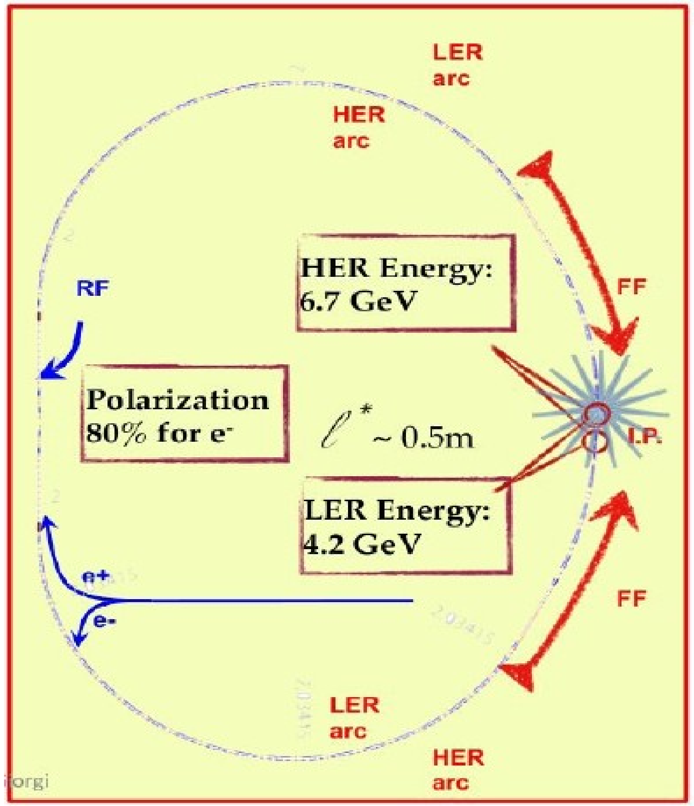
IPHC seminar – Apr. 5^{th} 2013

Bruno: a simulation tool for Machine backgrounds in a e^+e^- collider



Alejandro Pérez
INFN – Sezione di Pisa

Research activities: overview

- **BaBar (since 1/2006)**
  - Charmless three-body B decays (2006 - 2008): $B^0 \to K^0_s \pi^+\pi^-$ (thesis, LPNHE)
  - Radiative penguins (since 7/2009): $B \to X_s \gamma$ (post-docs at LAL and INFN-Pisa) **(Ongoing)**
- **CKM matrix phenomenology group (CKMfitter) (2008, thesis LPNHE)**
  - CKM phenomenology with $B \to K\pi\pi$ modes
- **SuperB-LAL group (Post-doc, 2009-2010)**
  - SuperB Detector parametric simulation (fast-sim): Semi-leptonic recoil package manager
  - Detector Layout Optimization: Physics potential of $B \to K^{(*)}\nu\nu / B^+ \to l^+(\tau,\mu,e)\nu$ modes
- **SuperB-INFN Pisa group (1st INFN Post-doc, 2010-2012)**
  - SuperB detector Geant4 simulation: Machine Detector Interface and final focus model
  - Coordinator of Geant4 simulation production and analysis: Machine background studies
  - Fast-sim background mixing framework: mixing of physics event with machine background
  - Physics task force: SuperB physics reach and comparison with other experiments
- **INFN Pisa (2nd INFN Post-doc, Since Sep. 2012)**
  - Since the latest news about cancellation of SuperB the group is moving on to Belle-II
  - SLIM5 collaboration: test of very low material silicon detectors for tracking applications

Outline

- **Introduction**
  - Hadron vs e+e- colliders (1 slide)
  - A low-energy/high-intensity e+e- collider: Super-KEKB and Belle-II
  - A high-energy/low-intensity e+e- collider: ILC

- **Machine induced backgrounds**
- **Bruno: a machine backgrounds simulation tool**
  - The tools
  - Types of machine backgrounds:
    Rad-bhabha, 2-photon, Touschek and beam-gas
  - An application example: rates induced on the SuperB detector

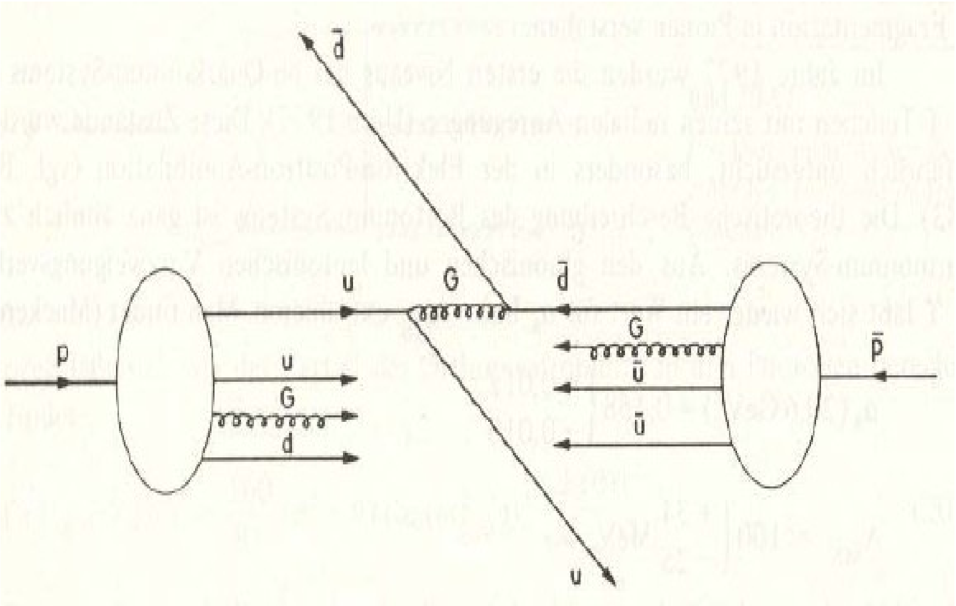
- **Summary and outlook**

Introduction

Hadron vs e+e- colliders (I)

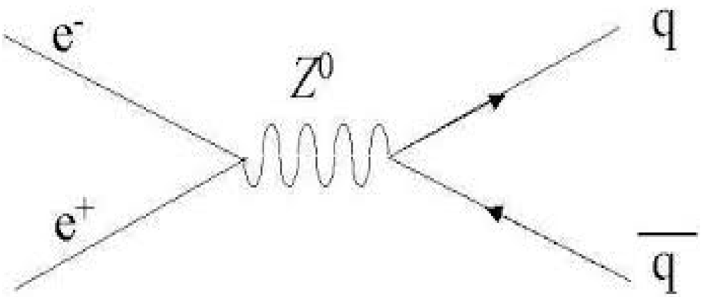
Hadron colliders

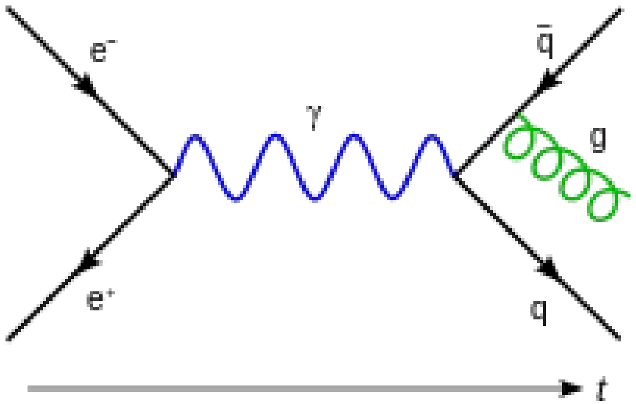
- Proton-proton collisions are more complex
  - More complex interactions due to proton substructure
  - Only part of the pp centre-of-mass energy available in the hard scattering process



e^+e^- colliders

- Excellent for precision physics!!
  - e^+e^- are point-like particles, no substructure $\Rightarrow$ clean events
  - Complete annihilation, centre-of-mass system, kinematics fixed





Hadron vs e+e- colliders (II)

Energy loss due to synchrotron radiation

- Radiated power: $$P = \frac{2\, e^2\, c}{3\, R^2} \left(\frac{E}{mc^2}\right)^4$$
- Energy loss per turn: $$-\Delta E \approx \frac{4\, \pi\, e^2}{3\, R} \left(\frac{E}{mc^2}\right)^4$$
- Ratio of energy loss between protons and electrons: $$\frac{\Delta E(e)}{\Delta E(p)} = \left(\frac{m_p}{m_e}\right)^4 \sim 10^{13}$$

<u>Hadron colliders</u>

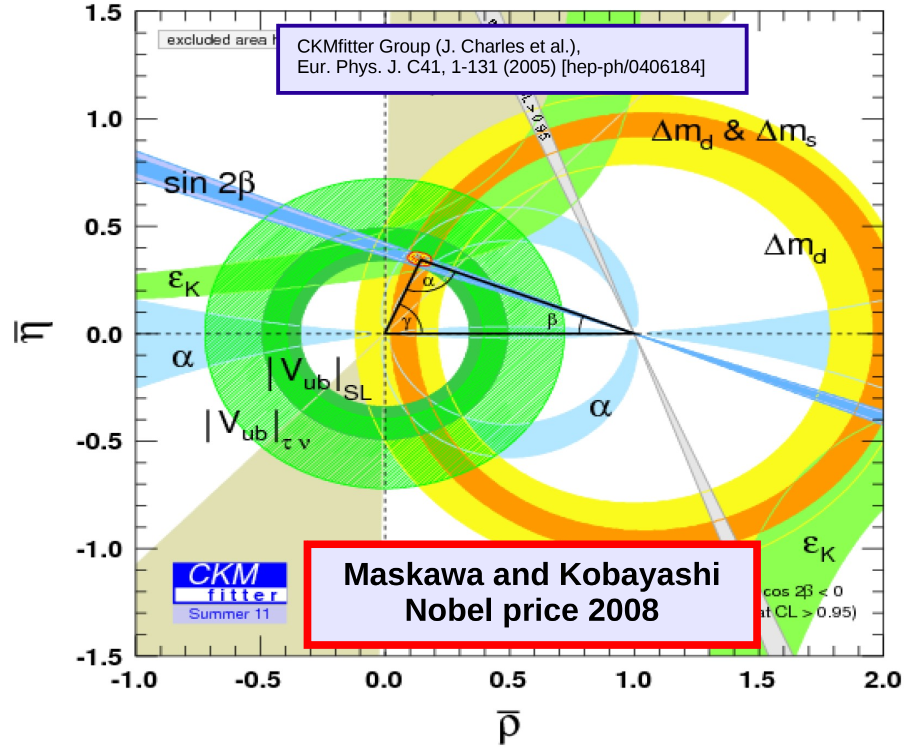
- Relatively small energy loss in circular rings
- Need high bending magnetic fields for high energies (8.3T in LHC magnets)

<u>e^+e^- colliders</u>

- Significant energy loss in circular rings
- Need significant acceleration gradient in linear accelerators (ILC design ~40MV/m)

Flavour physics and New Physics searches

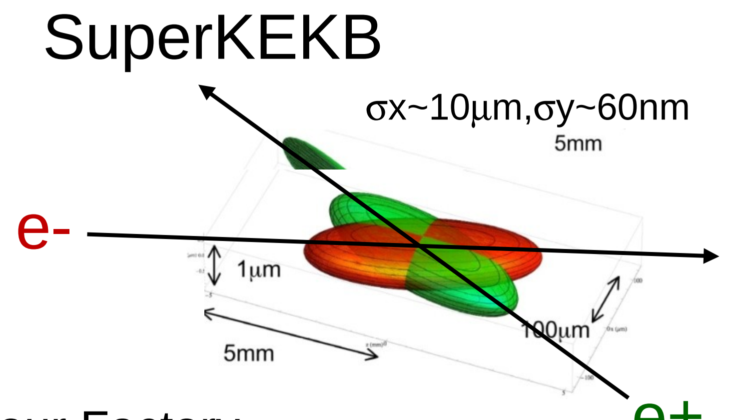
- **Direct new physics (NP) searches up to 1TeV scale are possible at LHC (ATLAS and CMS)**
- **Complementary approach (**high energies → high statistics**):** precision measurements on the flavour sector of the Standard Model (SM)
  - NP can reveal themselves via virtual effects in decays of SM particles (B and D)
  - The smallness of the effect depends on the NP energy scale ⇒ sufficiently precise measurements can allow to extend the NP searches beyond 1TeV
- **BaBar, Belle, Tevatron:** defined current flavour physics landscape
  - Substantially confirm CKM picture
  - No evidence on NP
  - Placed constraints (indirect) on NP that wont be superseded well into the LHC era (e.g. H^+ searches)
- **New generation of B-factories (Belle-II and LHCb) results will be used to constrain the flavour dynamics at high energy**



Belle-II: low-E/high-intensity e+e- collider

Belle II is expected to start taking data in 2016, and 1st full run expected to be completed one year later:

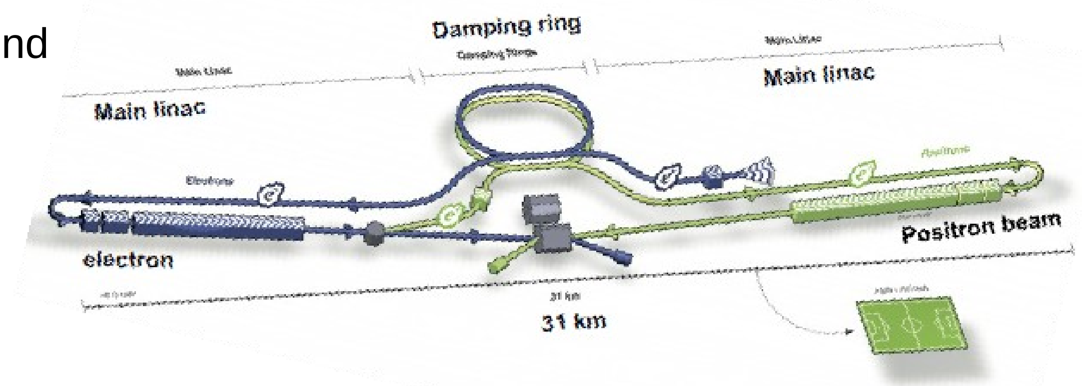
- Increase the luminosity by 40 times based on "Nono-beam" scheme proposed for SuperB by P. Raimondi



- $\Upsilon(4S)$ - peak asymmetric energy e^+e^- Super Flavour Factory
- Detector: moderately improved Belle detector
- Accelerator: **~40xB-factories luminosity.** Same power by squeezing beams (ILC)
- $L = 7.0 \times 10^{35}\ cm^{-2}s^{-1}$ around the $\Upsilon(4S)$
  - Y(4S): coherent B mesons & time-dep. measurements, charm hadrons, tau leptons
  - Emphasis: new physics sensitivity competitive and complementary with LHC experiments
  - Don't forget: e^+e^- clean data for precision measurements in almost every energy-accessible topic (with neutrals or missing momentum)

A high-energy/low-intensity e+e- collider

- **With the Higgs-like particle discovery**
  - We now have to face the missing dark matter in the SM
  - Compelling reasons for the next step
- **A new era of particle physics has begun ⇒ ILC is designed to lead the new era**
- **ILC in a nutshell:**
  - 500 GeV CM with 31 Km ⇒ upgrade later to ~1TeV CM with 50 Km
  - Beam size at IP: 6 nm x 500 nm x 300 μm
  - Luminosity ~2×10^{34} $cm^{-2}s^{-1}$
  - ~90% (30-60%) electron (positron) polarization
  - Precision measurements of SM and of possibly NP particles found at LHC



Machine induced backgrounds

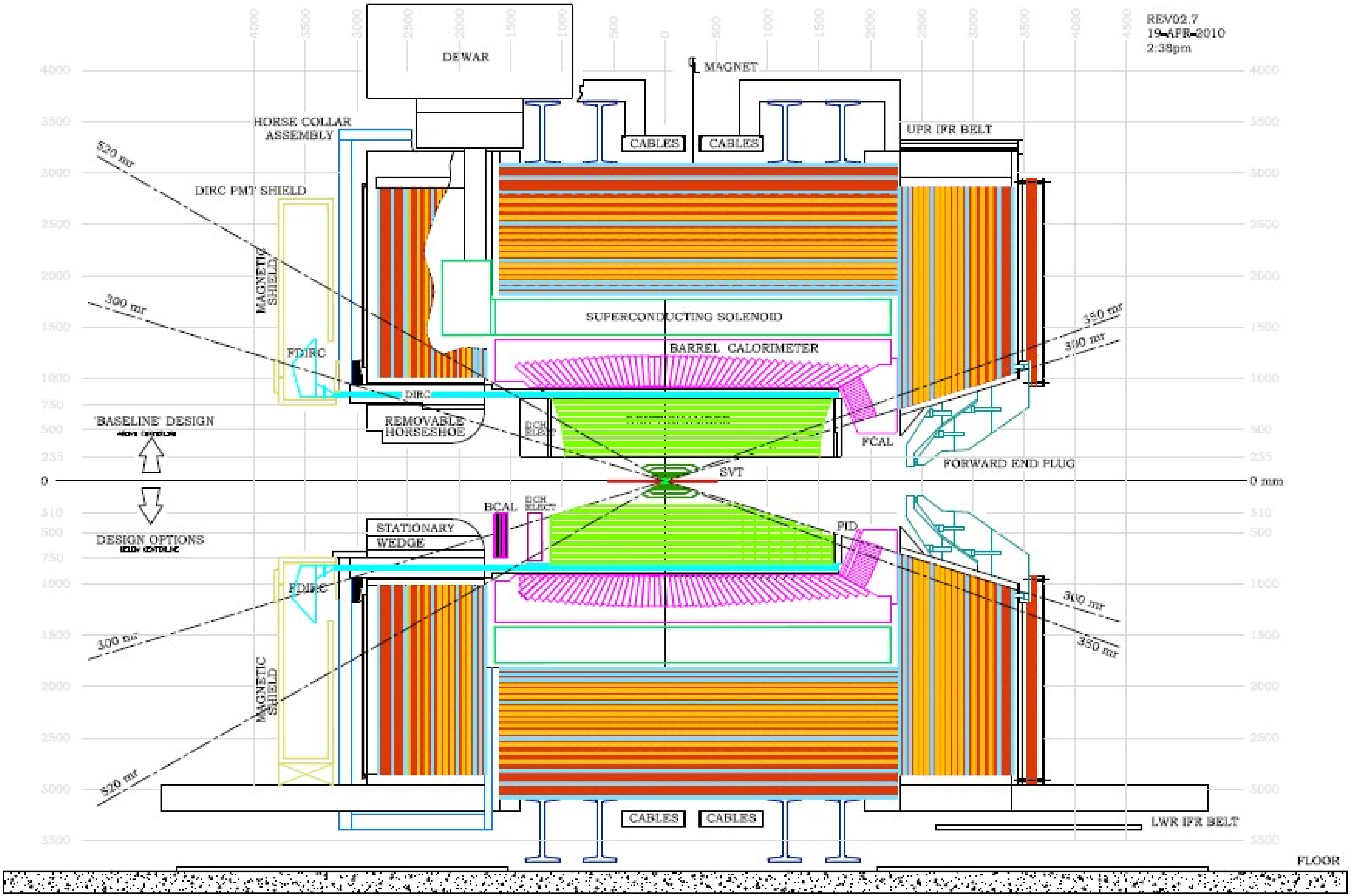
General remarks on machine backgrounds

- **Machine background considerations influence several aspects of the design**
  - Readout segmentation
  - Electronic shaping time
  - Data transmission rate
  - Triggering
  - Radiation hardness
- **Estimating machine induced backgrounds is strongly influenced by the imagination of the physicist**
  - Use intuition/experience to come-out with a list of possible background sources
    - The effectiveness of a given process depends on the production rate and the efficiency to produce hit in the apparatus
  - Need to define a way to generate the processes with the right kinematics $\Rightarrow$ primaries generation
    - Use all available generators on the market which are truth wordy
  - Then need to simulate the propagation and interaction of this primaries through the different elements of the experimental set-up

The Tools: primaries propagation

- **A Geant4 based program (code name Bruno, from Bruno Touschek) was created to:**
  - The transport of charged particles in the magnetic field of the final focus by numerical integration of the equation of motion
  - The magnetic field of the final focus is specified as a set of cylindrical regions in which the user prescribes dipolar and quadrupolar components of the field
  - The passage of particles through mater (machine elements)
  - The effects of secondaries in the detector (energy release, doses)
  - At present Bruno is not able to reconstruct the event
  - Each subsystem perform a post processing that “digitize” the energy releases: rates evaluation, impact on detector performances, physics reach

The SuperB Detector



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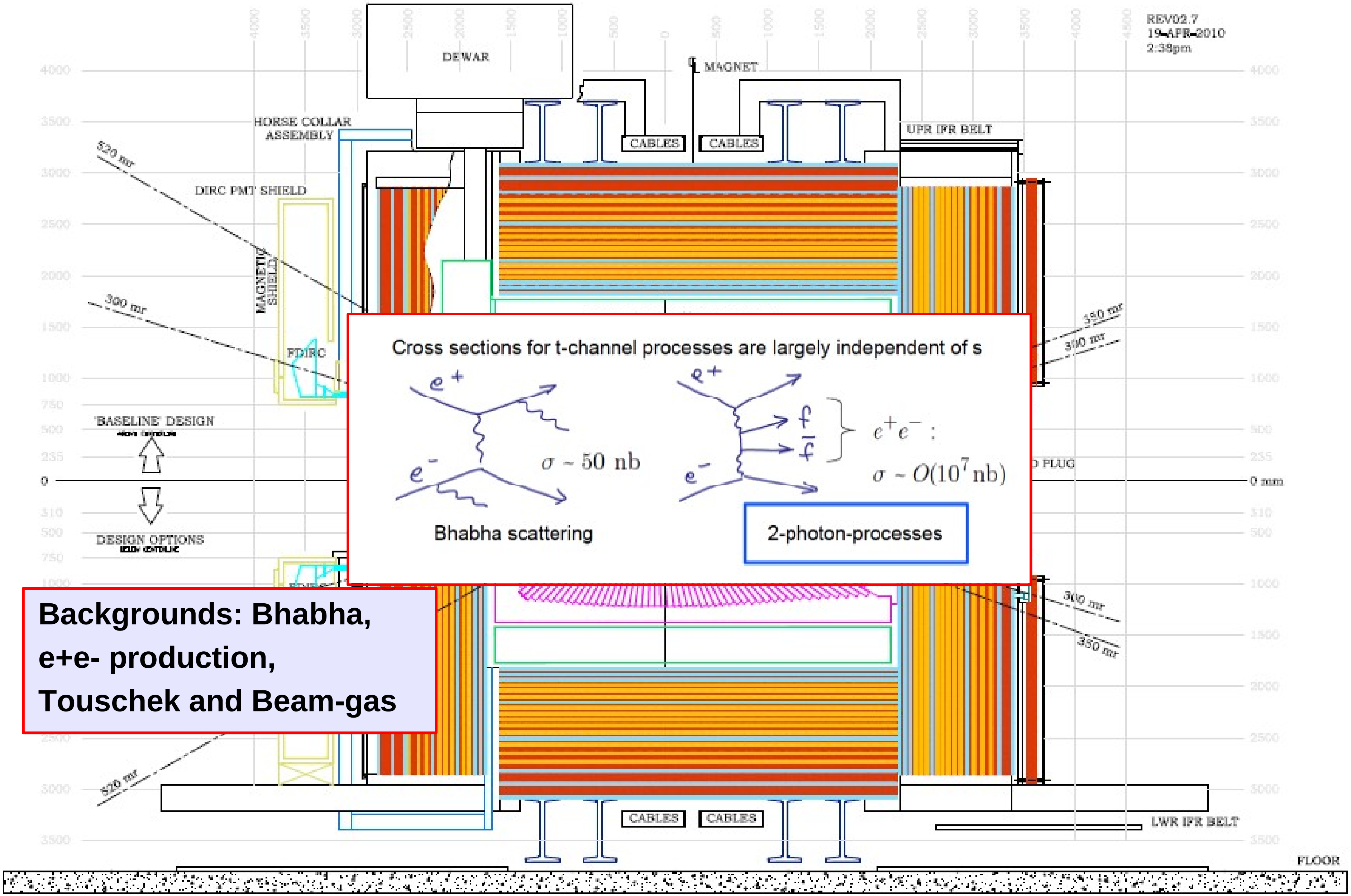
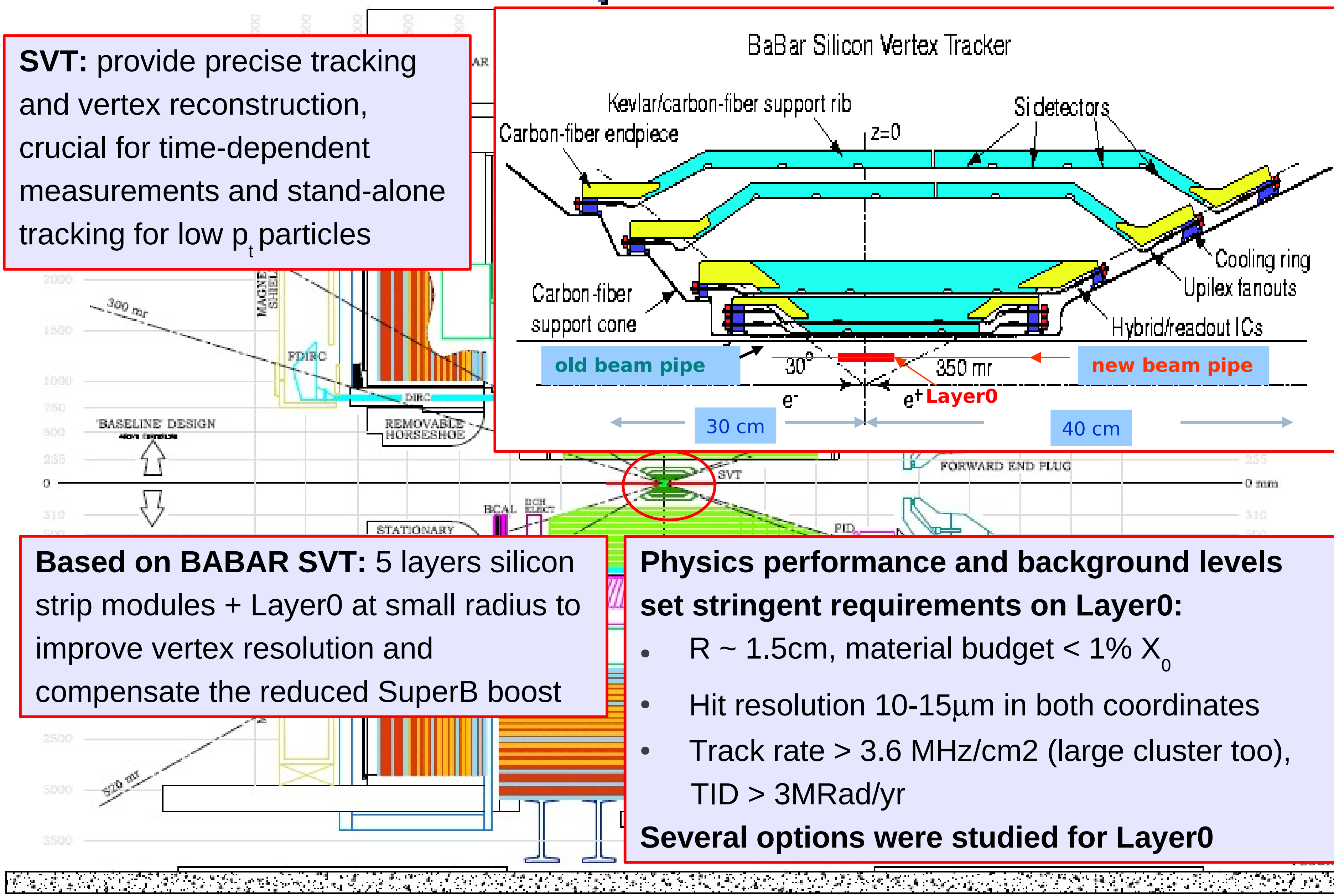


