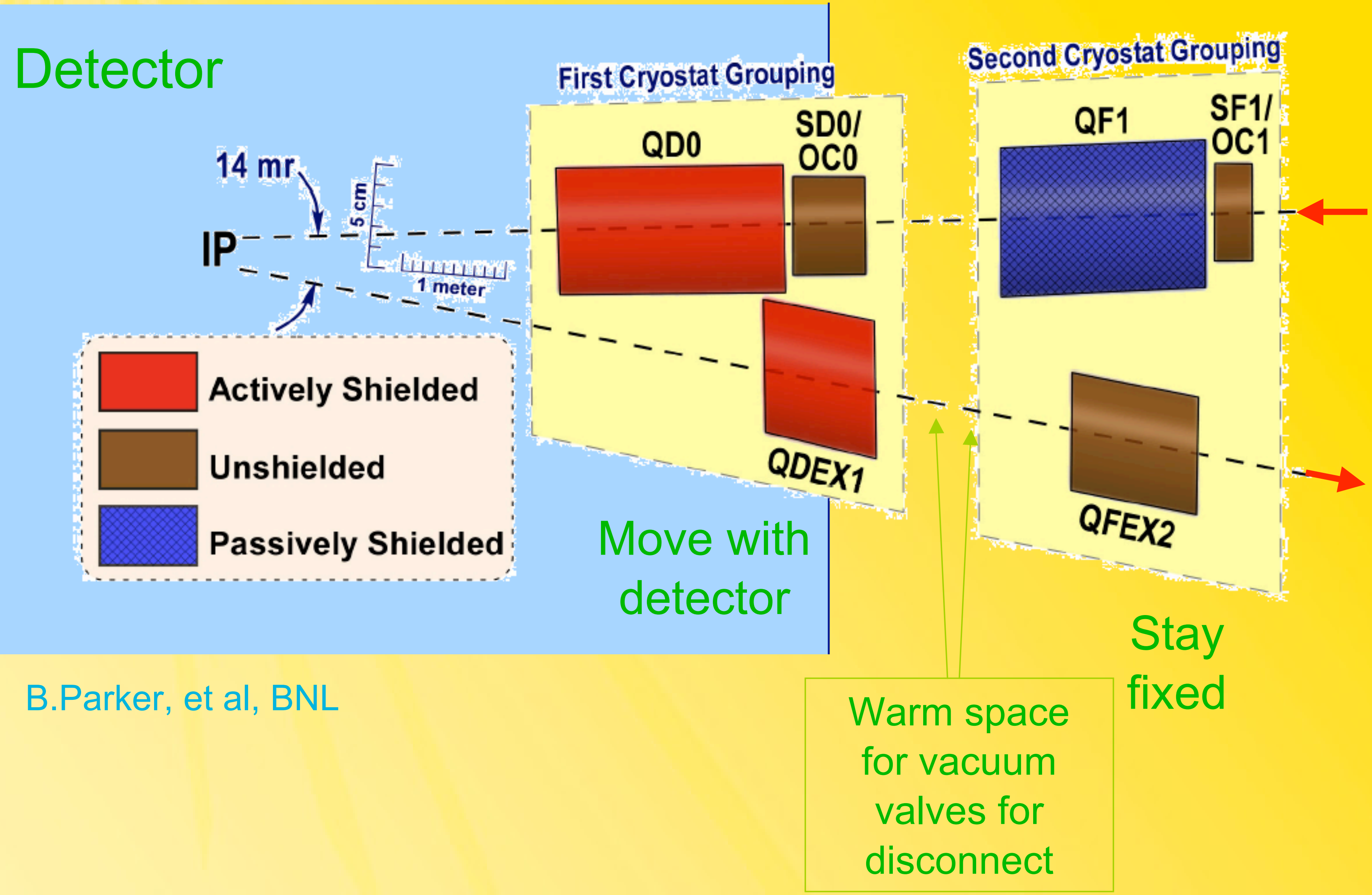
  - Pair background ~ 0mrad xing angle.
  - ×2 Bt for incoming beams
    → Worse for SR emittance growth