Backgrounds: Bhabha, e+e- production, Touschek and Beam-gas

The SuperB Detector



SVT: provide precise tracking and vertex reconstruction, crucial for time-dependent measurements and stand-alone tracking for low p_t particles

Based on BABAR SVT: 5 layers silicon strip modules + Layer0 at small radius to improve vertex resolution and compensate the reduced SuperB boost

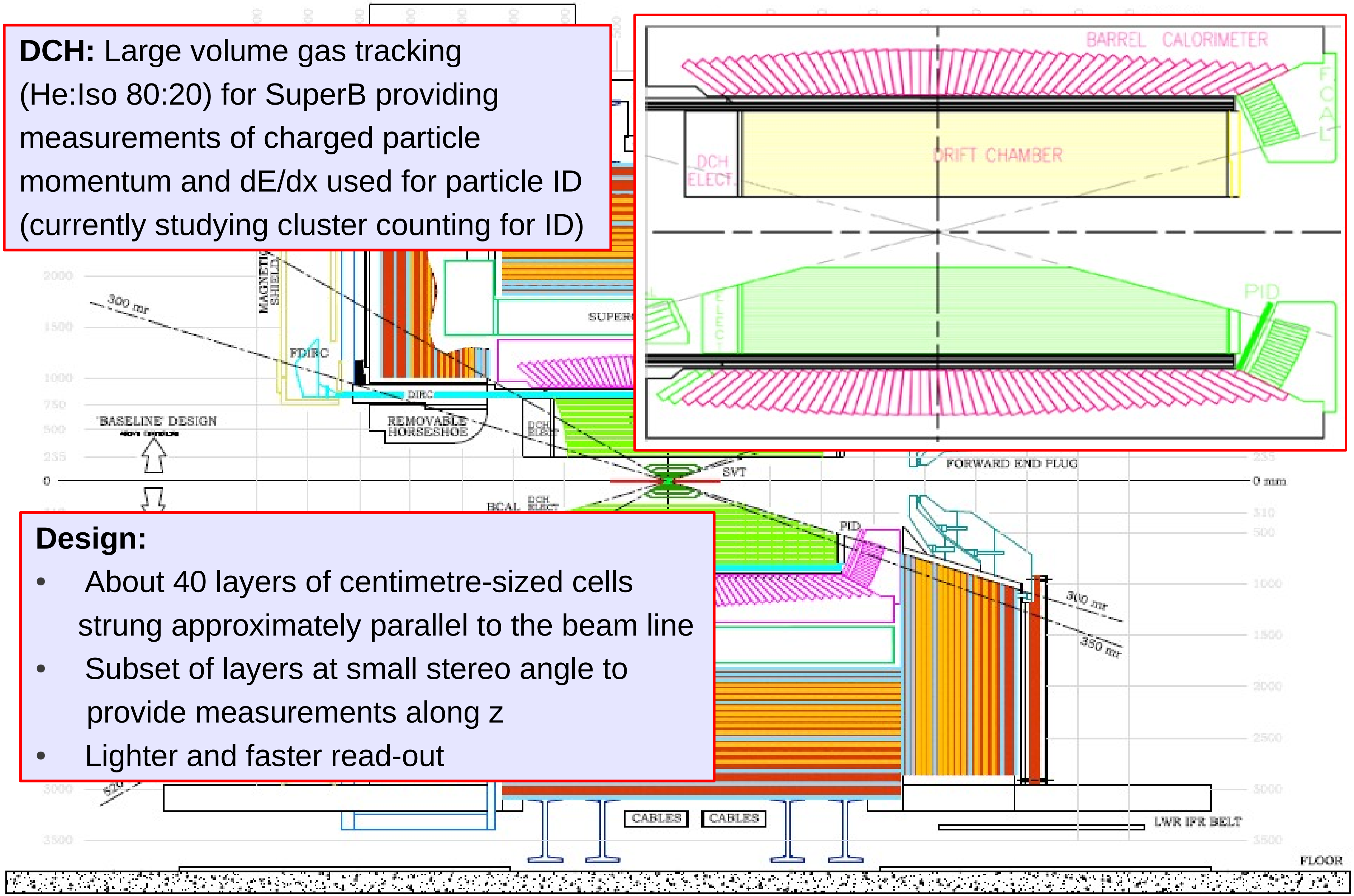
Physics performance and background levels set stringent requirements on Layer0:

- R ~ 1.5cm, material budget < 1% X_0
- Hit resolution 10-15µm in both coordinates
- Track rate > 3.6 MHz/cm2 (large cluster too), TID > 3MRad/yr

Several options were studied for Layer0

The SuperB Detector

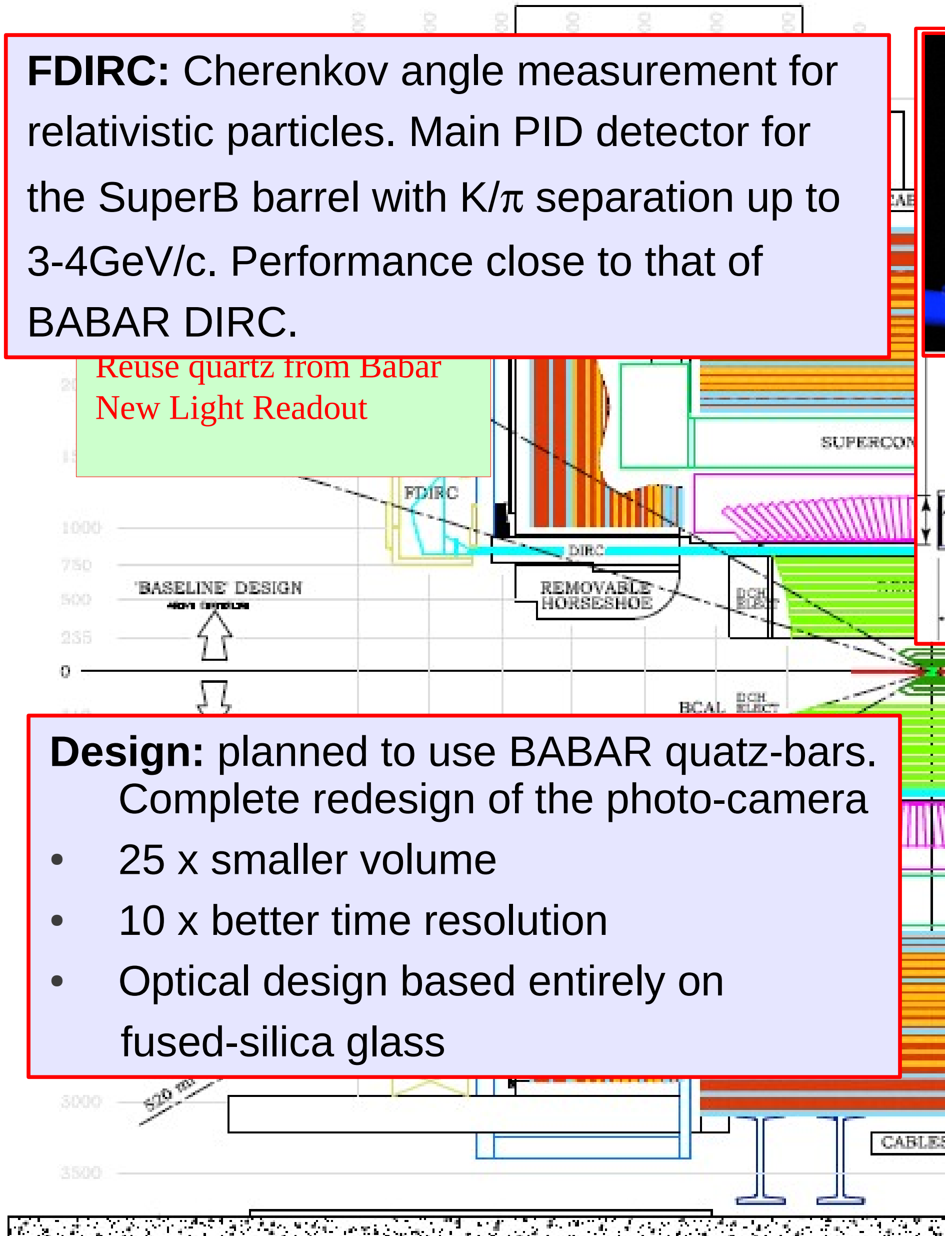
DCH: Large volume gas tracking (He:Iso 80:20) for SuperB providing measurements of charged particle momentum and dE/dx used for particle ID (currently studying cluster counting for ID)



Design:

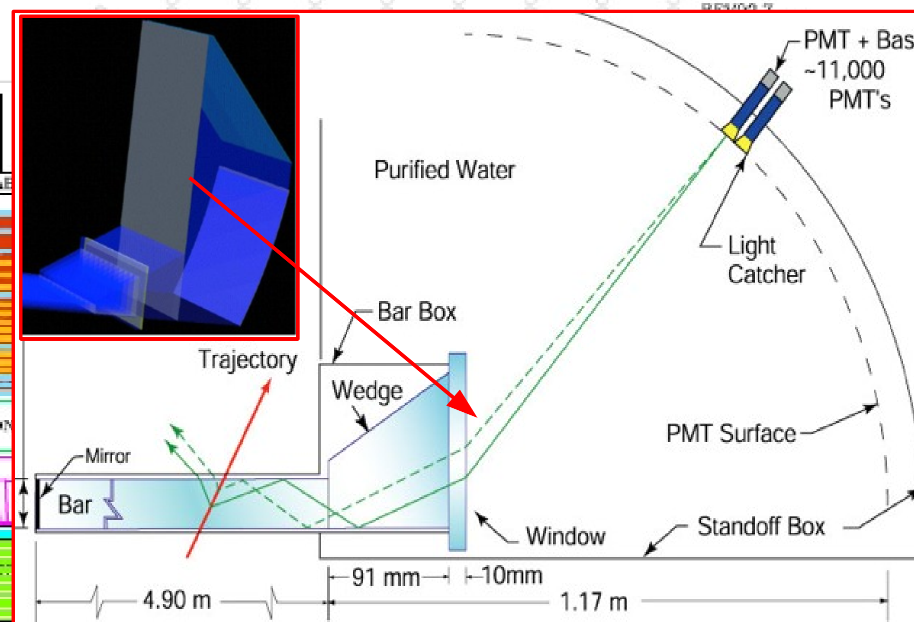
- About 40 layers of centimetre-sized cells strung approximately parallel to the beam line
- Subset of layers at small stereo angle to provide measurements along z
- Lighter and faster read-out

The SuperB Detector



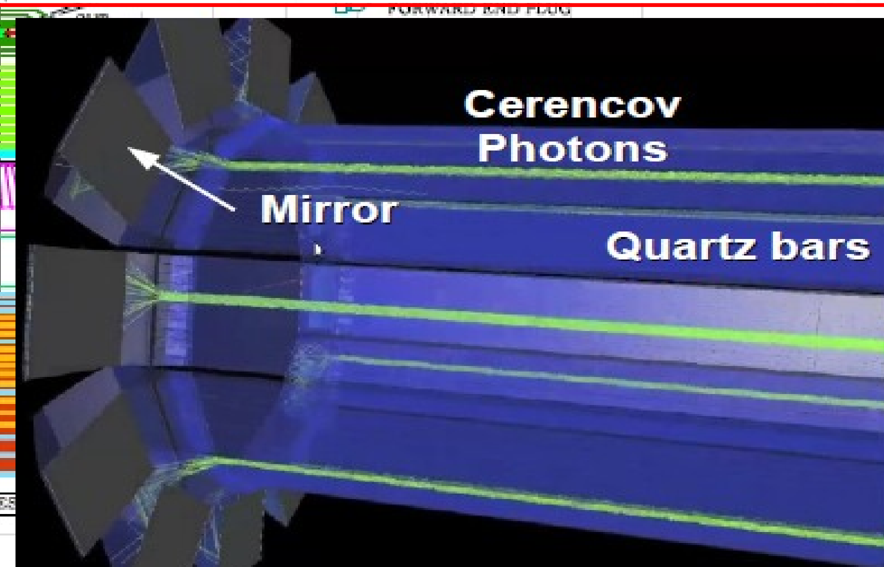
FDIRC: Cherenkov angle measurement for relativistic particles. Main PID detector for the SuperB barrel with K/π separation up to 3-4GeV/c. Performance close to that of BABAR DIRC.

Reuse quartz from Babar
New Light Readout



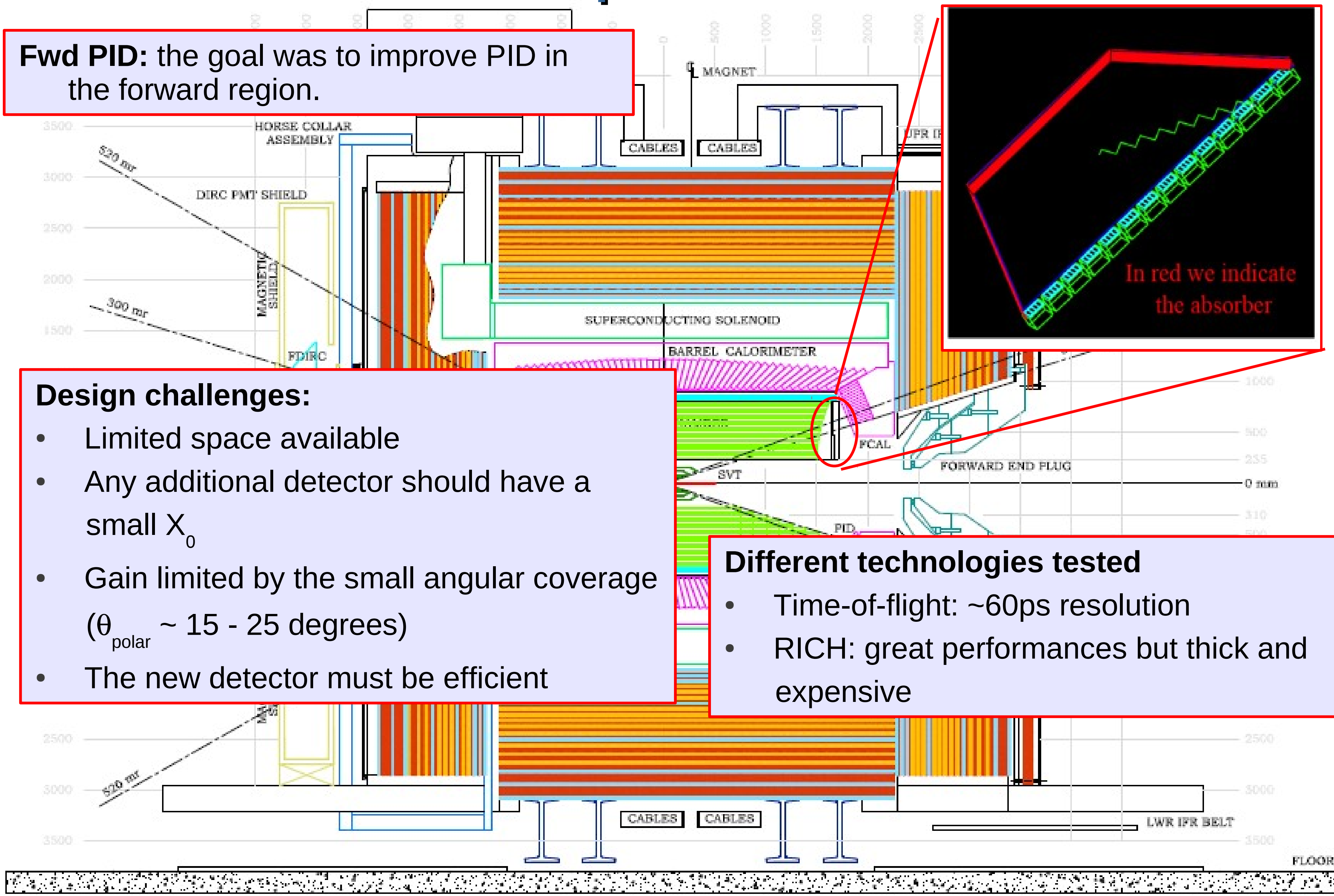
Design: planned to use BABAR quatz-bars. Complete redesign of the photo-camera

- 25 x smaller volume
- 10 x better time resolution
- Optical design based entirely on fused-silica glass



The SuperB Detector

Fwd PID: the goal was to improve PID in the forward region.



Design challenges:

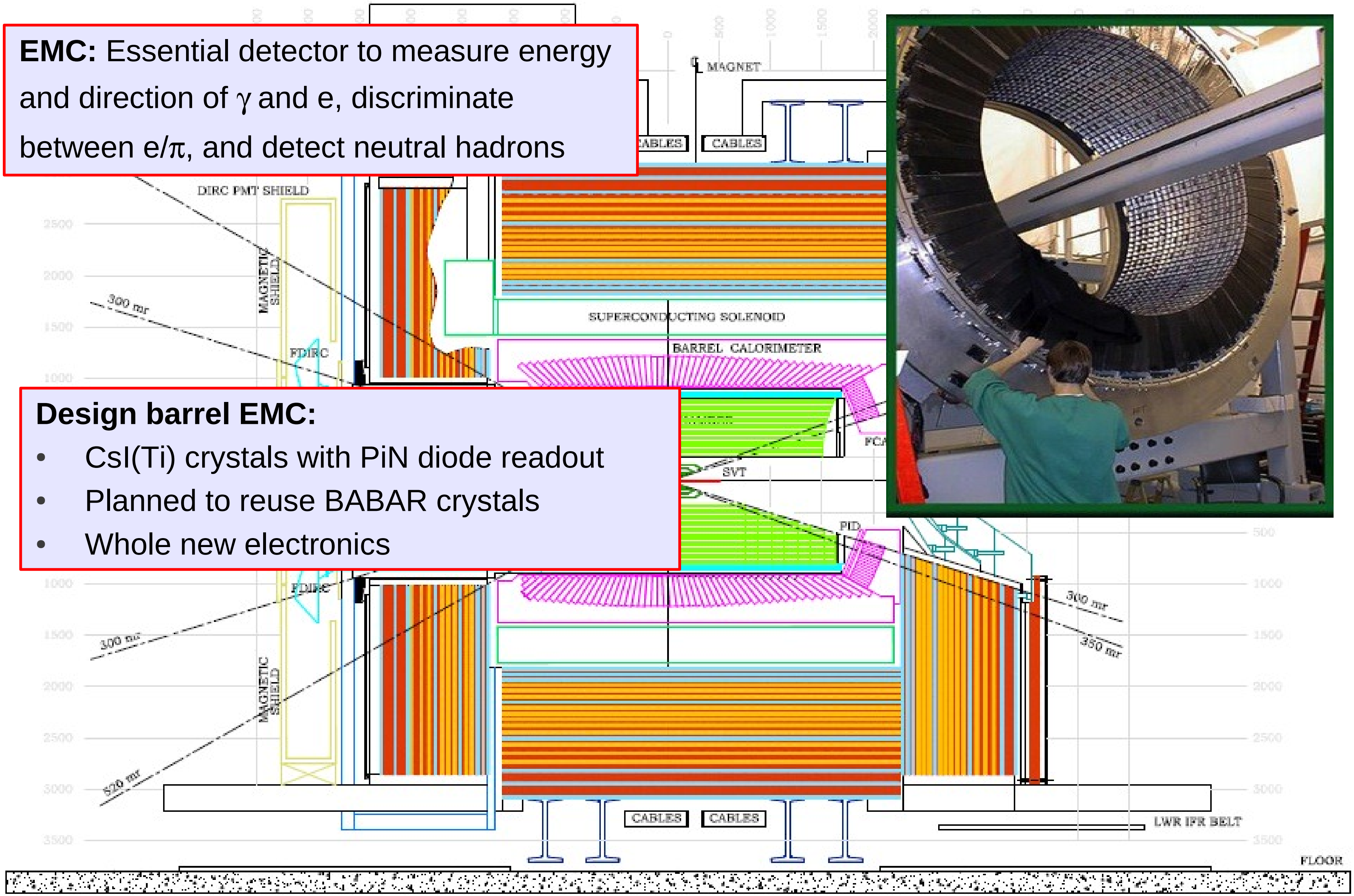
- Limited space available
- Any additional detector should have a small X_0
- Gain limited by the small angular coverage (θ_{polar} ~ 15 - 25 degrees)
- The new detector must be efficient

Different technologies tested

- Time-of-flight: ~60ps resolution
- RICH: great performances but thick and expensive

The SuperB Detector

EMC: Essential detector to measure energy and direction of γ and e, discriminate between e/π, and detect neutral hadrons

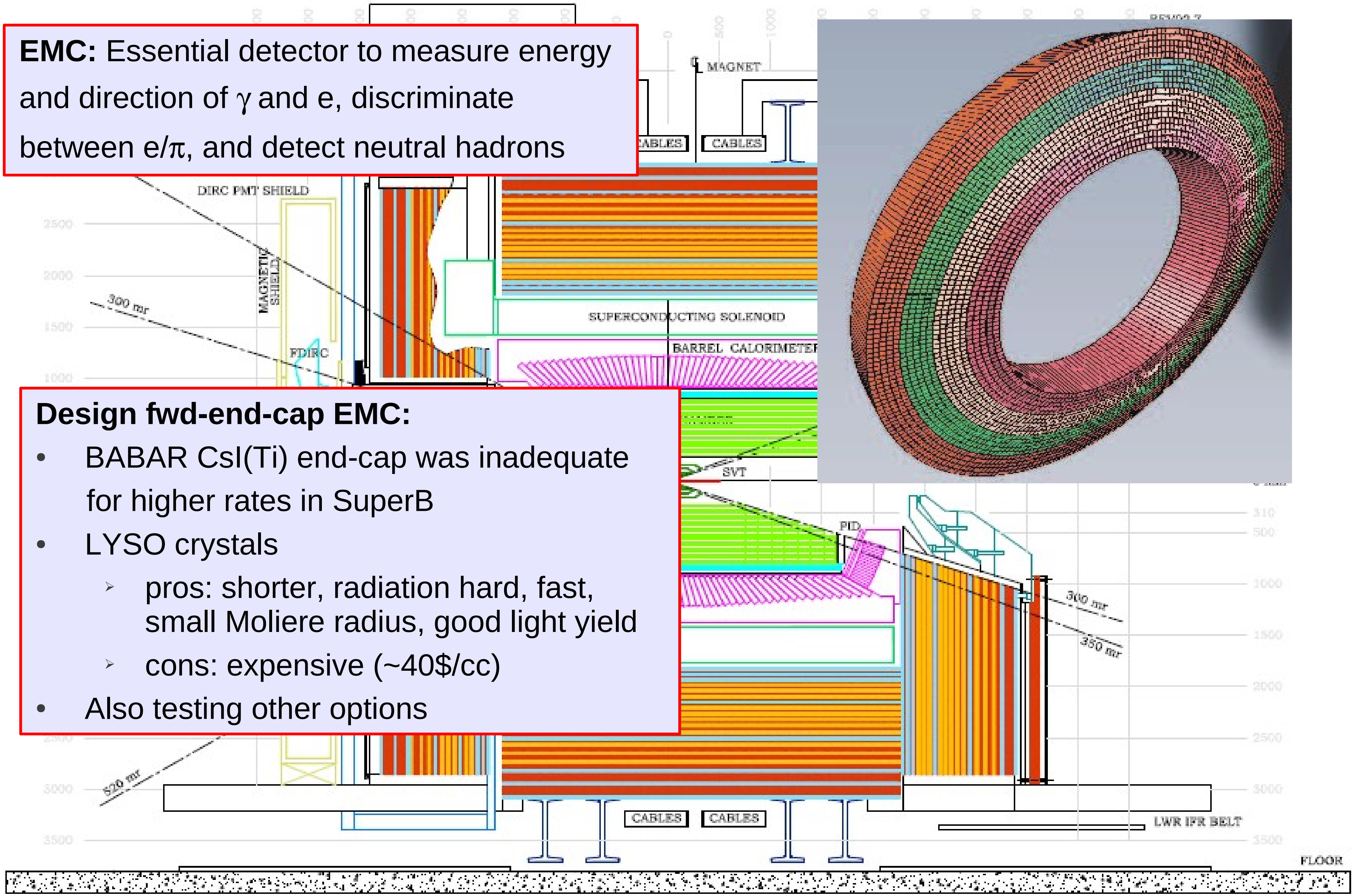


Design barrel EMC:

- CsI(Ti) crystals with PiN diode readout
- Planned to reuse BABAR crystals
- Whole new electronics

The SuperB Detector

EMC: Essential detector to measure energy and direction of γ and e, discriminate between e/π, and detect neutral hadrons



Design fwd-end-cap EMC:

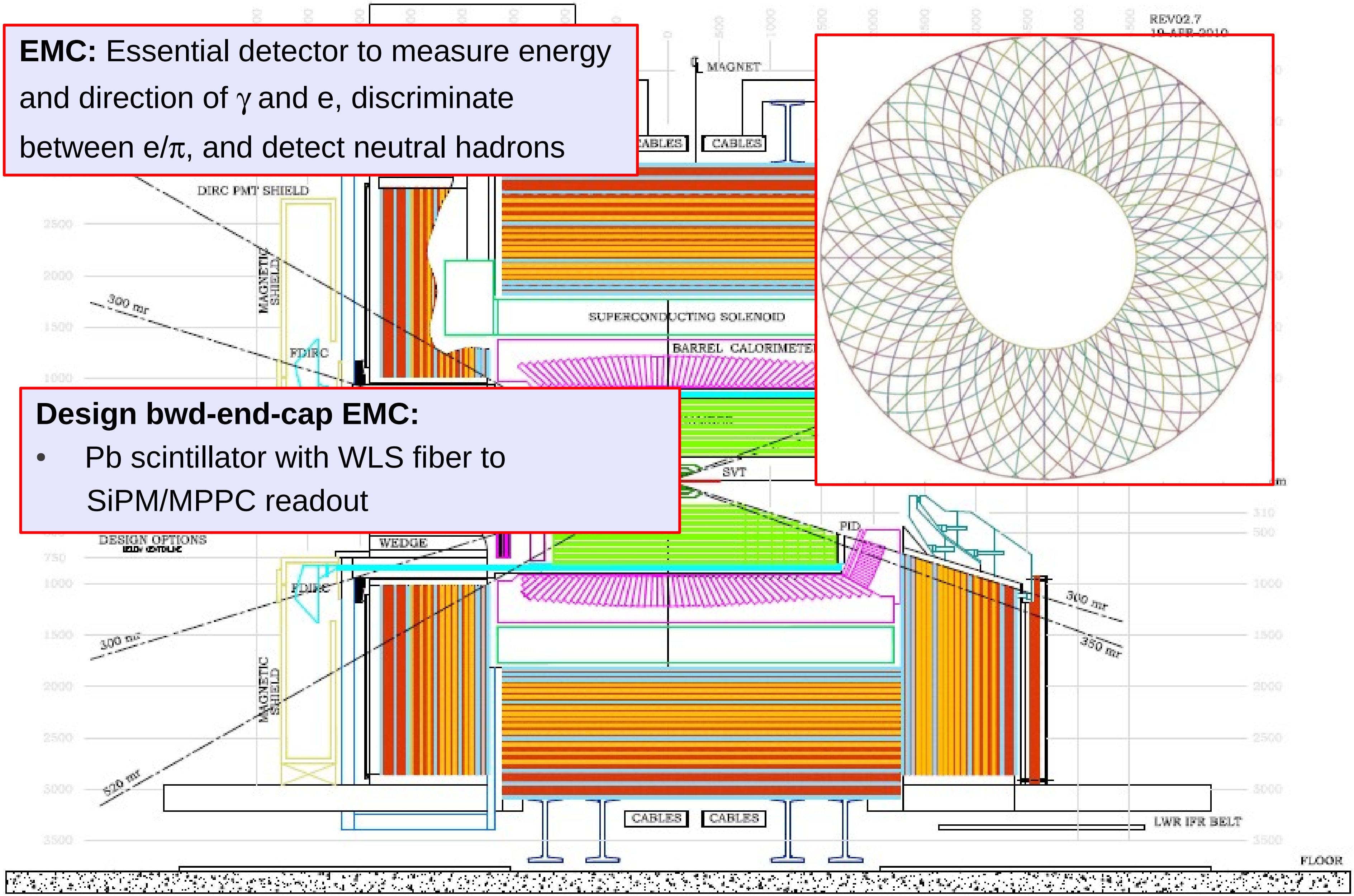
- BABAR CsI(Ti) end-cap was inadequate for higher rates in SuperB
- LYSO crystals
  - pros: shorter, radiation hard, fast, small Moliere radius, good light yield
  - cons: expensive (~40$/cc)
- Also testing other options

The SuperB Detector

EMC: Essential detector to measure energy and direction of γ and e, discriminate between e/π, and detect neutral hadrons

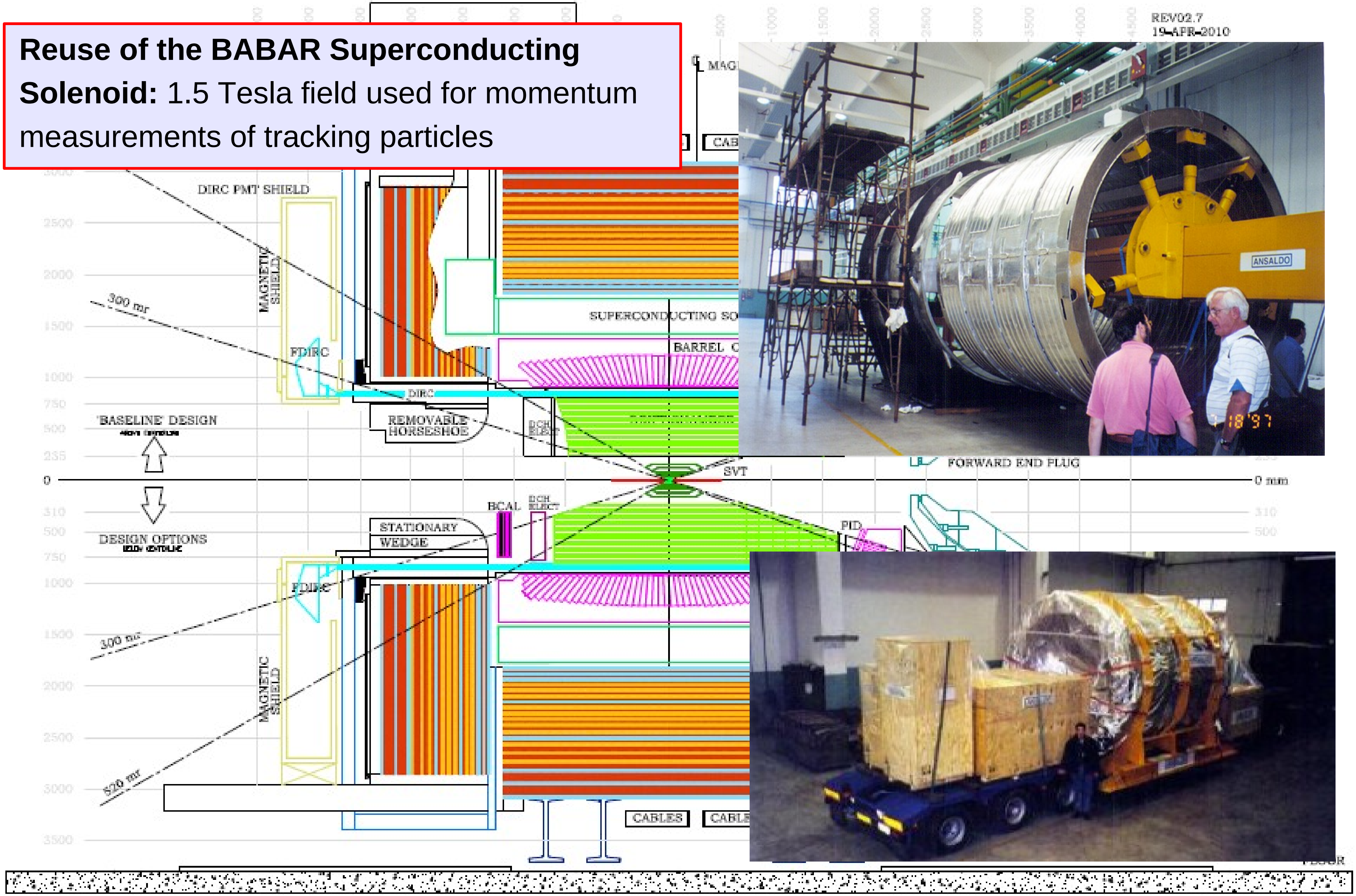
Design bwd-end-cap EMC:

- Pb scintillator with WLS fiber to SiPM/MPPC readout



The SuperB Detector

Reuse of the BABAR Superconducting Solenoid: 1.5 Tesla field used for momentum measurements of tracking particles



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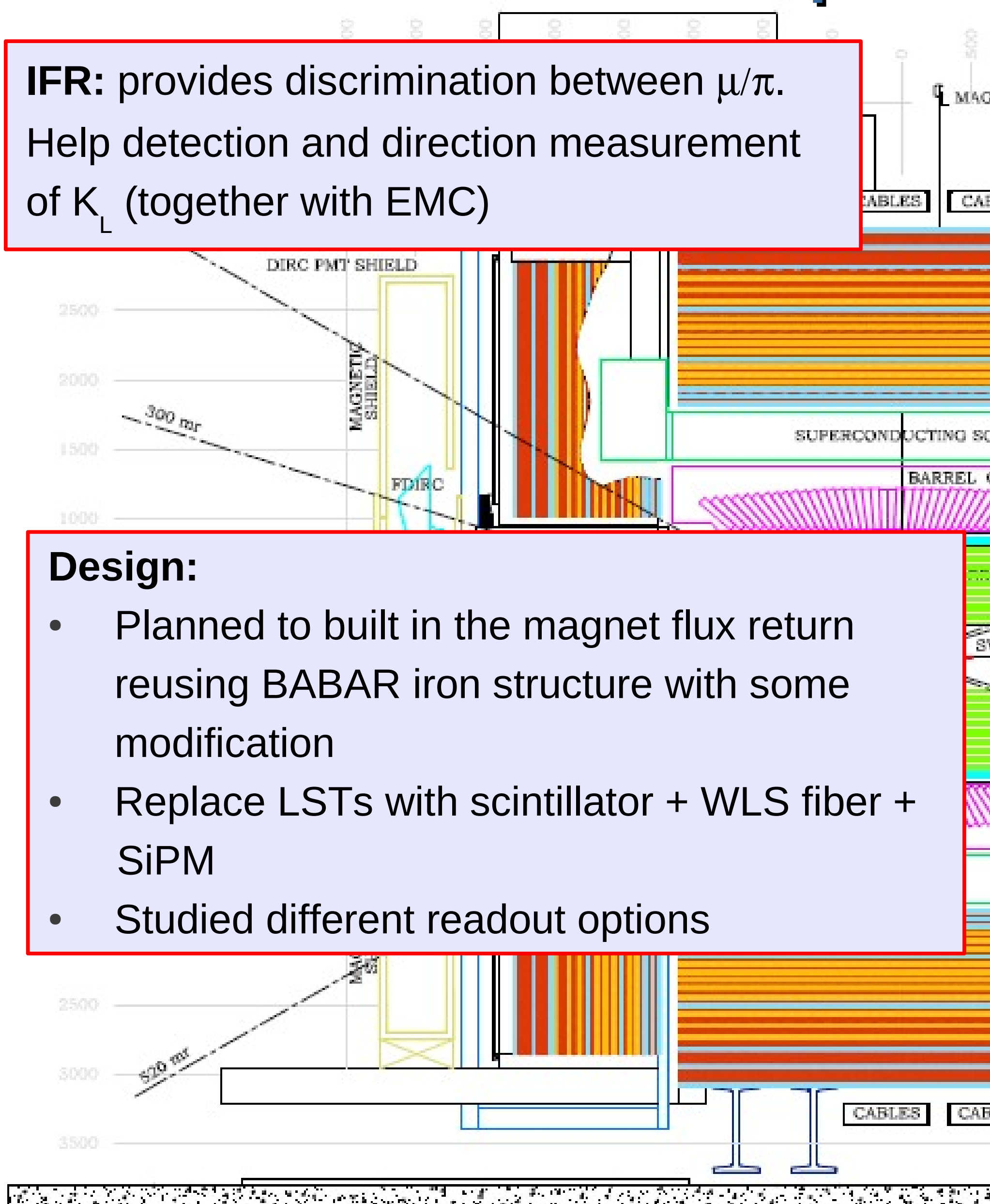
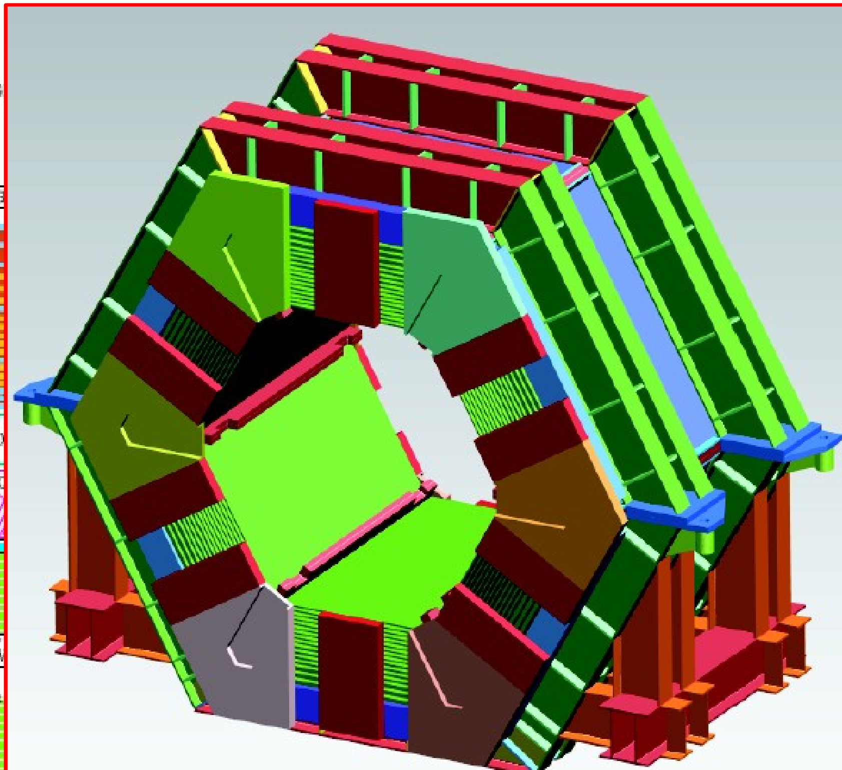


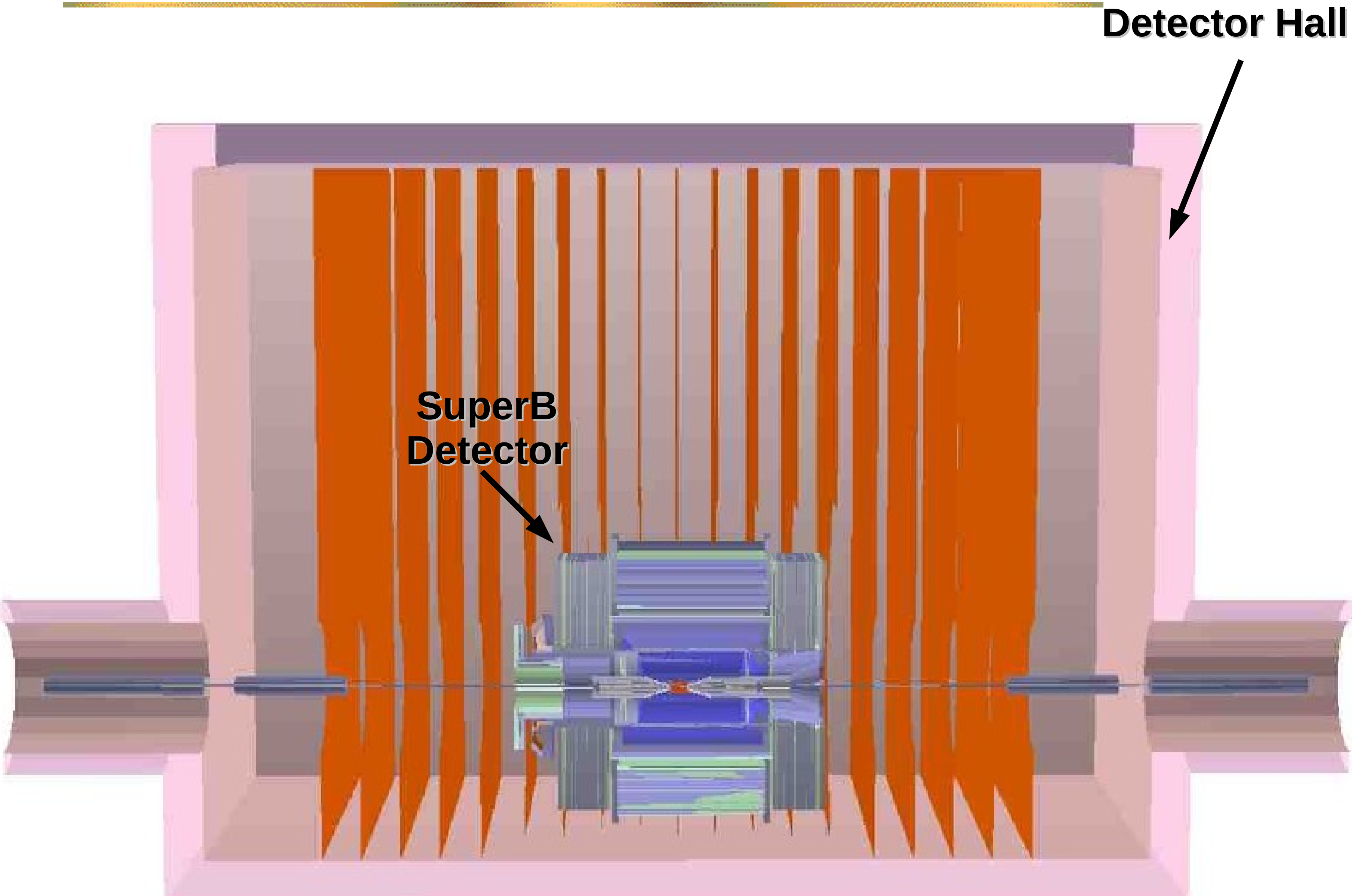


IFR: provides discrimination between μ/π.
Help detection and direction measurement of K_L (together with EMC)

Design:

- Planned to built in the magnet flux return reusing BABAR iron structure with some modification
- Replace LSTs with scintillator + WLS fiber + SiPM
- Studied different readout options

Bruno: Detector Model



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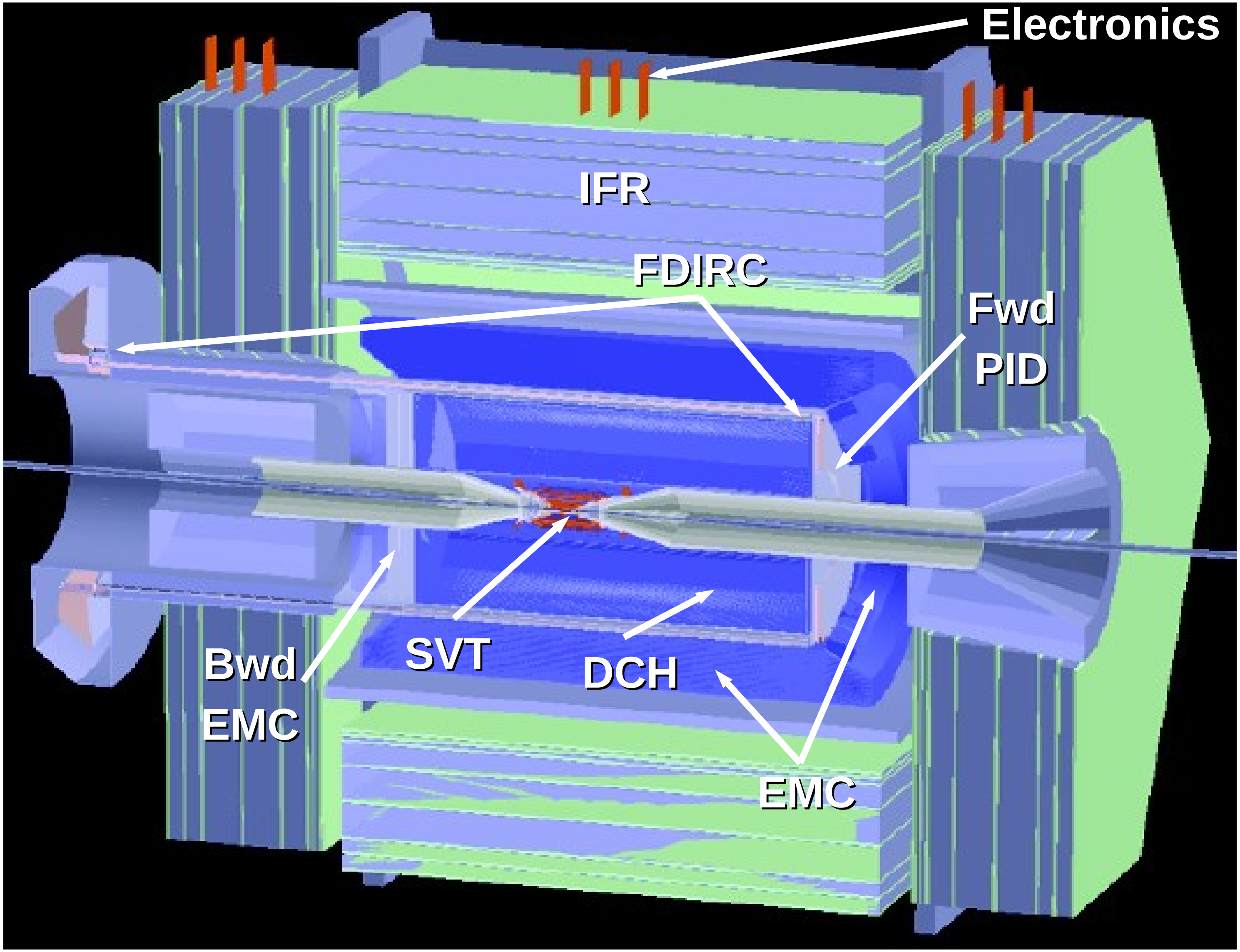
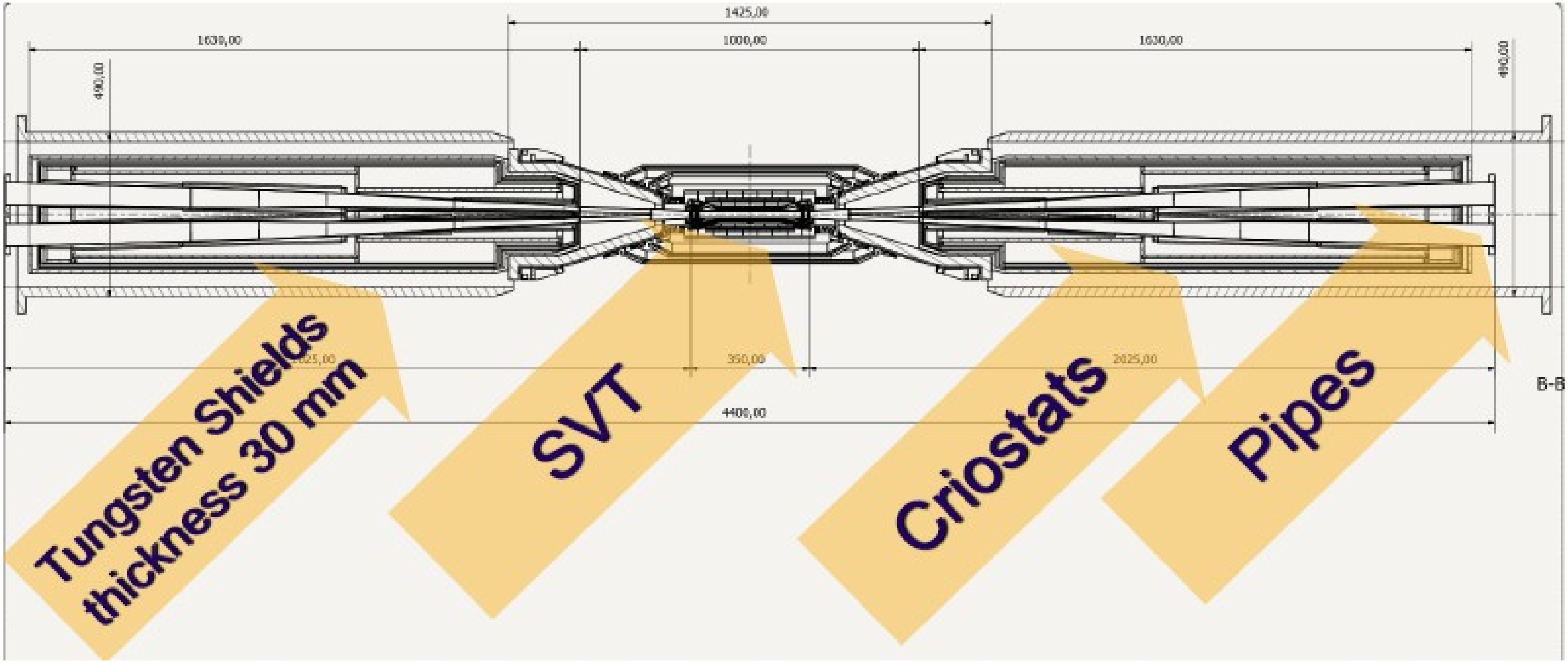


Bruno: Machine material

- **Detailed model of the beam pipe sizes, cryostat and cold mass**
- **3cm thick tungsten shield is put around the cryostat to protect the detectors from radiative Bhabha, Touschek and Beam-gas**

Final focus
Mechanical design



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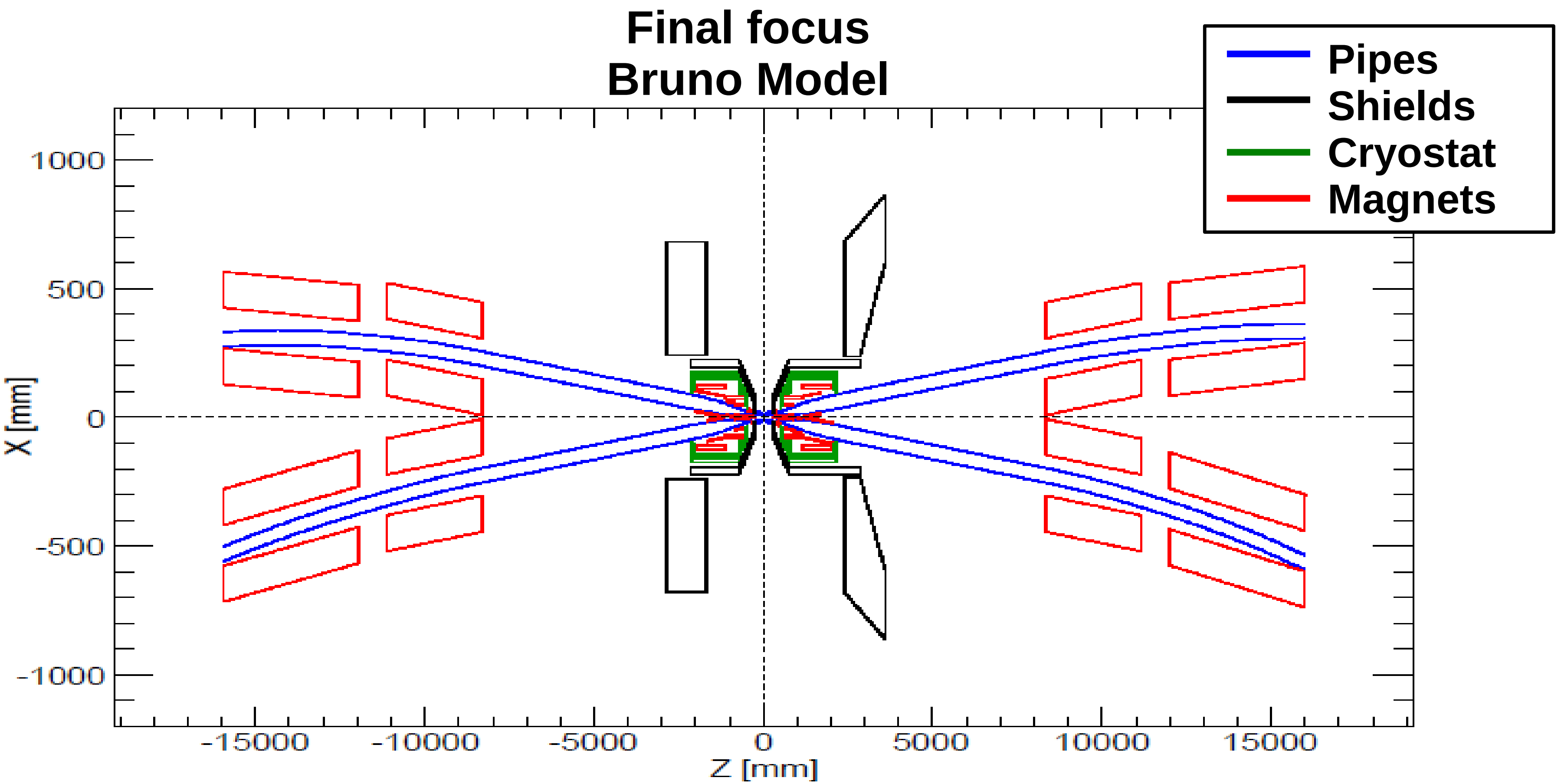

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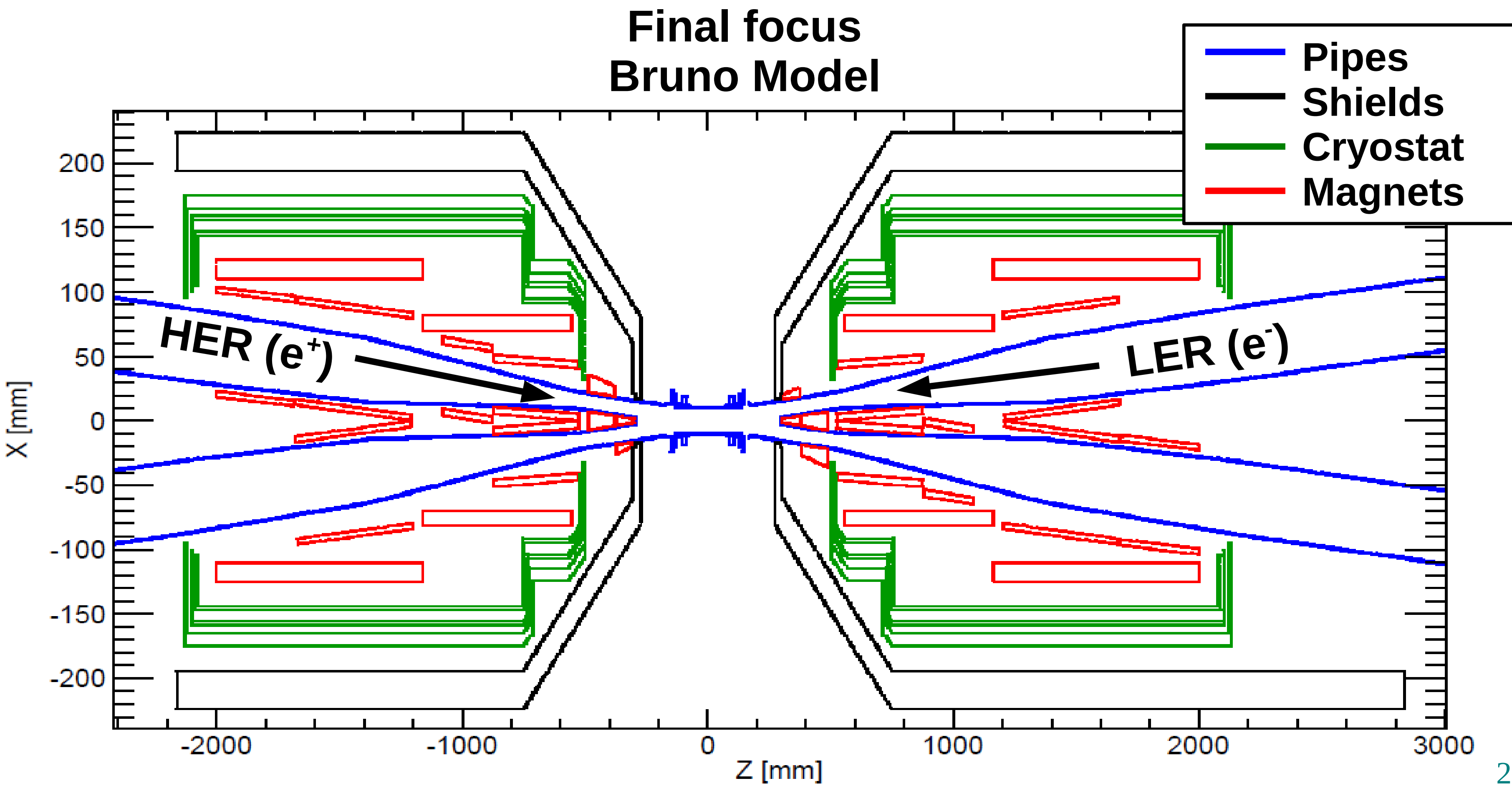

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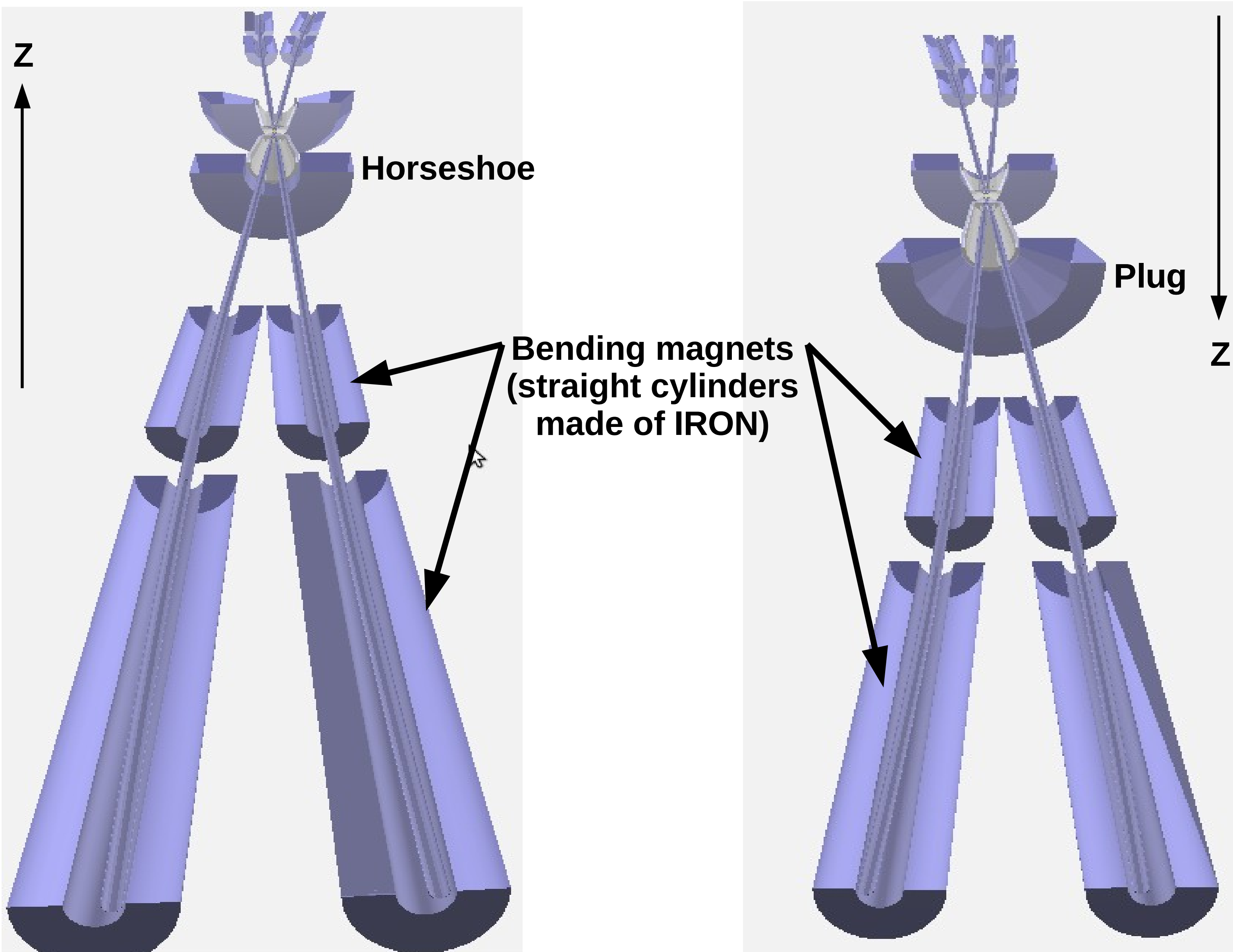
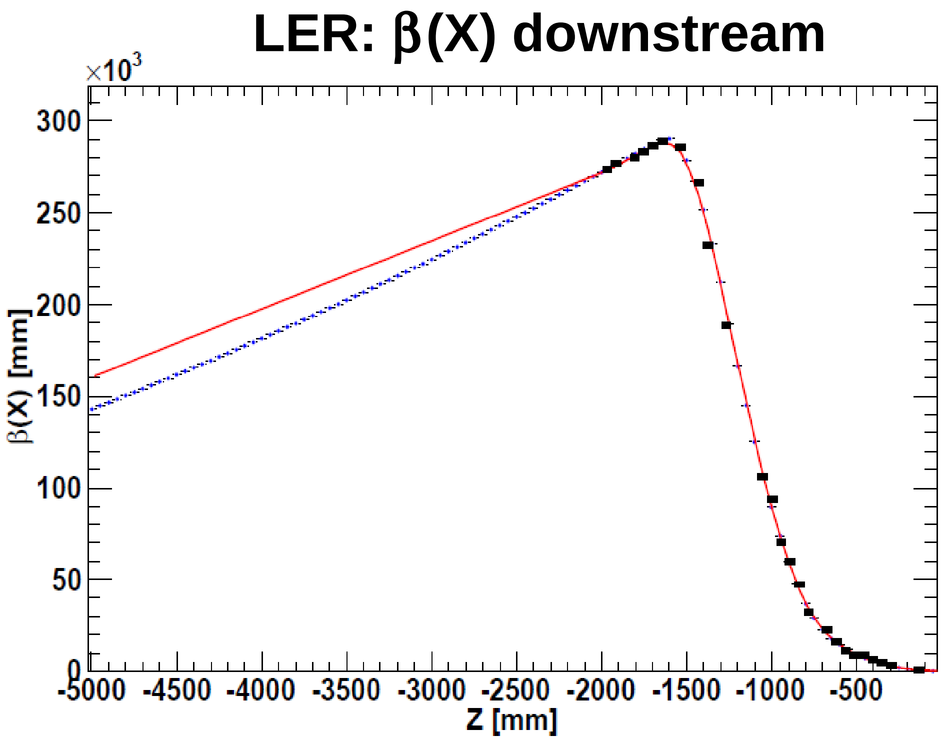
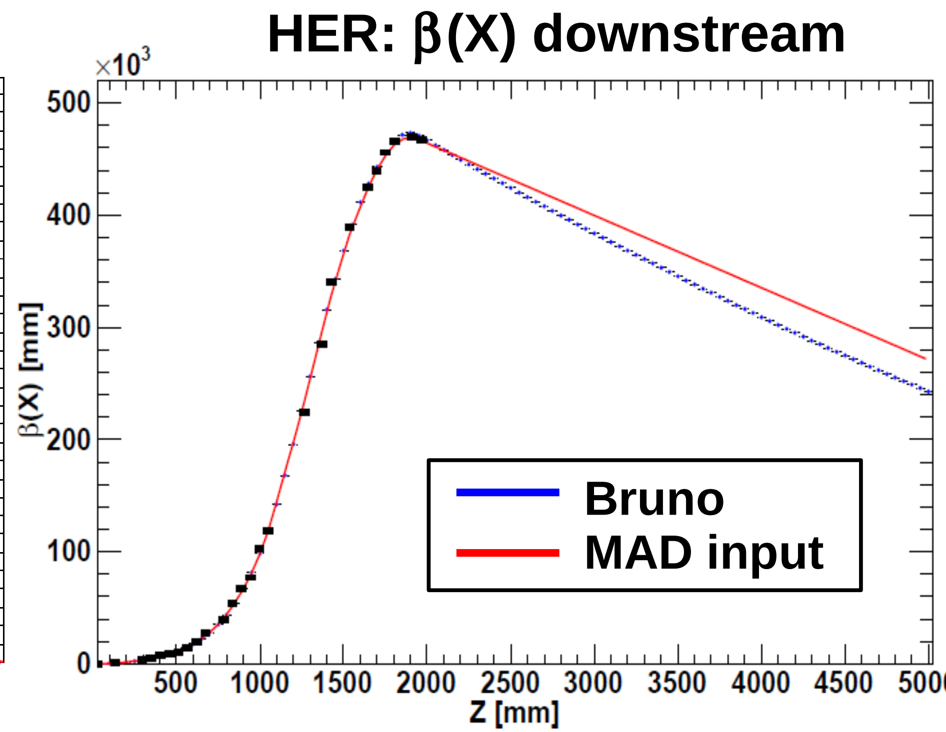


Bruno: beam-line magnetic model

- **Magnetic model directly extracted from Accelerator group simulation**
- **Features:**
  - Dipoles and Quadrupoles are perfect (no higher order components)
  - Fields modelled only inside cylinders, zero elsewhere (no fringing effects)





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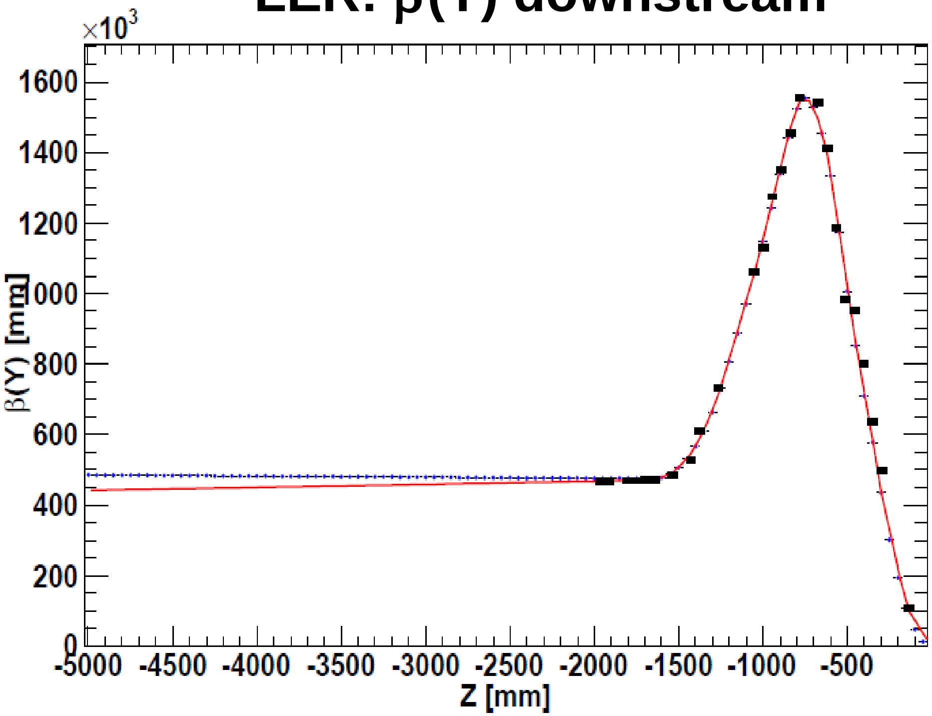
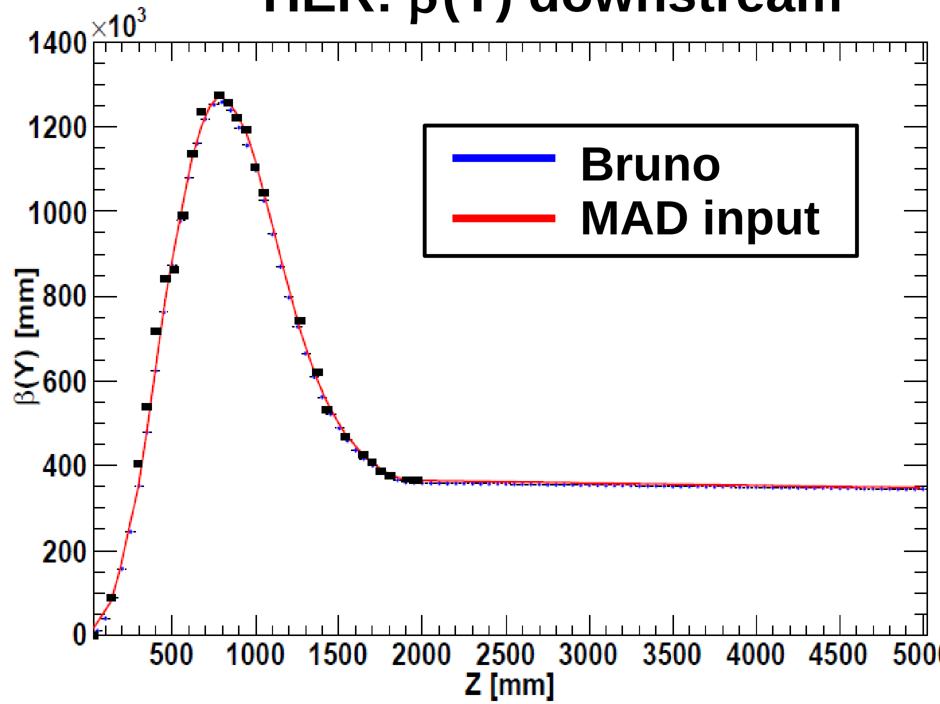
LER: β(Y) downstream



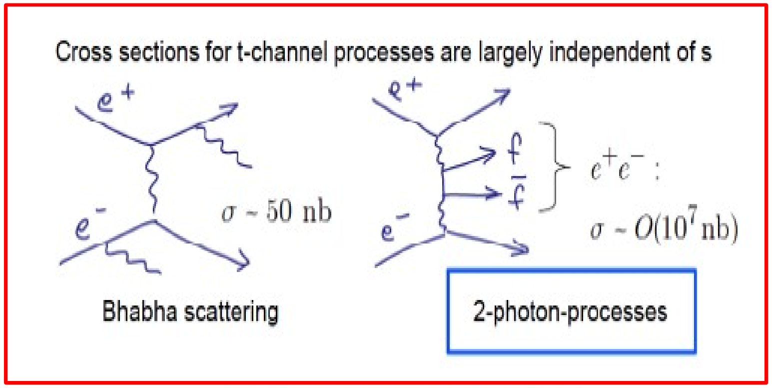
HER: β(Y) downstream



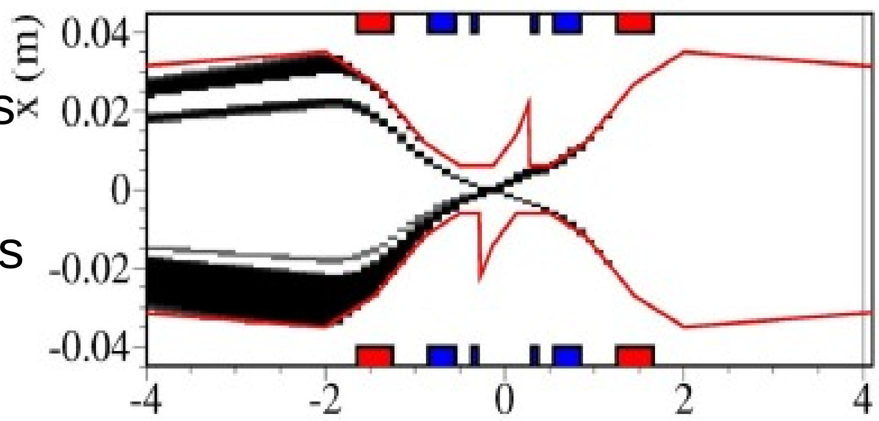
The machine backgrounds

- **Backgrounds sources give rise to primary particles that can either hit the detector directly, or generate secondary debris that enter the apparatus**

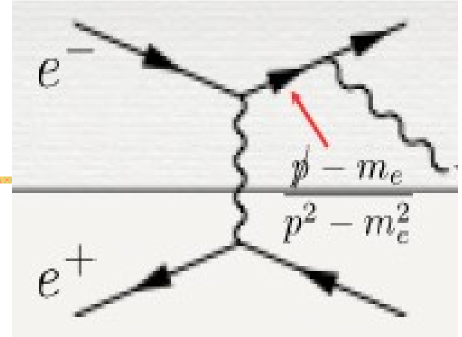
- **Types of background:**
  - Luminosity scaling
    - Radiative Bhabha (beam stahlung)
    - Pair production (2-photon)



  - Intensity scaling
    - Touschek: scattering of particles within the same bunch
    - Beam gas: scattering of particles with the residual gas
    - Synchrotron Radiation



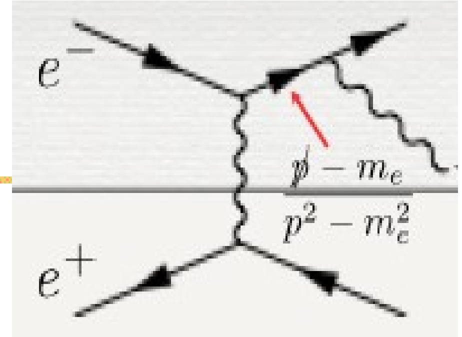
Radiative Bhabha



- **Quasi elastic Bhabha of the electron-positron with the emission of a photon** $e^+e^- \rightarrow e^+e^-\gamma \quad (\gamma \sim\| e^-)$

- **The final state particles escapes through the detector acceptance holes until**
  - Magnetic field deflect the lepton that radiated the photon
  - The photon and/or defected lepton hit the beam pipe
  - The debris of the electromagnetic shower hit the detector

Radiative Bhabha



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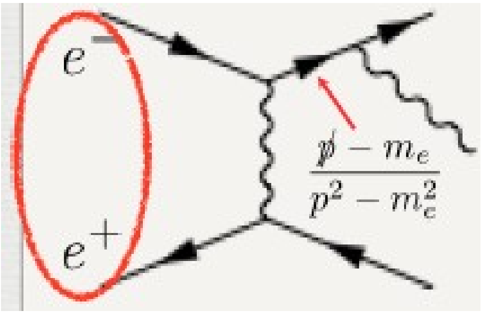
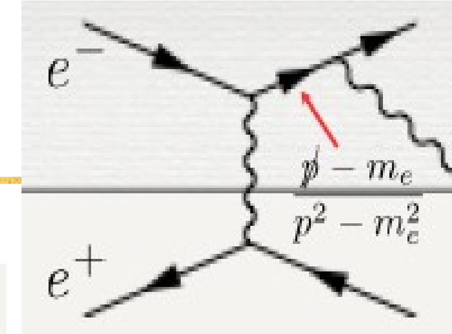


- Angular divergence of the beam pipe cannot be neglected
- Incoming particles momentum/position at the scattering vertex generated from first principles

Transversal size @ IP | **Transversal dev. @ IP** | **Bunch length @ IP** | **E spread @ IP**

$$\rho_{\text{ph.sp.}} \propto e^{-\frac{1}{2}\left[\left(\frac{x}{\sigma_x}\right)^2+\left(\frac{x'}{\sigma_{x'}}\right)^2+\left(\frac{y-y'\,x\,\chi/\vartheta}{\sigma_y}\right)^2+\left(\frac{y'}{\sigma_{y'}}\right)^2+\left(\frac{s}{\sigma_z}\right)^2+\left(\frac{\epsilon}{\sigma_\epsilon}\right)^2\right]}$$

Radiative Bhabha



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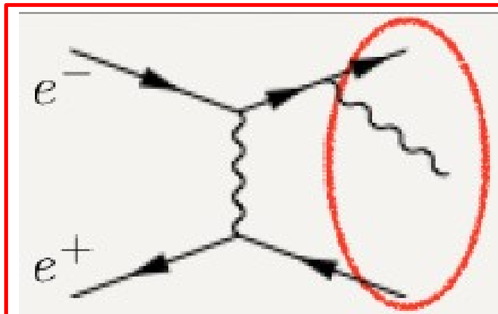
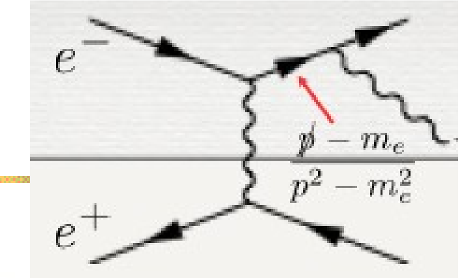
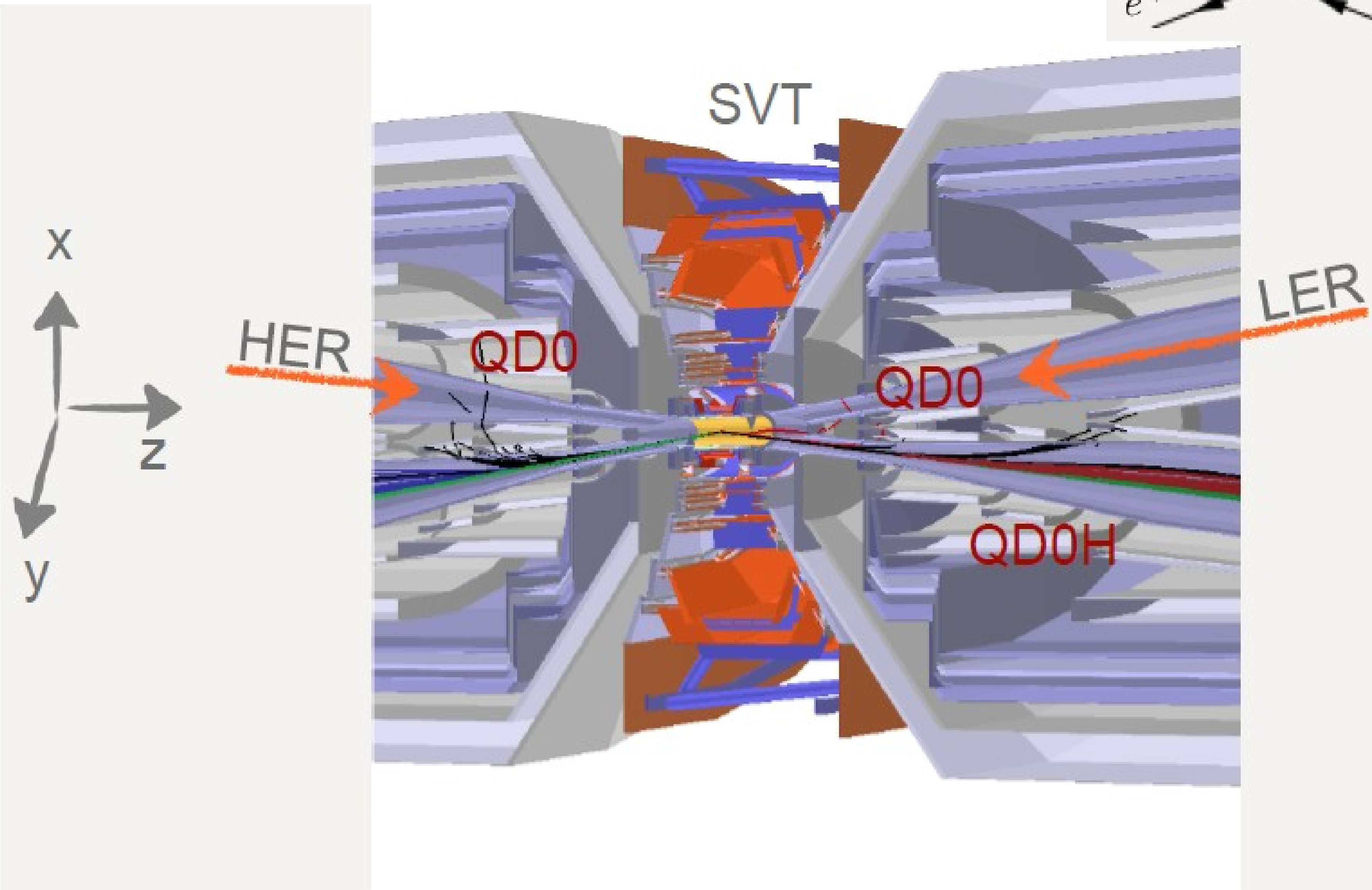