DID or antiDID, not both simultaneouly

BDS Layout for New Baseline

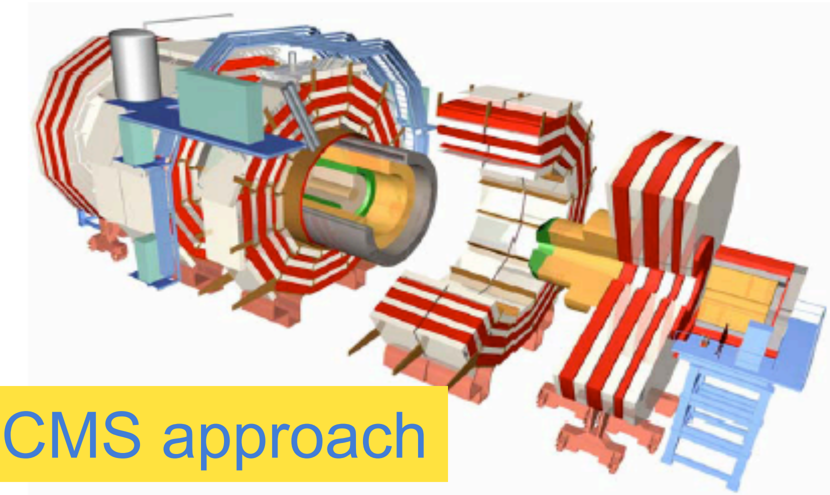


IR conceptual design

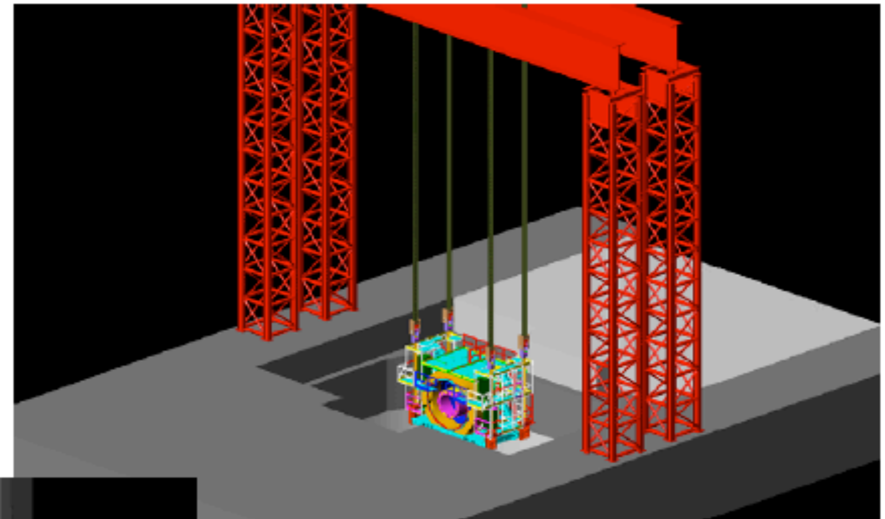


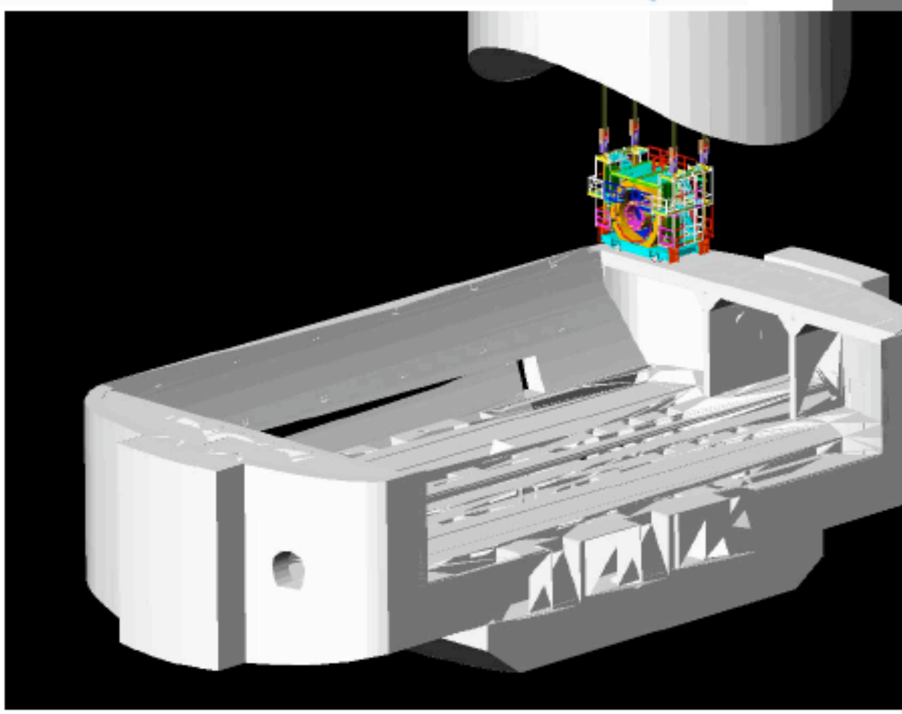
B.Parker, et al, BNL

On-surface assembly of ILC detectors



CMS approach





- **Assembled on the surface in parallel with underground work**
- **Allows pre-commissioning before lowering**
- **Lowering using dedicated heavy lifting equipment**
- **Potential for big time saving**
- **Reduce size of underground hall required**