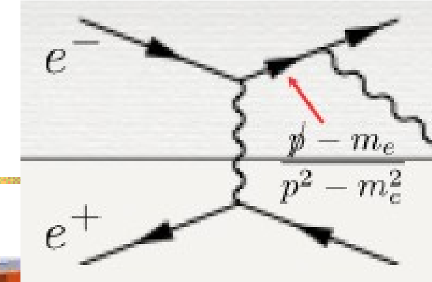
- BBBrem (R. Kleiss, H. Burkhardt) arXiv: hep-ph/9401333
- Only two out of the eight Feynman diagrams are considered
- Finite bunch density is taken into account by an infra-red cut-off parameter that fixes the minimum momentum transfer $\Rightarrow p_{min} \sim hc/d$

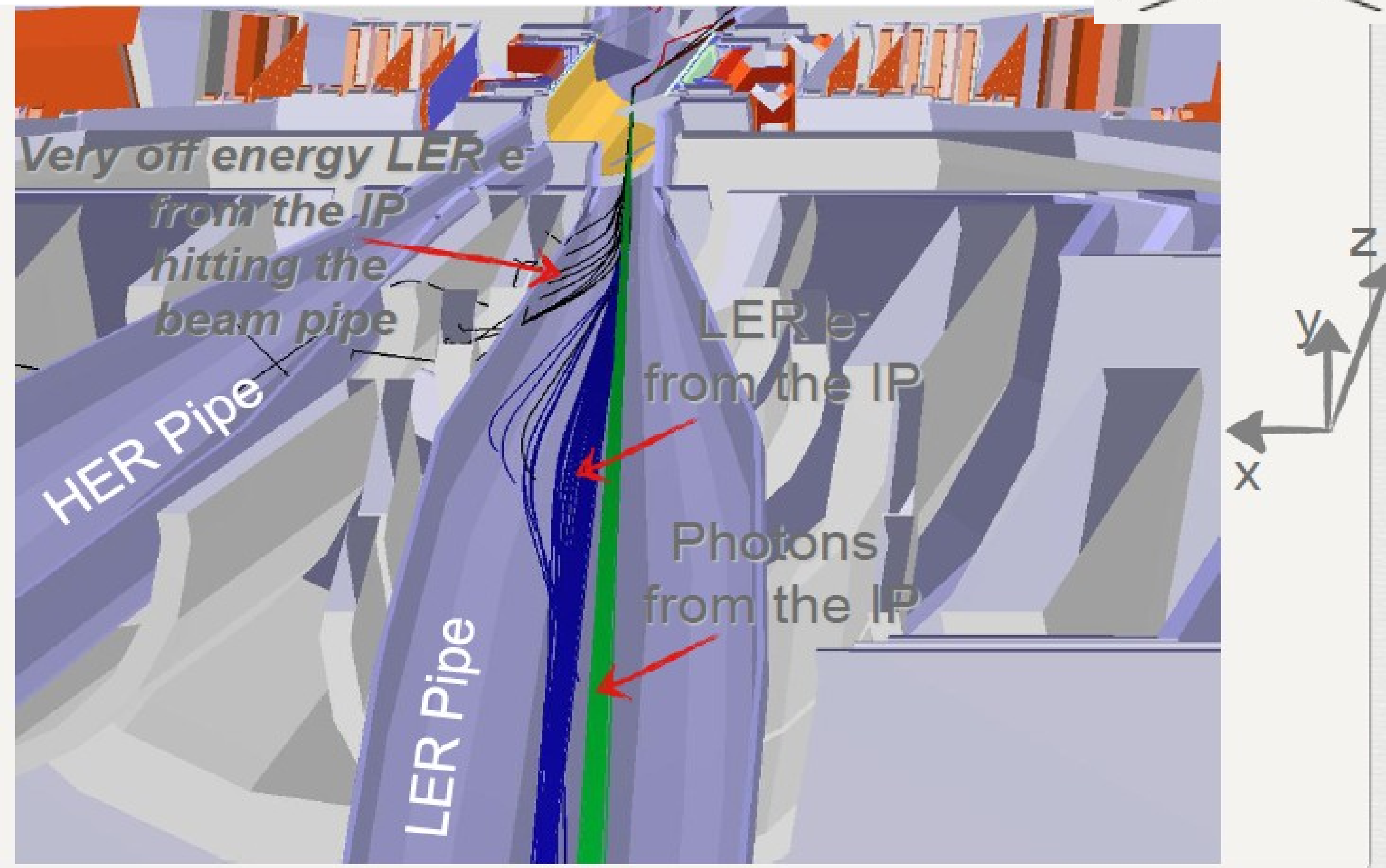
A single bunch crossing:
The primaries



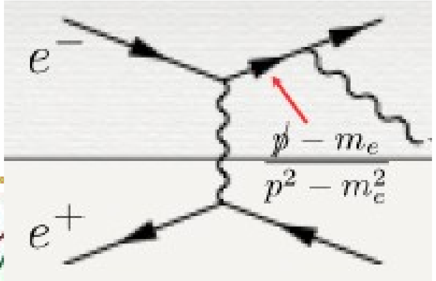


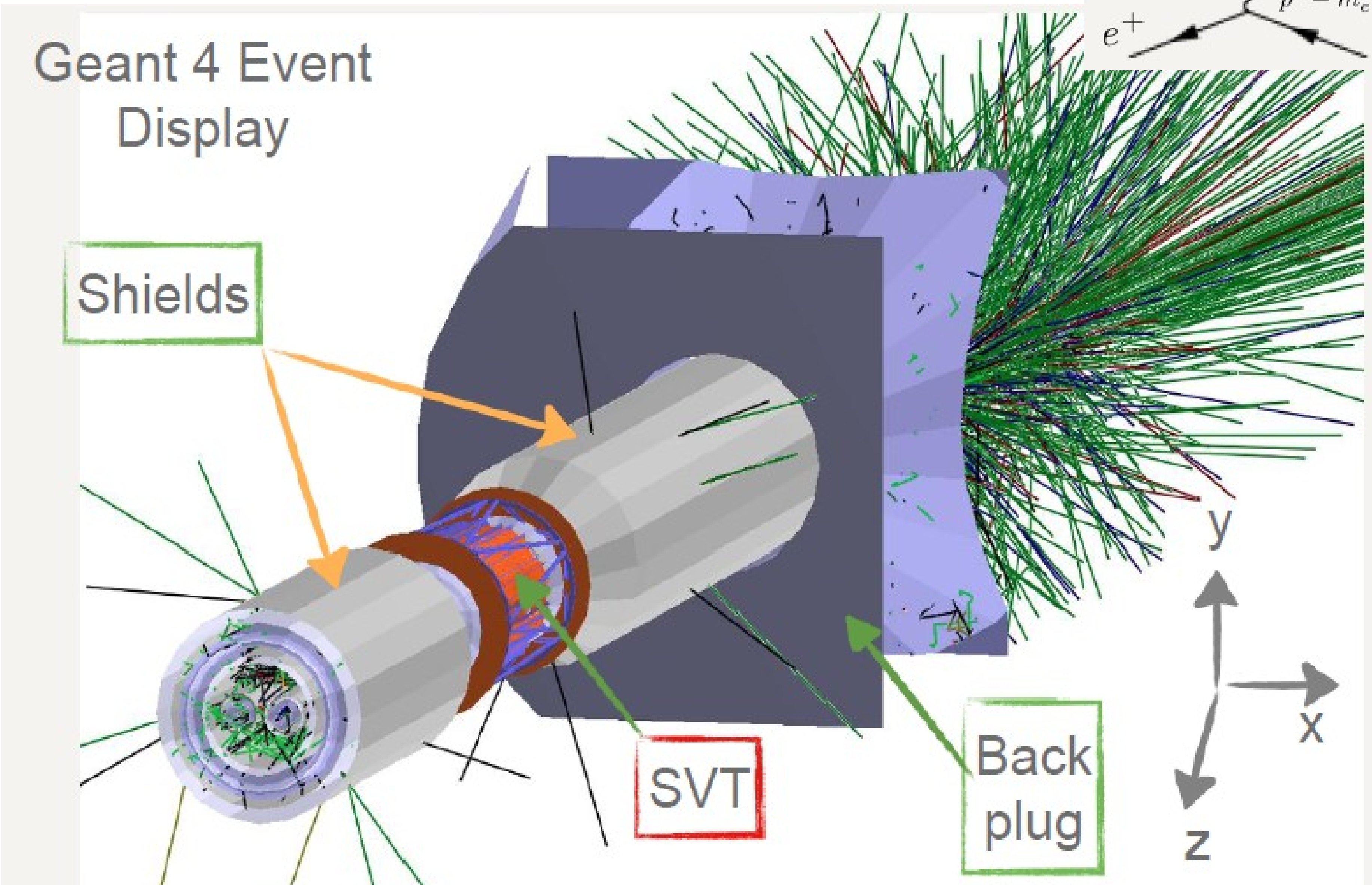
A single bunch crossing: The primaries





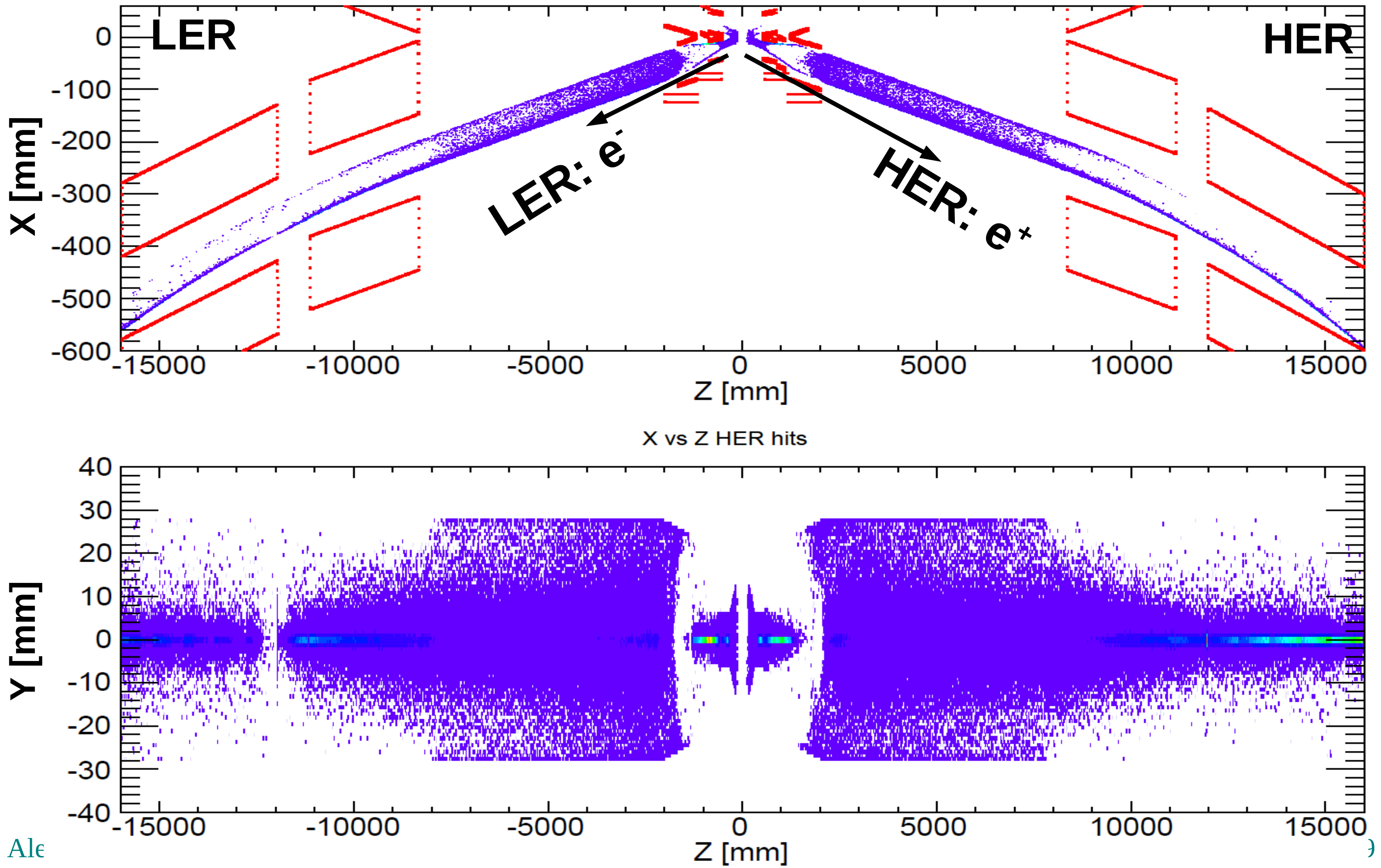
A single bunch crossing: The secondaries





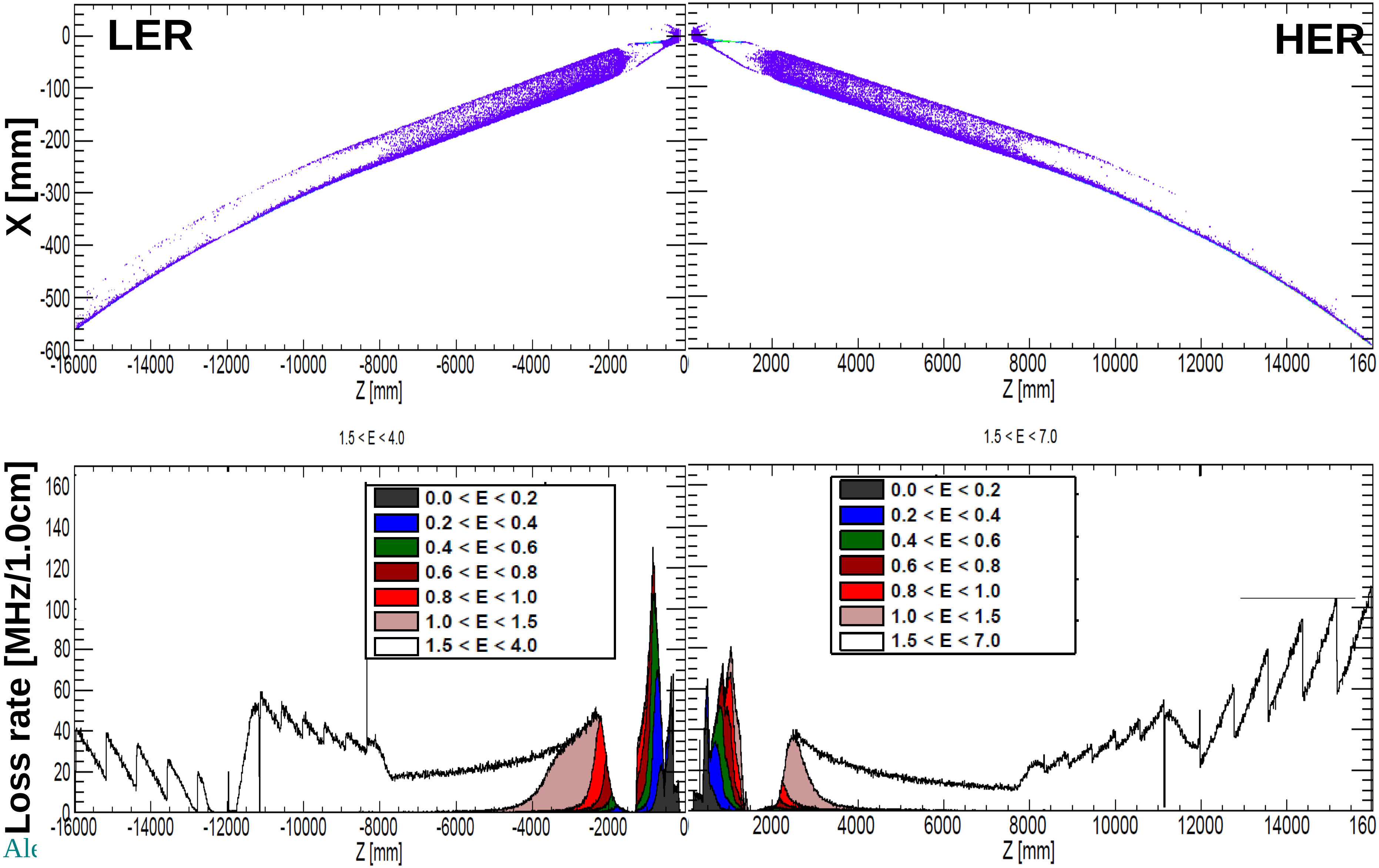
Rad-Bhabha Losses at the Beam-pipe: e^+e^-

- V12-sf11 layout: HER = e^+ (6.69 GeV) and LER = e^- (4.18 GeV)



Rad-Bhabha Losses at the Beam-pipe: e^+e^-

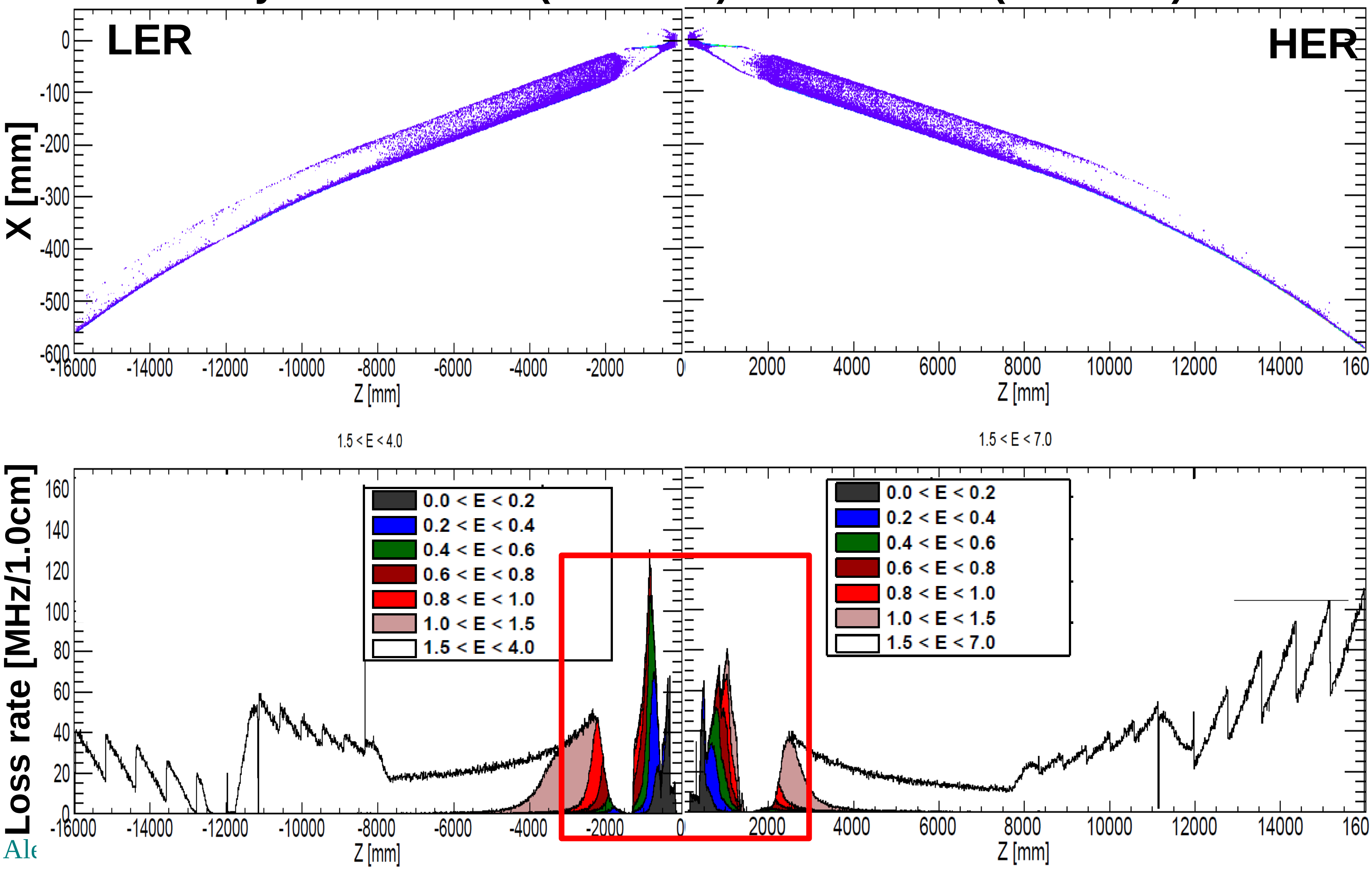
- V12-sf11 layout: HER = e^+ (6.69 GeV) and LER = e^- (4.18 GeV)



Ale

Rad-Bhabha Losses at the Beam-pipe: e^+e^-

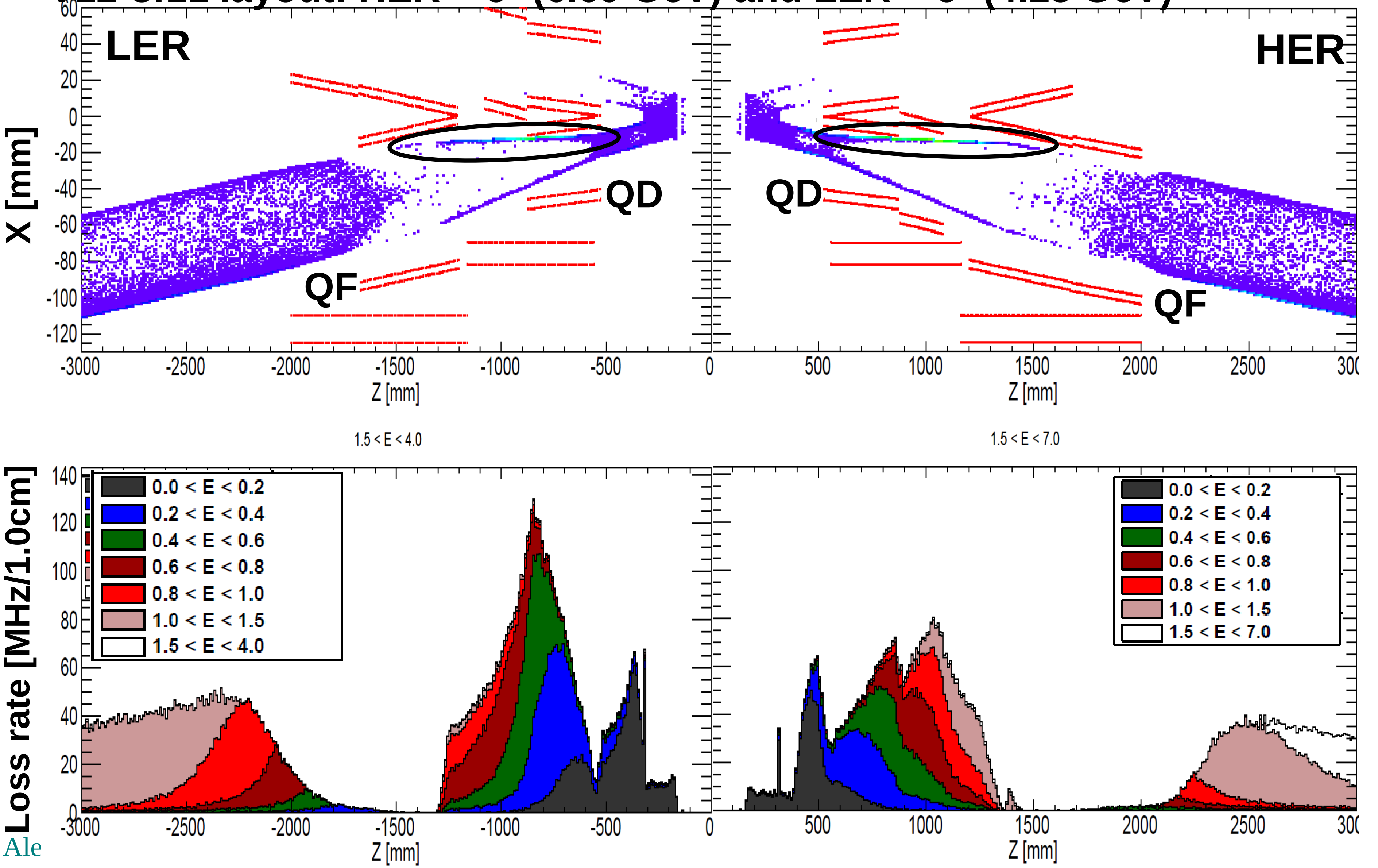
- V12-sf11 layout: HER = e^+ (6.69 GeV) and LER = e^- (4.18 GeV)



Ale

Rad-Bhabha Losses at the Beam-pipe: e^+e^-

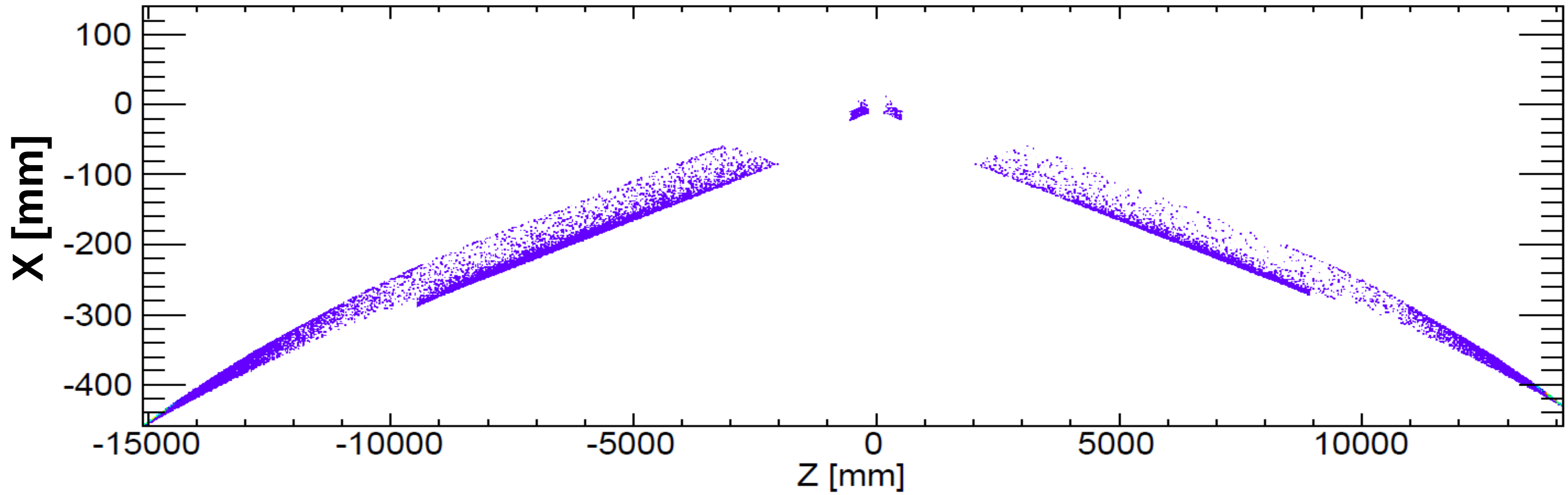
- V12-sf11 layout: HER = e^+ (6.69 GeV) and LER = e^- (4.18 GeV)

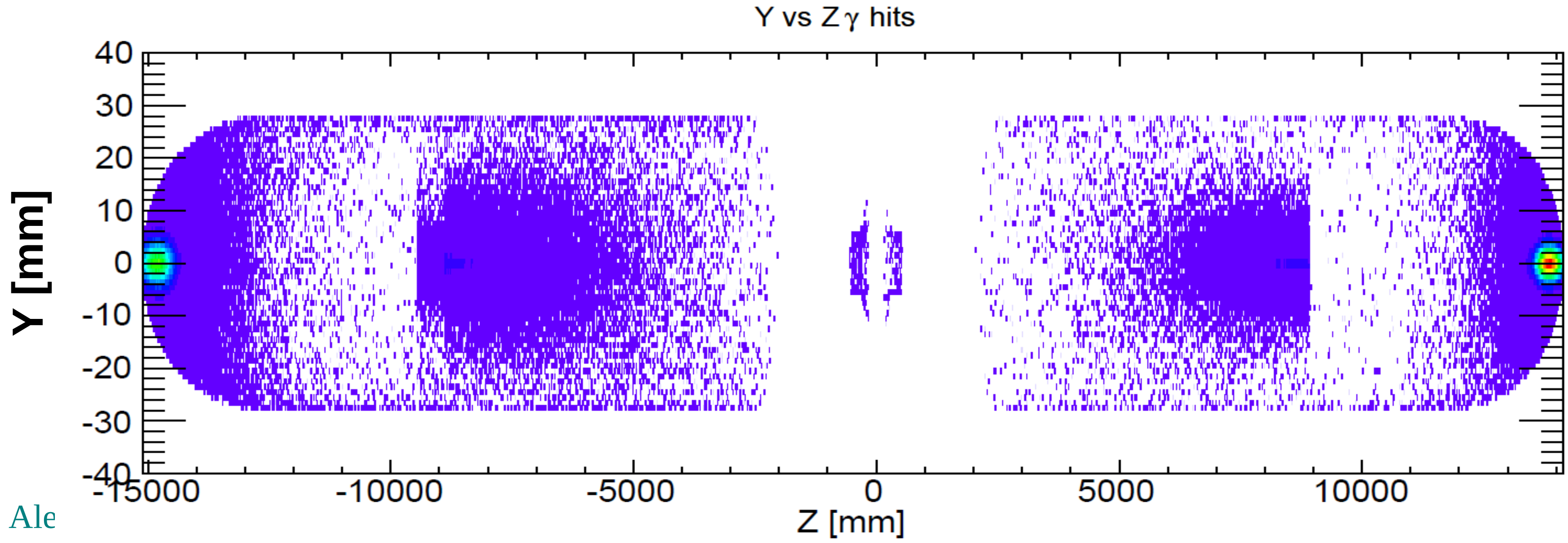


Ale

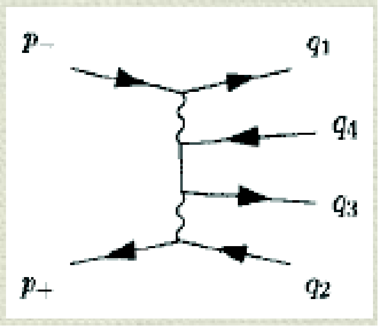
Rad-Bhabha Losses at the Beam-pipe: rad-γ

- V12-sf11 layout: HER = e^+ (6.69 GeV) and LER = e^- (4.18 GeV)





Pairs production

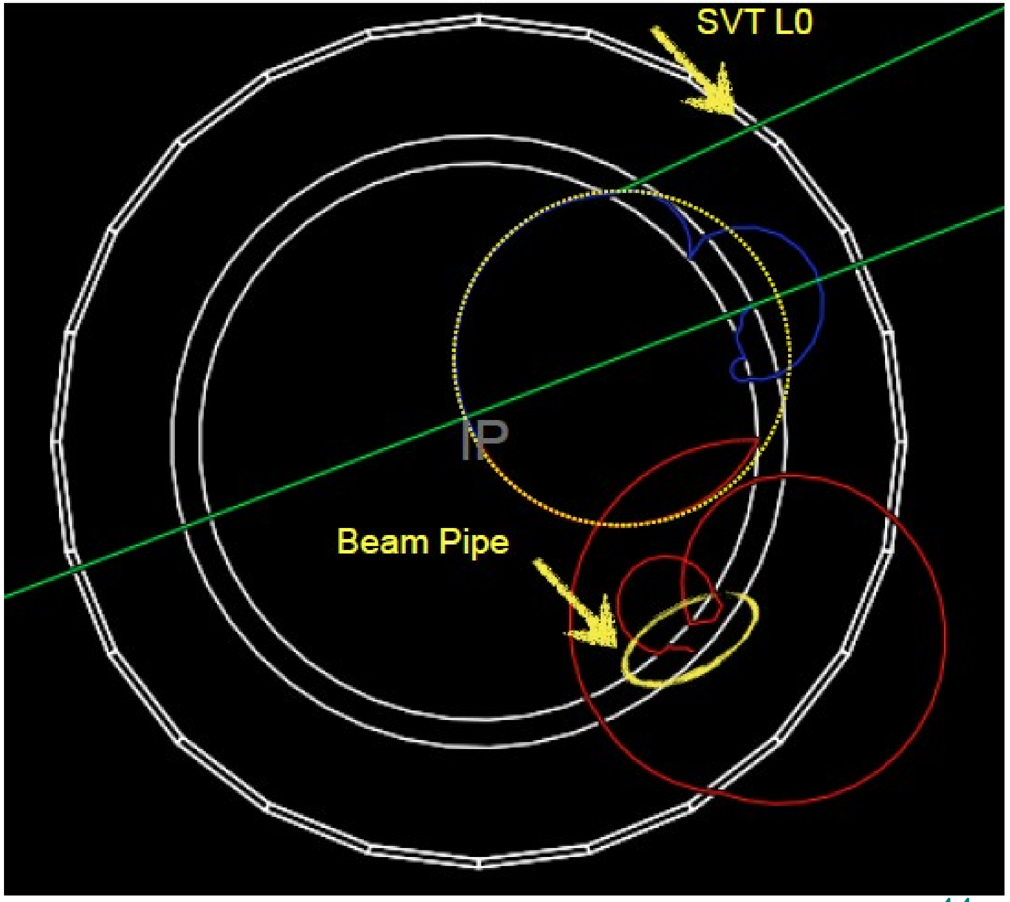


- **Main background source on SVT Layer0**

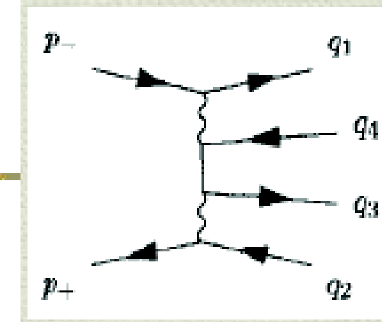
$$e^+ e^- \rightarrow e^+ e^- e^+ e^-$$

$$\sigma \sim \frac{\alpha^2 r_e^2}{\pi} \left(\frac{28}{27} \ln^3 \frac{s}{m^2} - 6.59 \ln^2 \frac{s}{m^2} - 11.8 \ln^2 \frac{s}{m^2} + 104 \right)$$

- **Primaries are very soft (few MeV)**
  - Multiple Coulomb scattering and dE/dx at beam-pipe are not negligible
  - Particles with p_t < 3.5 MeV/c can still hit beam pipe ⇒ Coulomb scattering can increase p_t at expense of long. momentum



Pairs production



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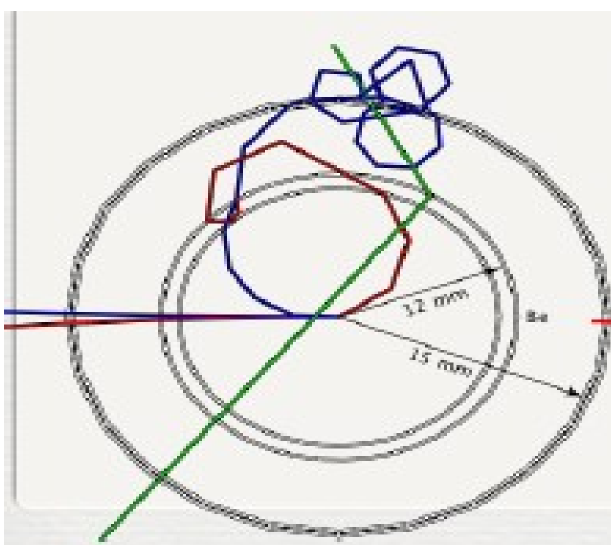
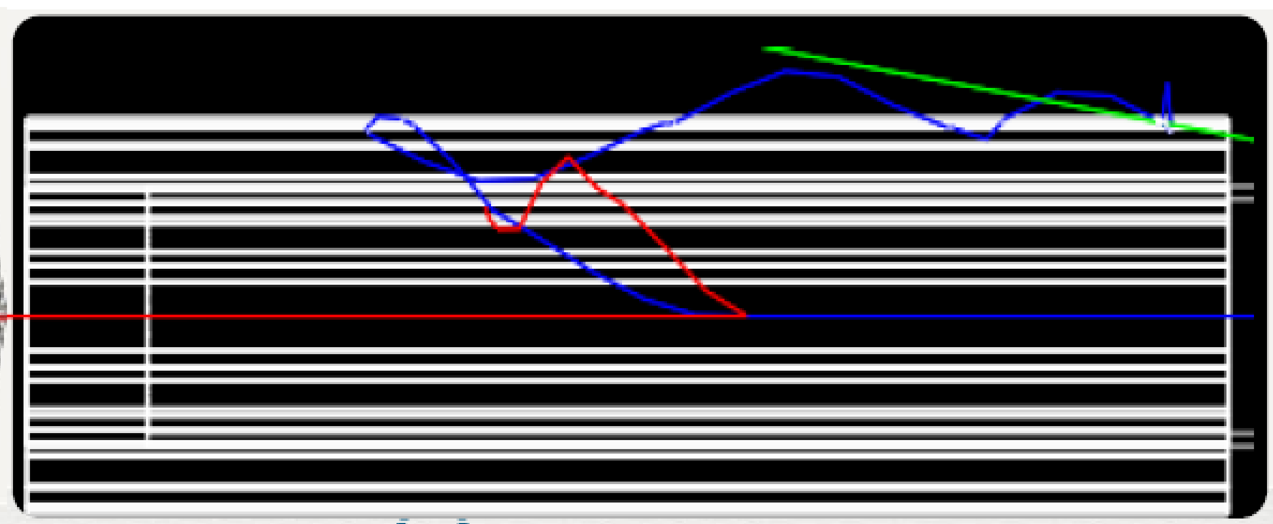
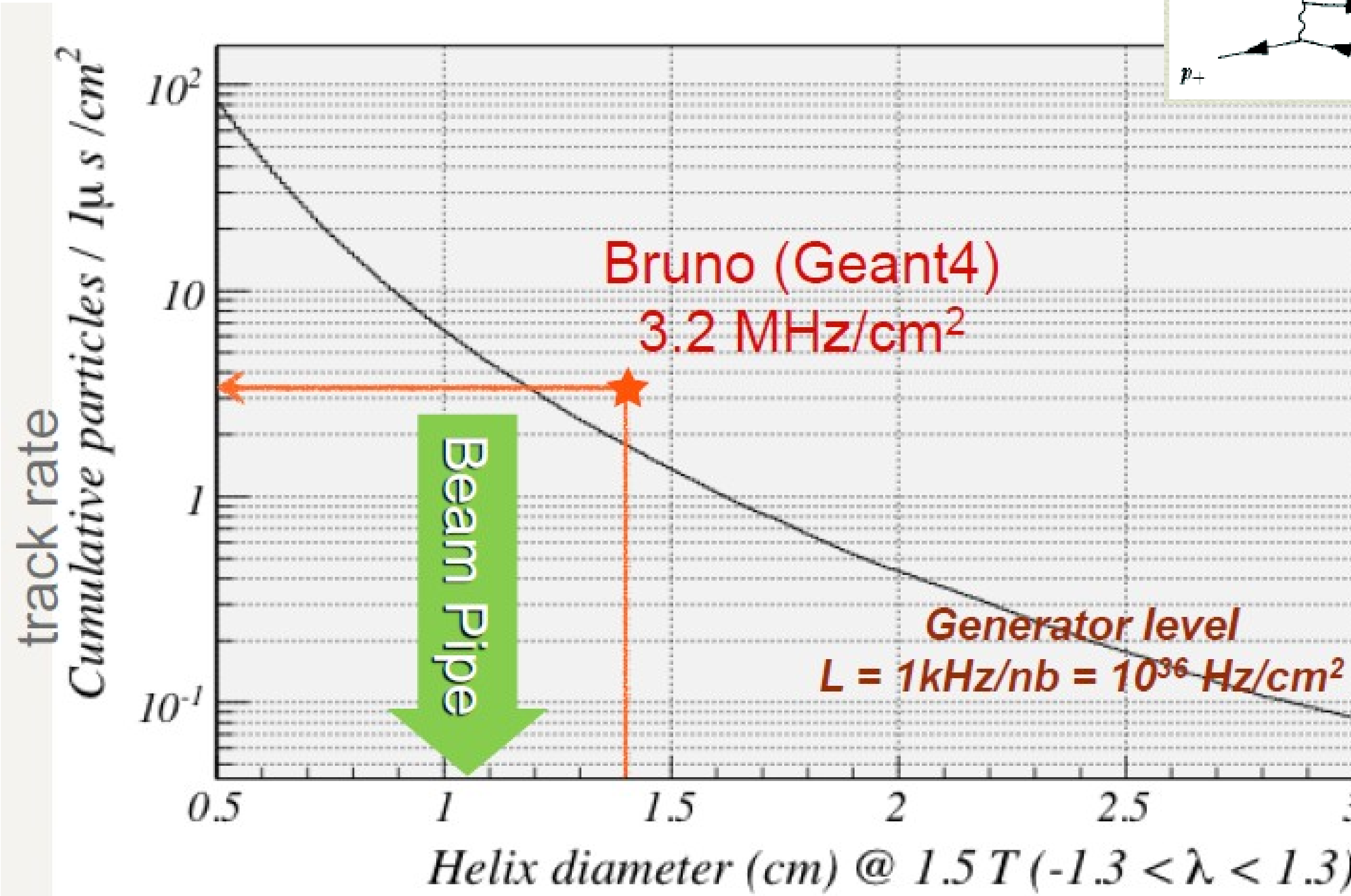
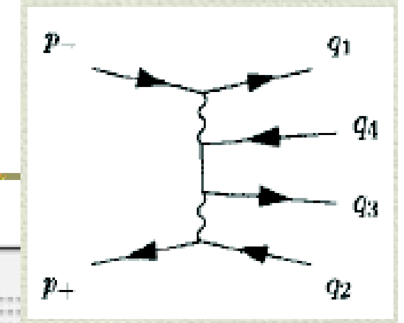
- **Primaries can have enough p_t to enter into the detector**
  - The detector solenoidal field is the main trap for particles with small p_t
  - Non trivial effects from interactions with the beam pipe





Pairs production:
Bruno evaluation example





Intensity dependent backgrounds

- **Touschek and beam-gas scattering generates non-gaussian tails in the bunch transverse profile**

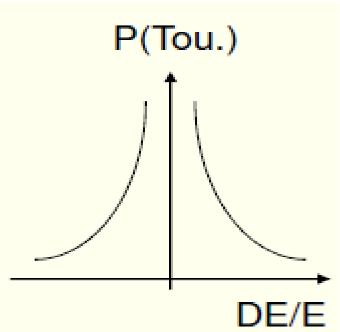
- **The finite aperture of the beam pipe and large β-functions at the final focus double-conspire to make these particles in the tails impinge on the beam pipe**

- **The non-gaussian tails generation and transport through the lattice is simulated with an external code to Bruno until they hit the beam pipe: STAR (M. Boscolo – LNF)**

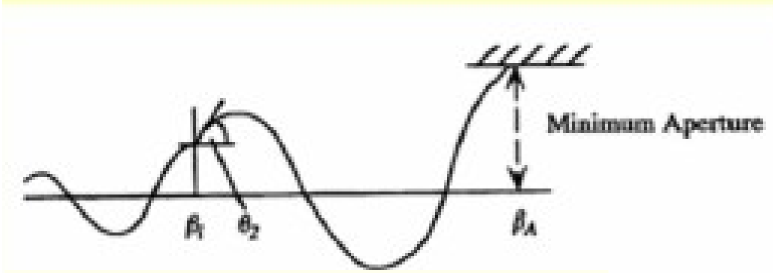
- **Bruno simulates the interaction of these loosed particles near the IP to predict the effects on the detector**

Touschek

- Touschek spectra related with bunch parameters along beam-line (bunch-volume ($V = \sigma_x\sigma_y\sigma_l$), ε, σ_p, N)



- Particle losses depend on machine parameters/optics (physical aperture, dispersion, ...)



- Calculation of Touschek energy spectra along ring averaging Touschek pdf over 3 magnetic elements

$$\frac{1}{\tau} = \int_{\varepsilon}^{\infty} P_{Tou}(E)\,dE$$

$$\frac{1}{\tau} = \frac{\sqrt{\pi}\, r_e^2 c N}{\gamma^3 (4\pi)^{3/2} V \sigma'_x \varepsilon^2} C(u_{\min})$$

$$\sigma'_x = \sqrt{\frac{\varepsilon_x}{\beta} + \sigma_p^2\left(D'_x + D_x \frac{\alpha_x}{\beta_x}\right)^2}$$

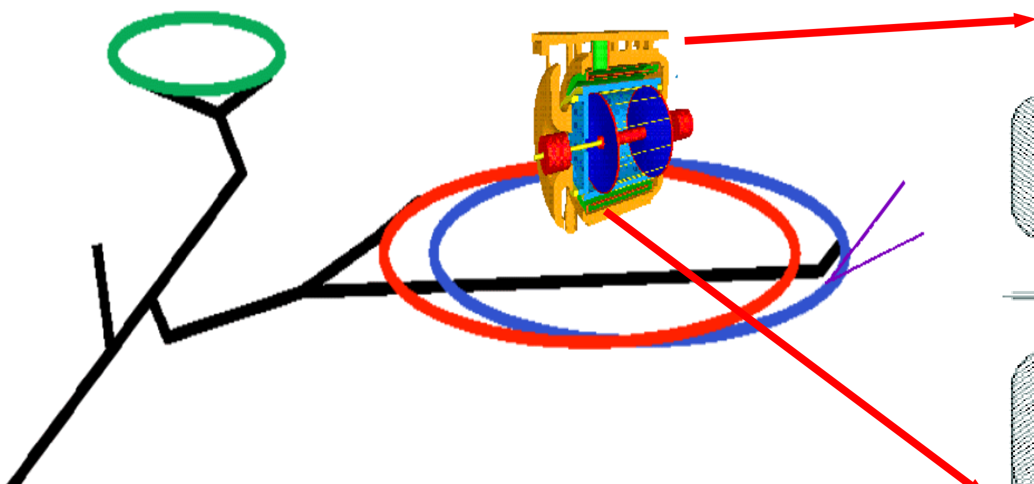
$$\varepsilon = \frac{\Delta E}{E} \qquad u_{\min} = \left(\frac{\varepsilon}{\gamma\sigma'_x}\right)^2$$

- **Tracking of Touschek particles:** start with transverse gaussian distribution and proper energy spectrum every 3 elements
  - Track over many turns or until they are loss
  - Estimation of IR and total Touschek particles losses
  - Estimation of Touschek lifetime

Touschek Simulation tool used at DAΦNE: Machine Background Measurements vs MC

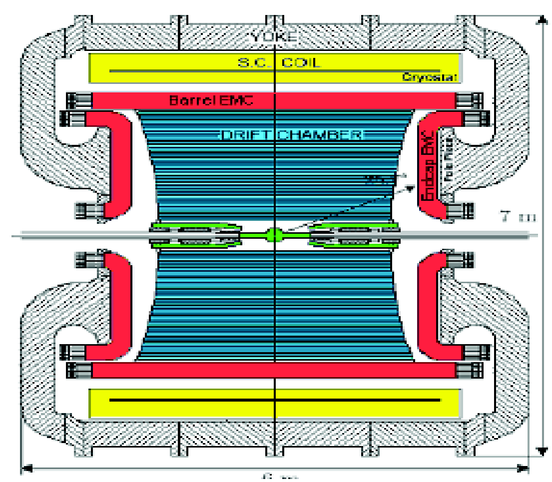
- **DAΦFNE: the Frascati ϕ-factory (e^+e^- collider @ $\sqrt{s} = M(\phi) = 1019.4$ MeV mainly for Kaon physics)**
- **Innovative SuperB collision scheme implemented at DAΦFNE**
- **High background (Touschek) at KLOE-2 prevents using DAΦNE full luminosity**

  The background rates prevented the KLOE-2 drift chamber to take data
- **Estimate machine backgrounds using data and compare with simulation using the SuperB tools**
- **The goal of this analysis was two-fold:**
  - To test the SuperB simulation tools on data (data vs simulation agreement)
  - To study different DAFΦNE final layout (shields) that could reduce backgrounds



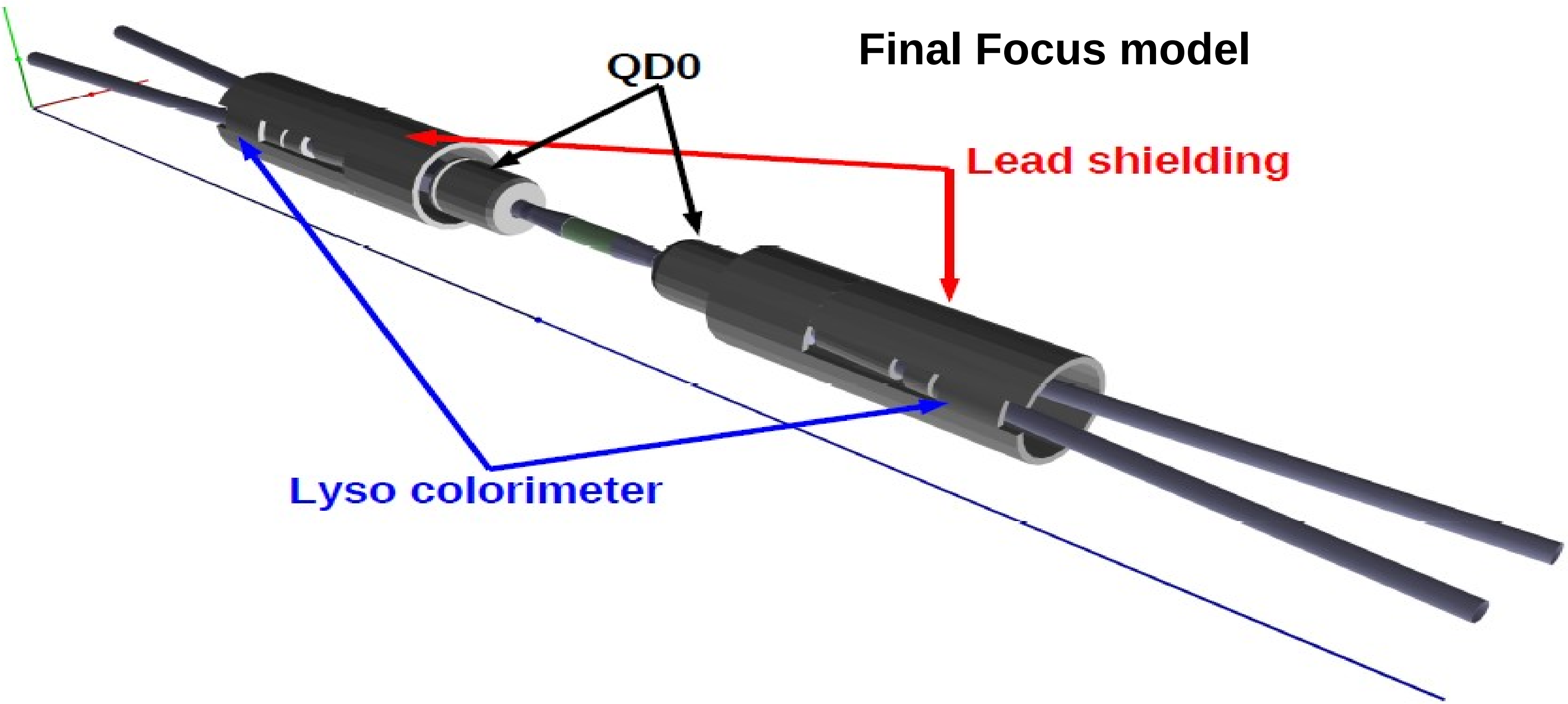
Superconducting coil

B = 0.52 T



Touschek Simulation tool used at DAΦNE: Machine Background Measurements vs MC

- **Simulation Strategy:**
  - Use STAR code to get the Touschek primaries
  - Built a final focus model of DAFΦNE (material and magnetic fields)
  - Simulation of Touschek primaries inside final focus up to entering KLOE-2
  - KLOE-2 code to simulate and reconstruct particles that get into the detector
  - Use KLOE-2 end-cap calorimeter as a background counter



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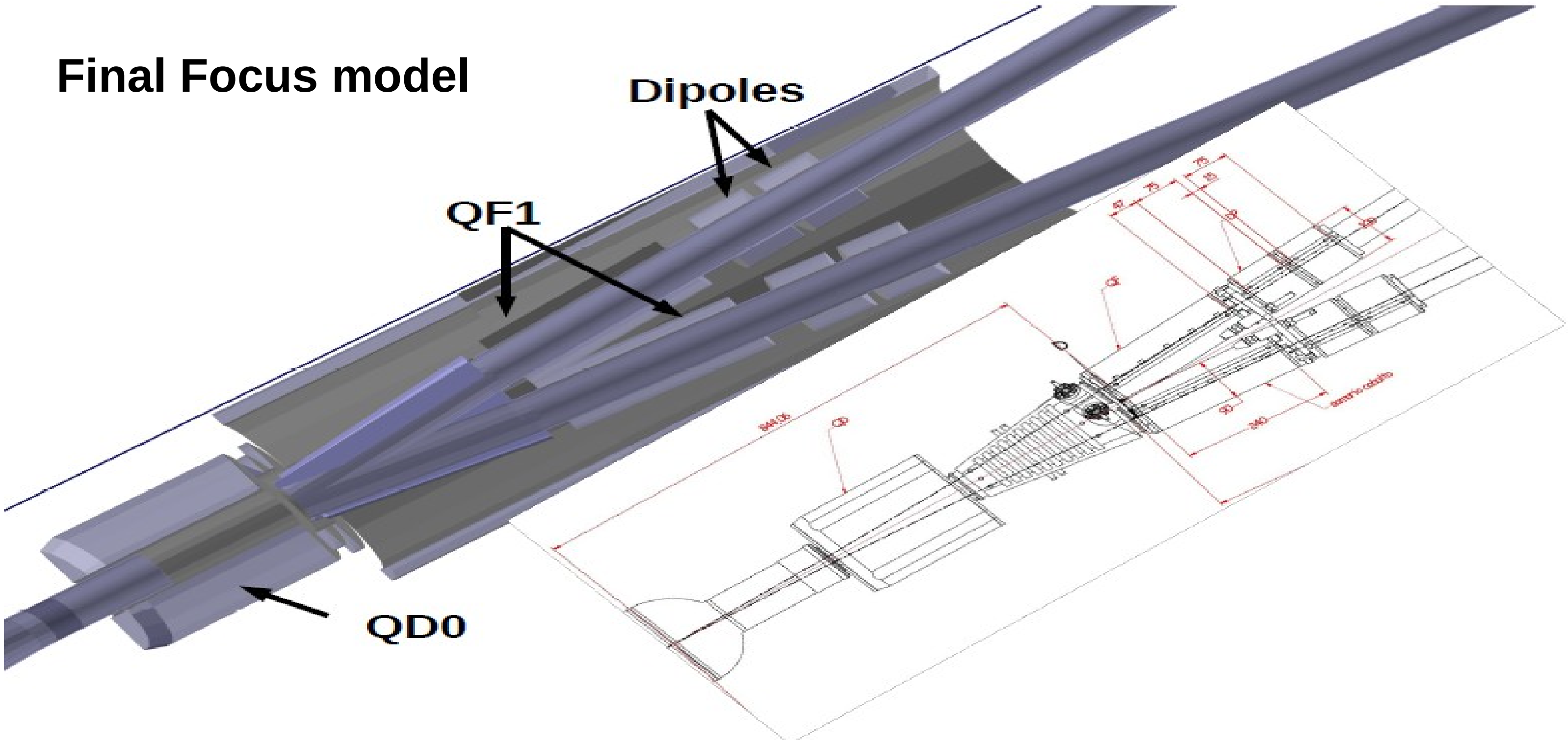
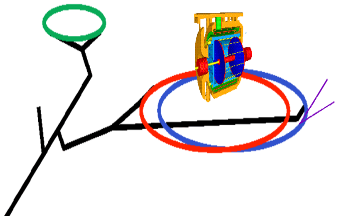
Final Focus model



Touschek Simulation tool used at DAΦNE: Machine Background Measurements vs MC



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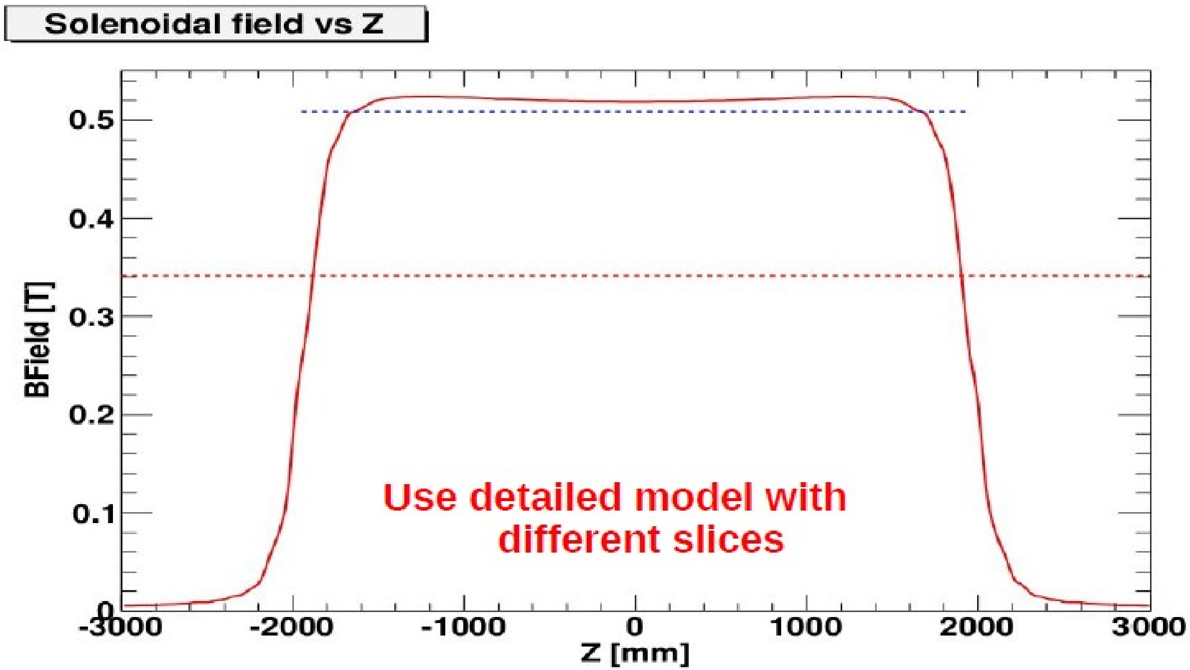
KLOE-2 Solenoidal field



Touschek Simulation tool used at DAΦNE: Machine Background Measurements vs MC

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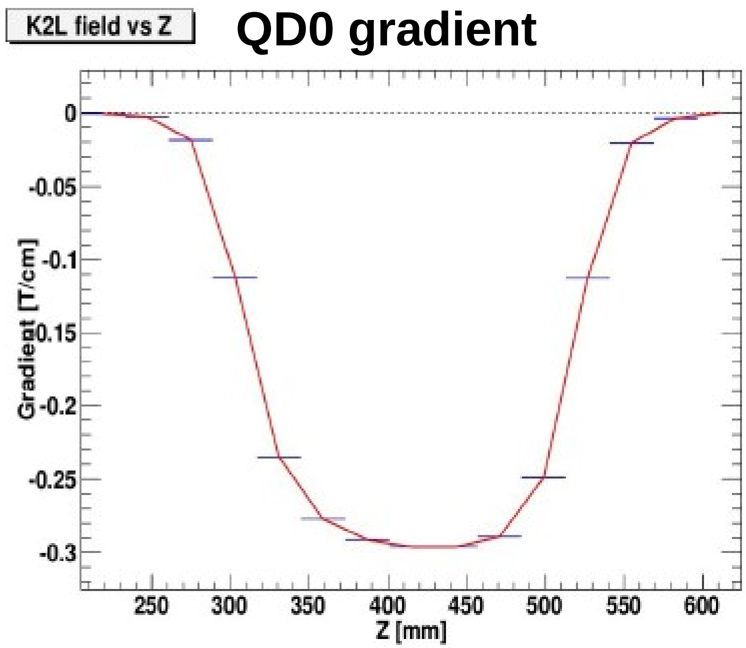
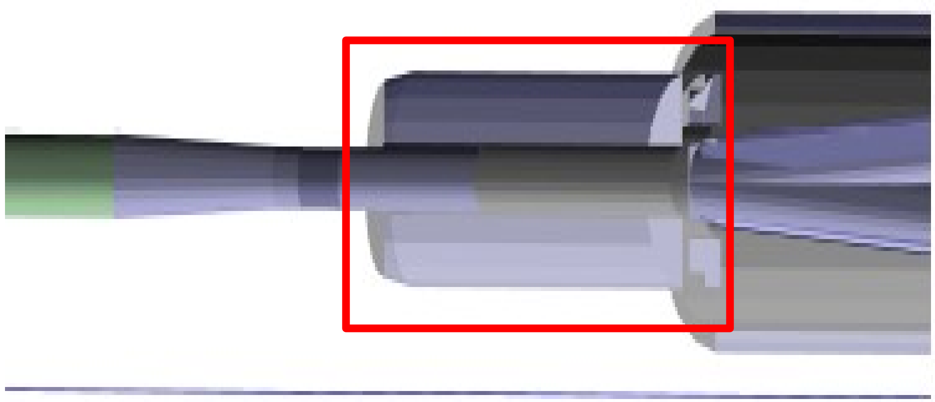
Magnetic field model (QD0)

QD0 gradient





Touschek Simulation tool used at DAΦNE: Machine Background Measurements vs MC

- **Simulation Strategy:**
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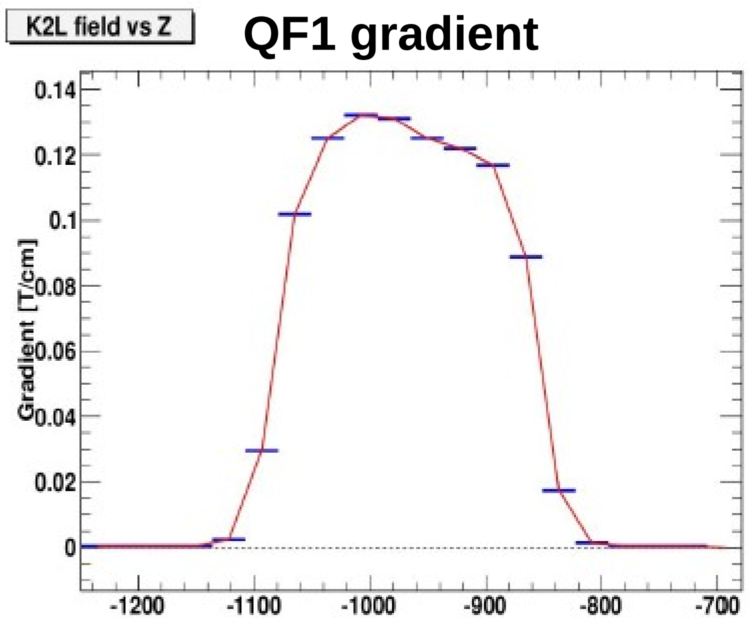
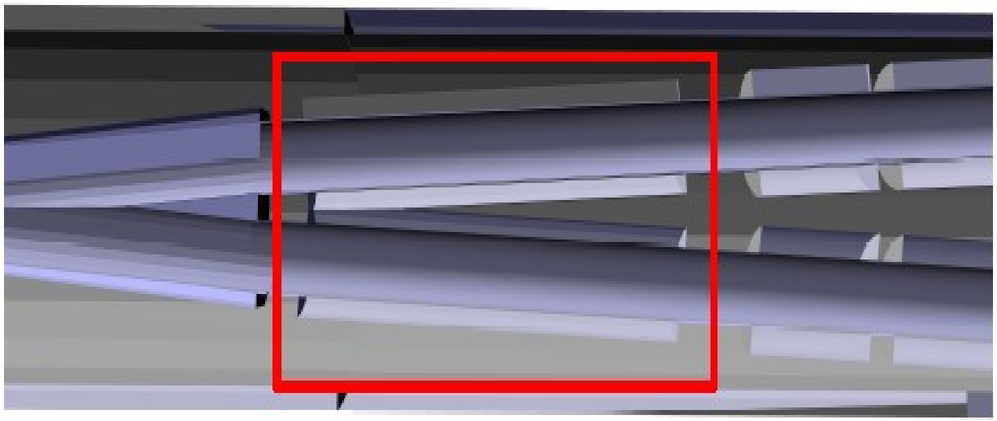
  - Use KLOE-2 end-cap calorimeter as a background counter

Magnetic field model (QF1)

QF1 gradient





Touschek Simulation tool used at DAΦNE: Machine Background Measurements vs MC

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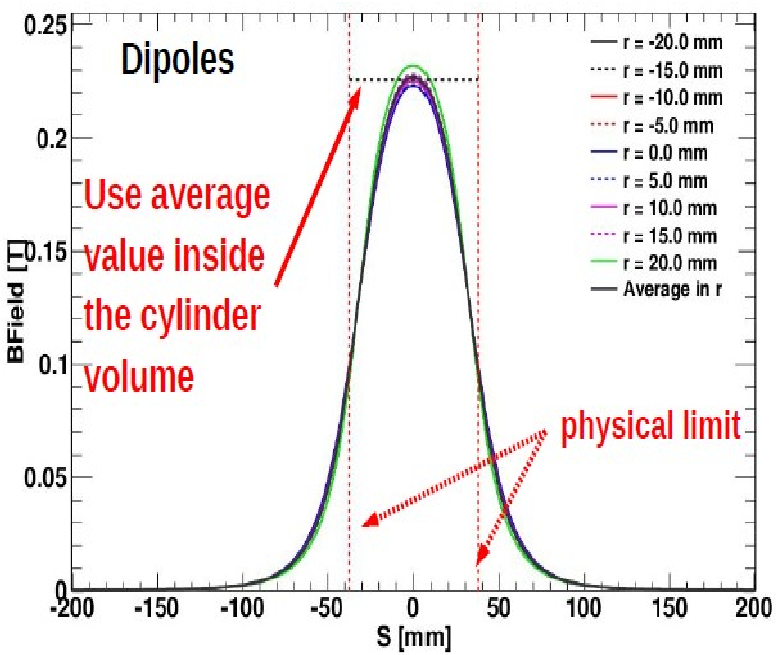
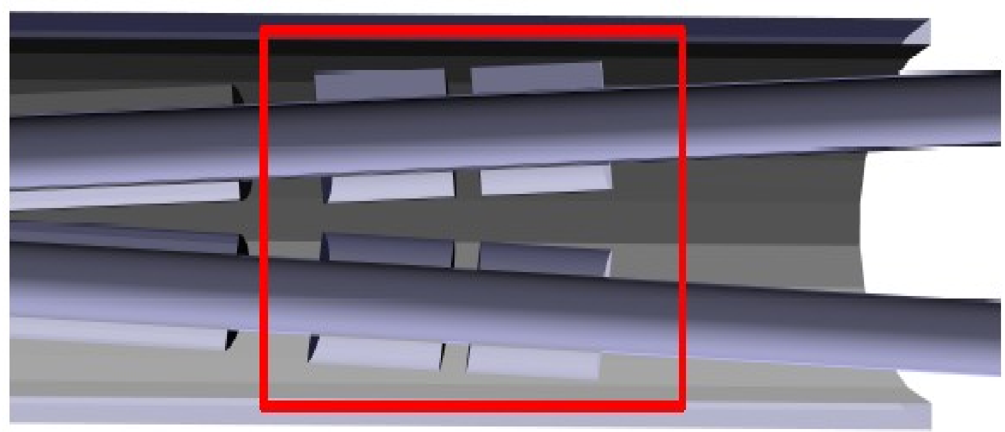
  - Simulation of Touschek primaries inside final focus up to entering KLOE-2
  - KLOE-2 code to simulate and reconstruct particles that get into the detector
  - Use KLOE-2 end-cap calorimeter as a background counter

Magnetic field model (Dipoles)





Touschek Simulation tool used at DAΦNE: Machine Background Measurements vs MC

- **Simulation Strategy:**
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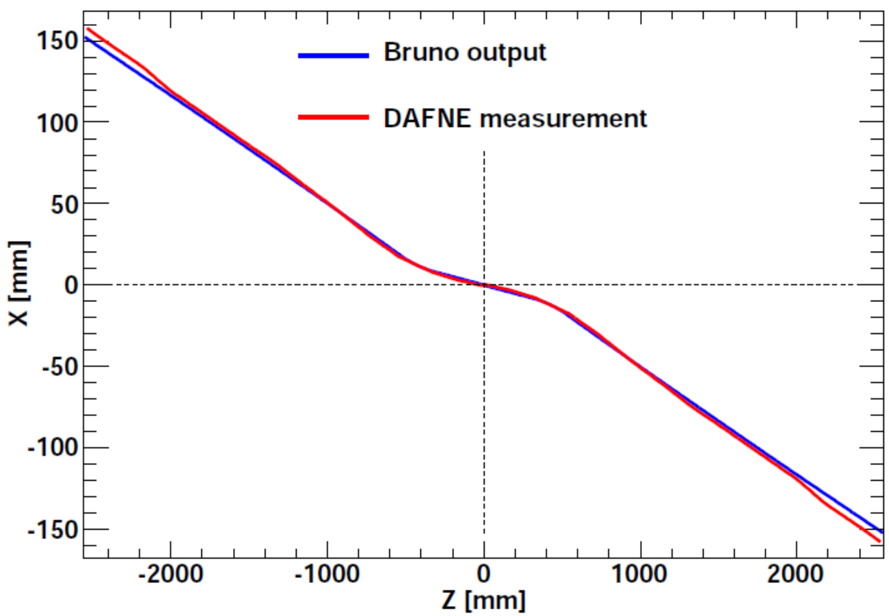
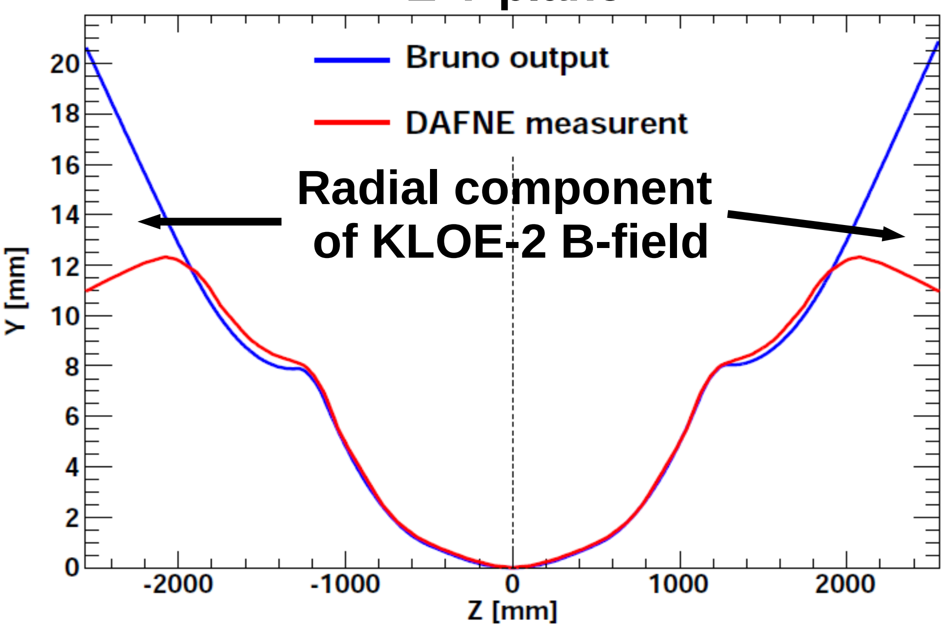
  - KLOE-2 code to simulate and reconstruct particles that get into the detector
  - Use KLOE-2 end-cap calorimeter as a background counter

Nominal trajectory

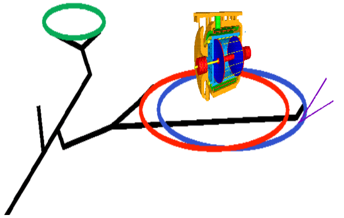
Z-X plane



Z-Y plane



Touschek Simulation tool used at DAΦNE: Machine Background Measurements vs MC



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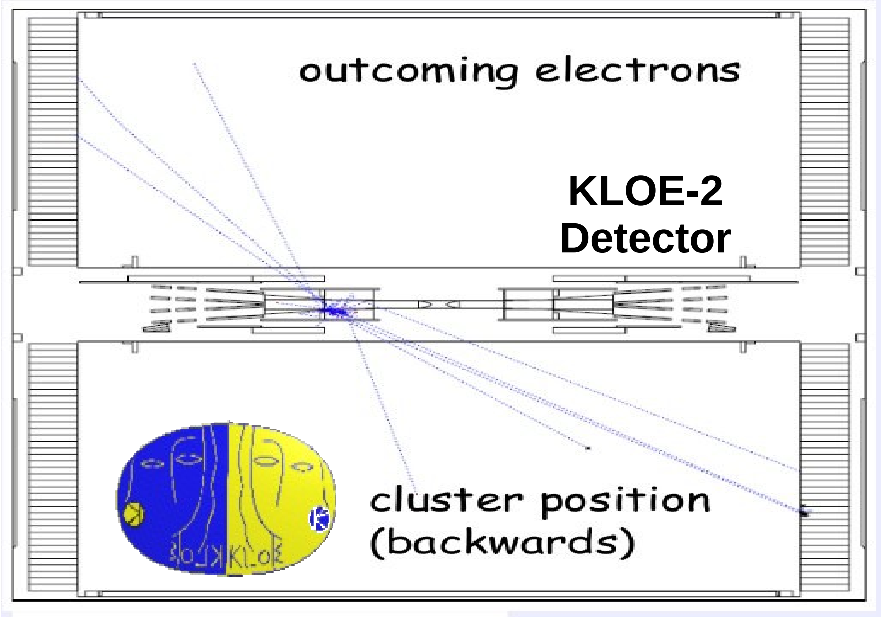
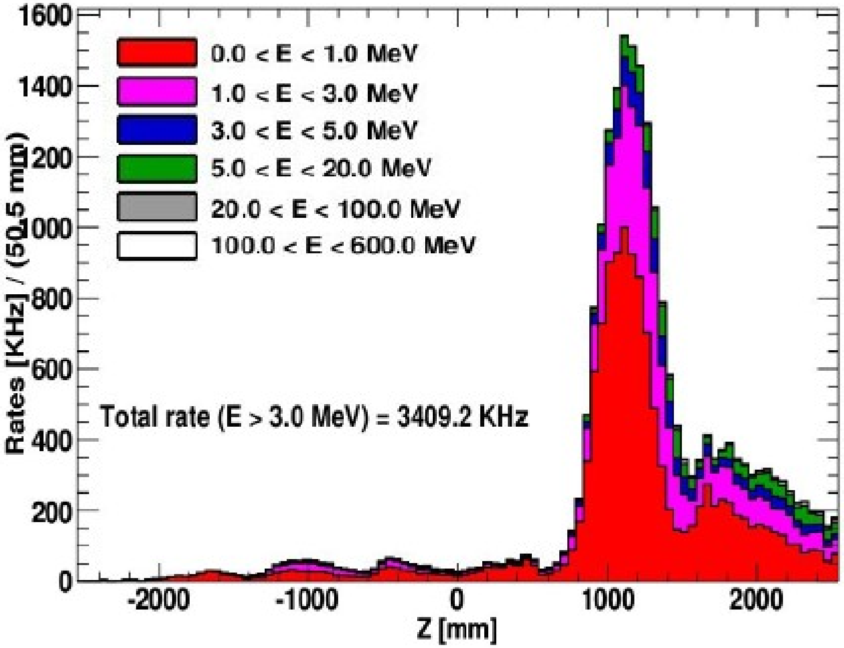
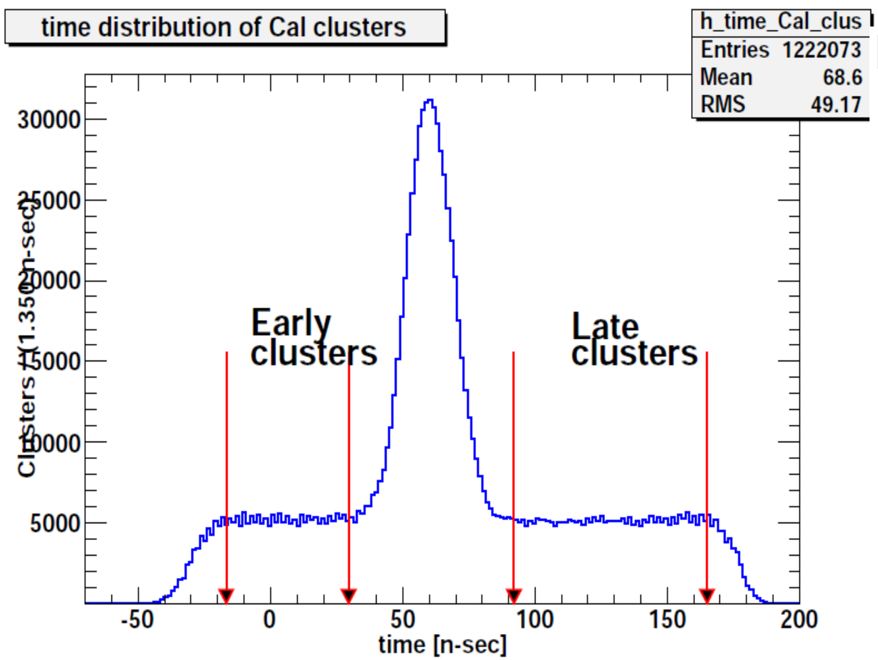
Rate of particles exiting the final focus (photons)

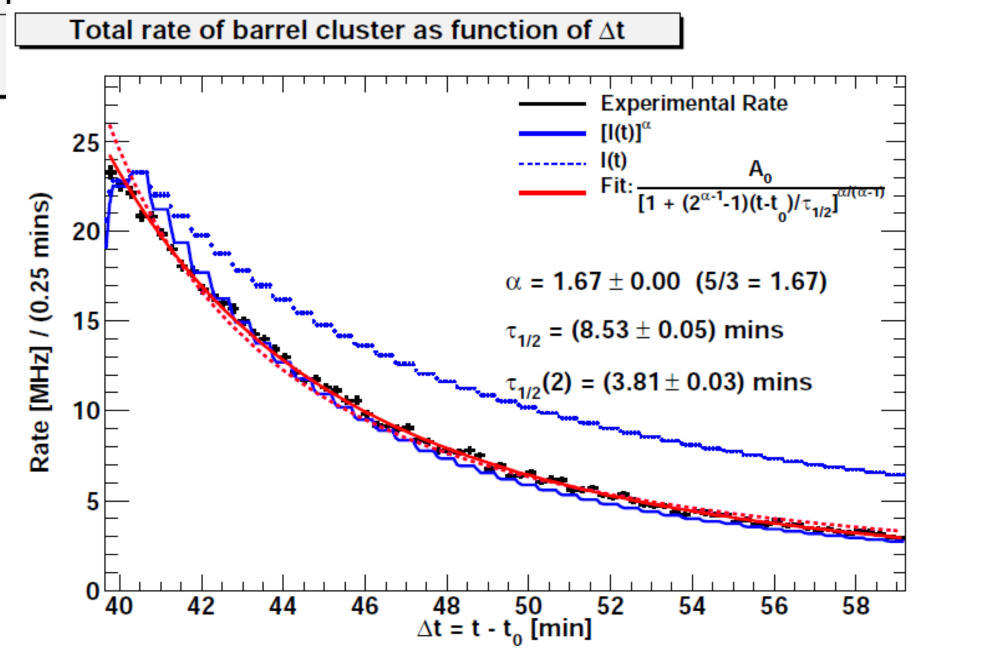




Touschek Simulation tool used at DAΦNE: Machine Background Measurements vs MC

- **Data analysis strategy:**
  - Use single beam (electron) data using cosmic trigger
  - Select hits on the ECal that are off-time w.r.t the cosmic ray hits
  - Correct rates by bunch life-time (not included in simulation)
  - Count ECal clusters as a function of time and estimate the cluster rate



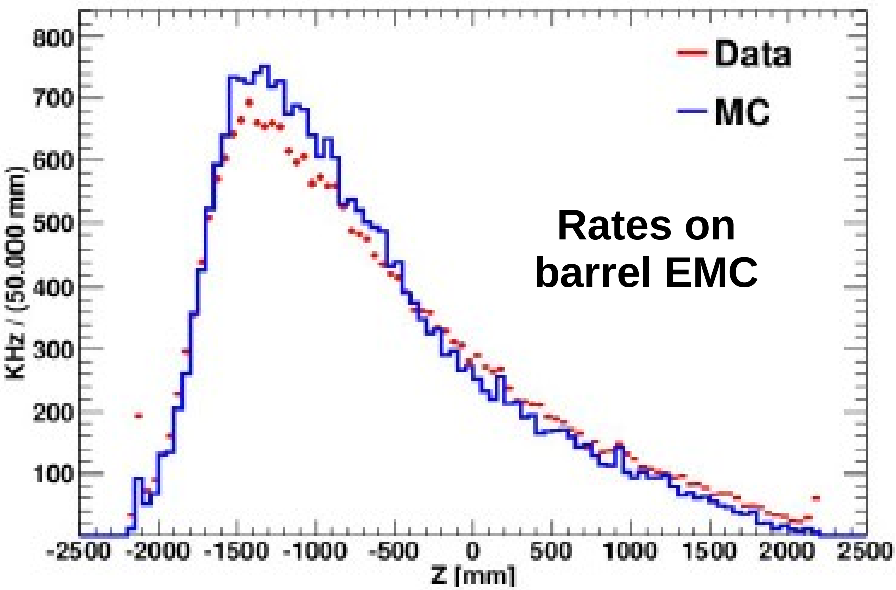


Touschek Simulation tool used at DAΦNE: Machine Background Measurements vs MC

- **Data vs simulation comparison:**
  - Simulation gives very similar shapes as data both on Barrel and end-caps of ECal
  - Total rates agree within a factor of 2

    ⇒ great achievement for machine background estimations
  - In the data used the beam was not optimal (slightly off orbit). Simulation should do better with better beam quality

Data vs MC normalized to same total rate

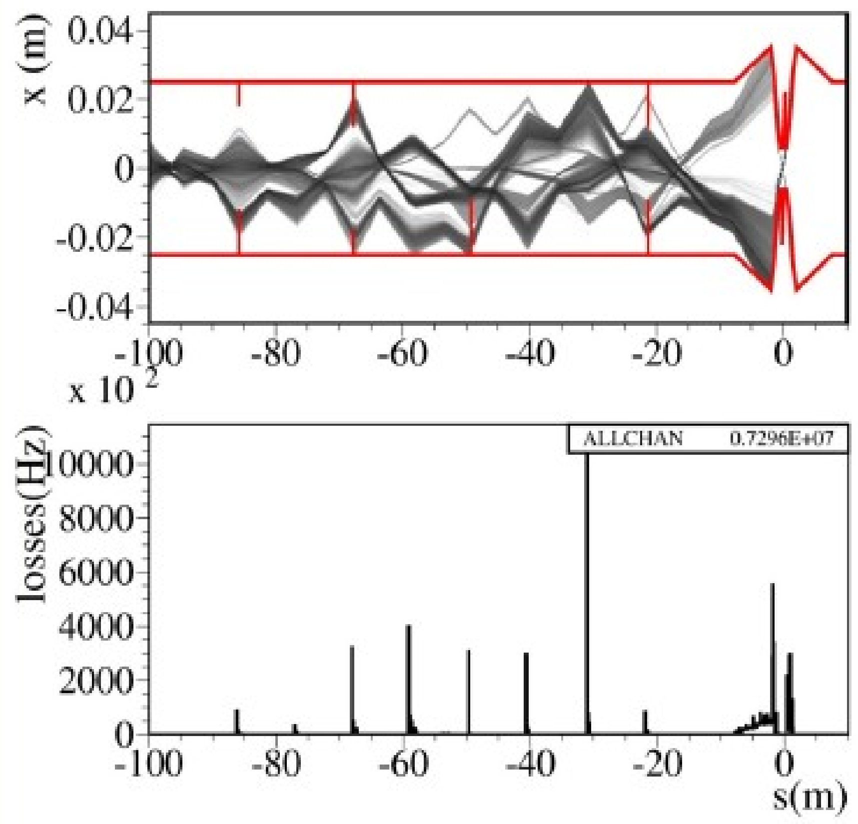


A. Perez et al., IPAC11 (2011) p. 2262.

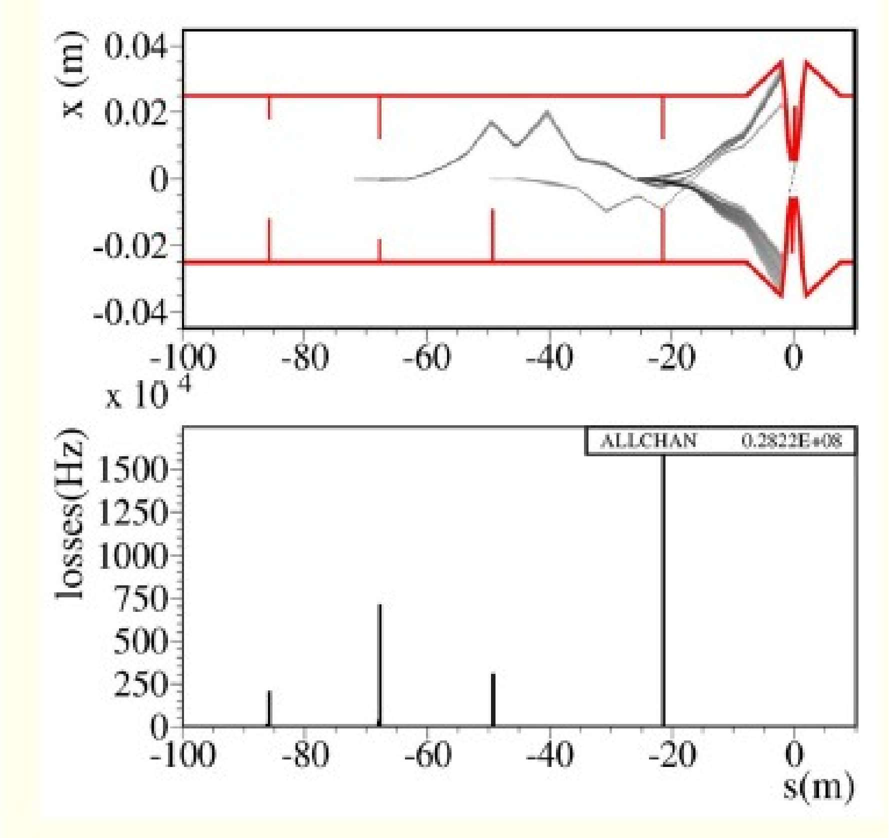
EmC Region	Data rates	MC rates	Data/MC
Barrel	24.7 MHz	33.3 MHz	0.74
Forward	3.0 MHz	1.6 MHz	1.87
Backward	37.4 MHz	78.0 MHz	0.48

Touschek trajectories: HER

No collimators



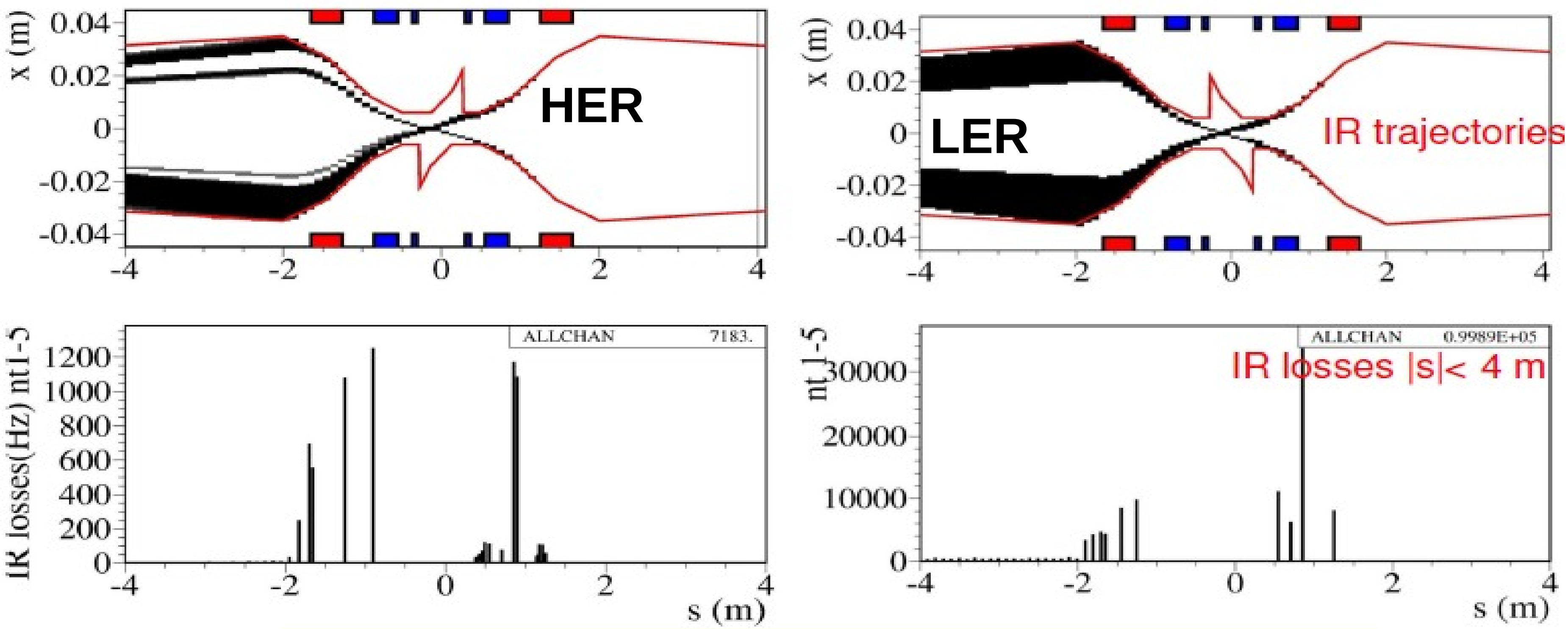
With collimators



- Touschek losses mainly on the horizontal plane
- Found a horizontal collimator set that reduces losses rates at the IR and maximizes lifetime. Real set will be found experimentally

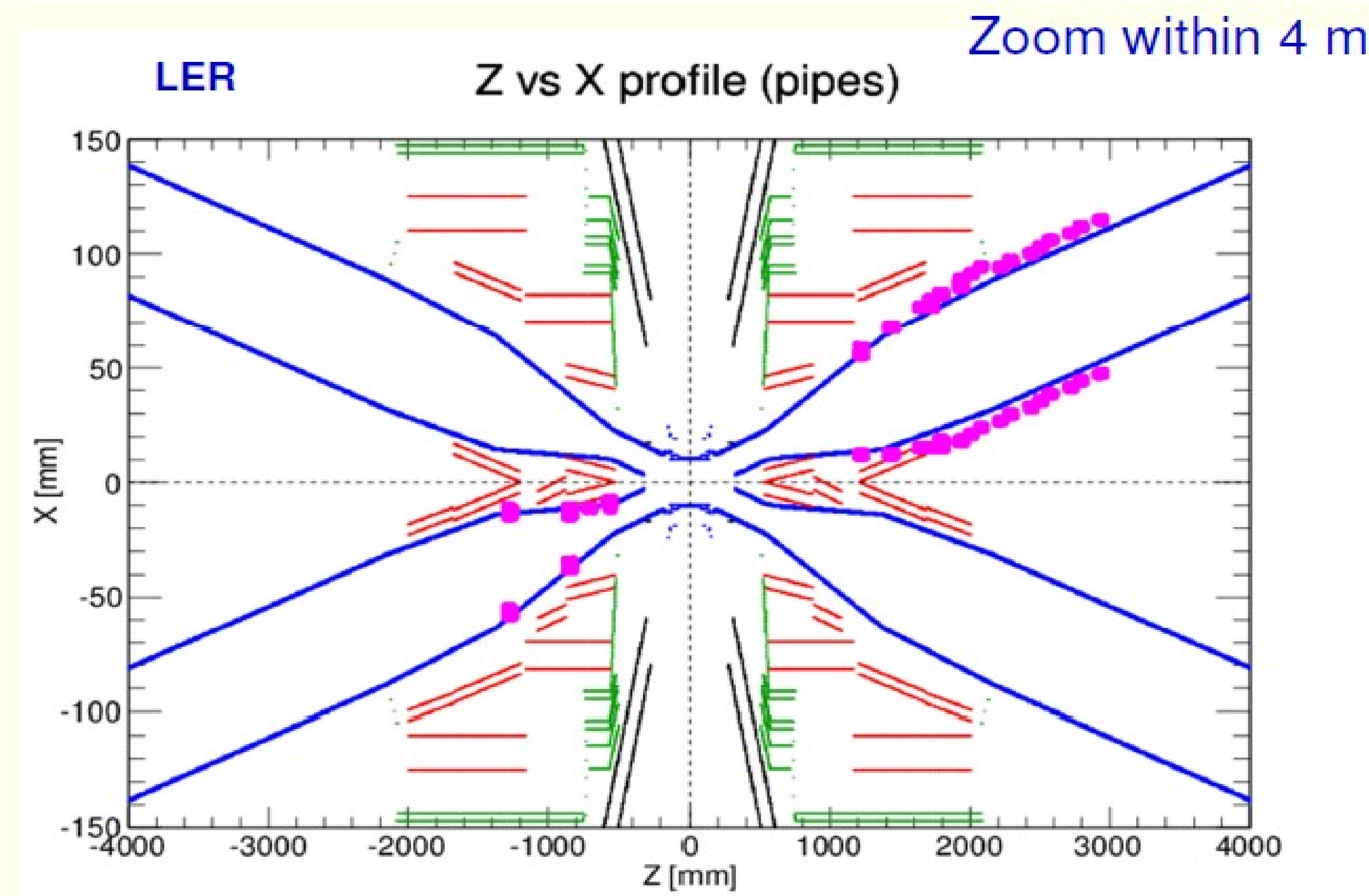
Touschek IR rates: HER/LER

With collimators



Touschek	HER	LER
No collimators, ε_x with IBS	2.4 GHz	17 GHz
With Collimators, ε_x with IBS	**6.8 MHz**	**72 MHz**

Touschek primaries for Bruno



Beam-gas

- Two kind of interactions between bunch particles and residual gas:
  - Inelastic (Bremsstrahlung)

consider both nuclear and electrons interactions

$$\frac{d\sigma}{du} = 4\alpha\, r_e^2\, Z(Z+1)\, \frac{4}{3u}(1-u+.75u^2)\ln\left(\frac{183}{Z^{1/3}}\right) \quad (4.1)$$

$$u = \frac{k}{E}$$

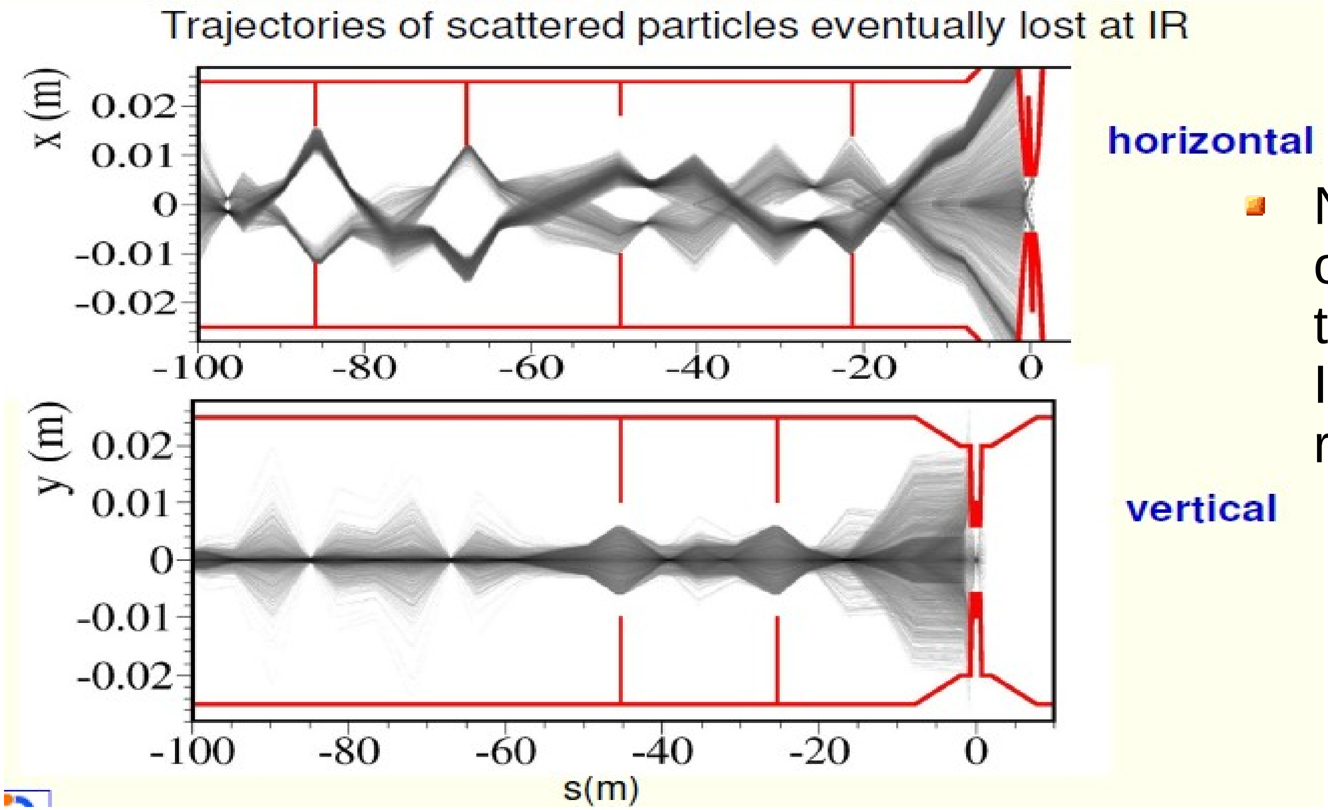
  - Elastic (Coulomb)

$$\frac{d\sigma}{d\Omega} = 4r_e^2\; Z^2 \frac{\left(\frac{m}{p}\right)^2}{(\theta^2+\theta_1^2)^2},$$

$$\theta_1 = \alpha Z^{1/3}\left(\frac{m}{p}\right)$$

- Calculation of beam-gas energy spectra along ring averaging scattering pdf over 3 magnetic elements
- Pressure and gas composition can vary along the ring
- **Tracking of Beam-gas particles:** start with transverse gaussian distribution and proper energy spectrum every 3 elements
  - Track over many turns or until they are loss
  - Estimation of IR and total Beam-gas particles losses
  - Estimation of Beam-gas lifetime

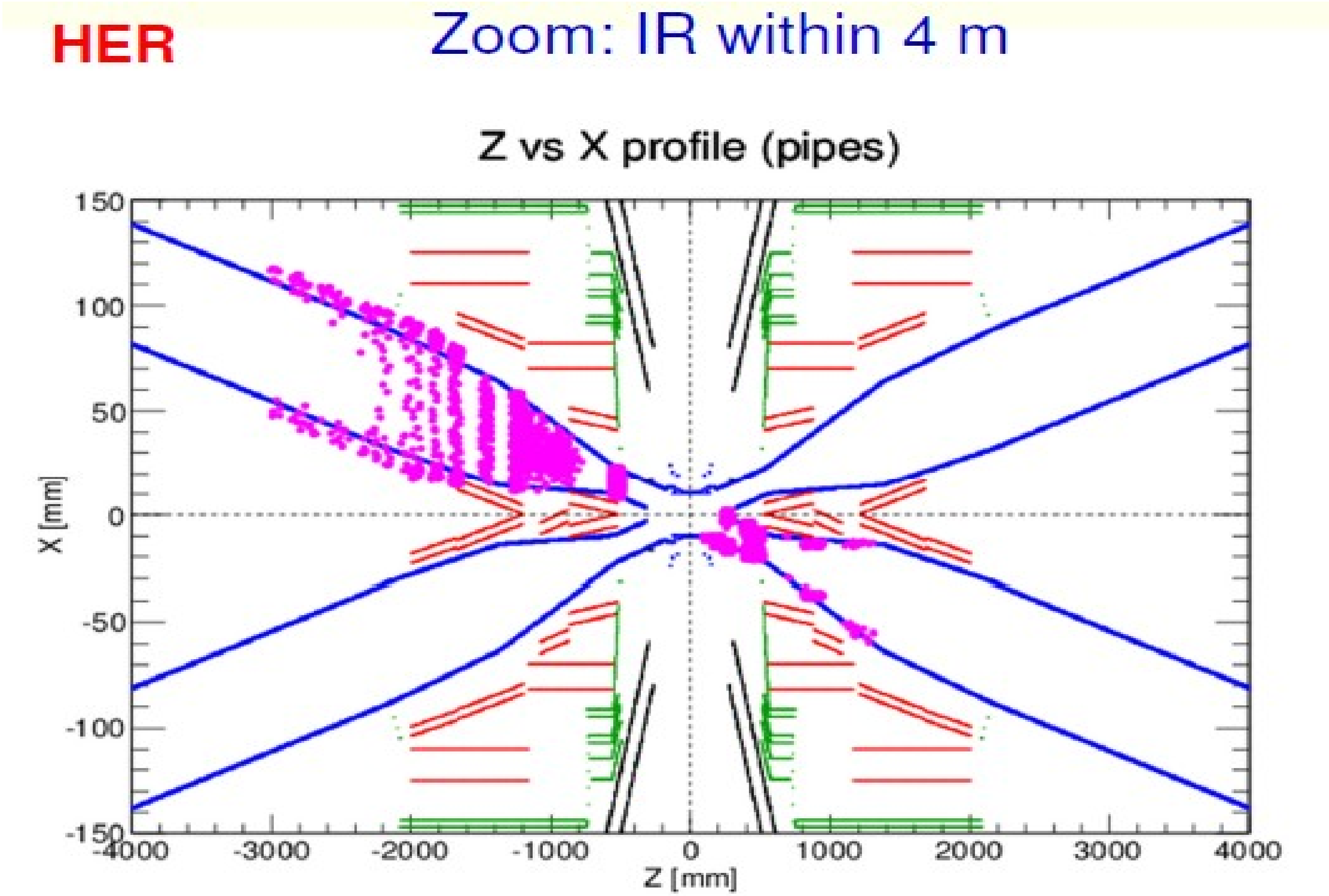
Beam-gas trajectories and losses at IR: HER



- Need an additional set of vertical collimators to reduce losses at the IP while getting a reasonable lifetime

Coulomb No collimators, ε_x with IBS	10.5 GHz	25 GHz
Coulomb with collimators, ε_x with IBS	**3.7MHz**	**36 MHz**
Bremsstrahlung with coll	130KHz	450KHz

Beam-gas primaries for Bruno



Touschek vs Rad. Bhabha

- **LER Touschek IR loss rate 100MHz vs 10GHz from Rad. Bhabha**
- **But: the Touschek losses are fairly energetic (~4 GeV) while radiative BhaBha are soft (< 1 GeV)**
- **The energy spectrum and angular distributions of the secondaries are quite different**
  - The total rate of Touschek secondaries is smaller
  - The energy spectrum of the Touschek secondaries is harder

Rad-Bhabha Losses at the Beam-pipe

Total rates around the IP (-3 to 3 mts)

HER positron rates

E range (GeV)	Rate (GHz)
0.0 – 1.0	4.735
1.0 – 2.0	2.789
2.0 – 3.0	0.025
3.0 – 4.0	0.003
4.0 – 5.0	0.003
5.0 – 6.0	0.003
6.0 – 7.0	0.005
0.0 – 7.0	7.563

LER electron rates

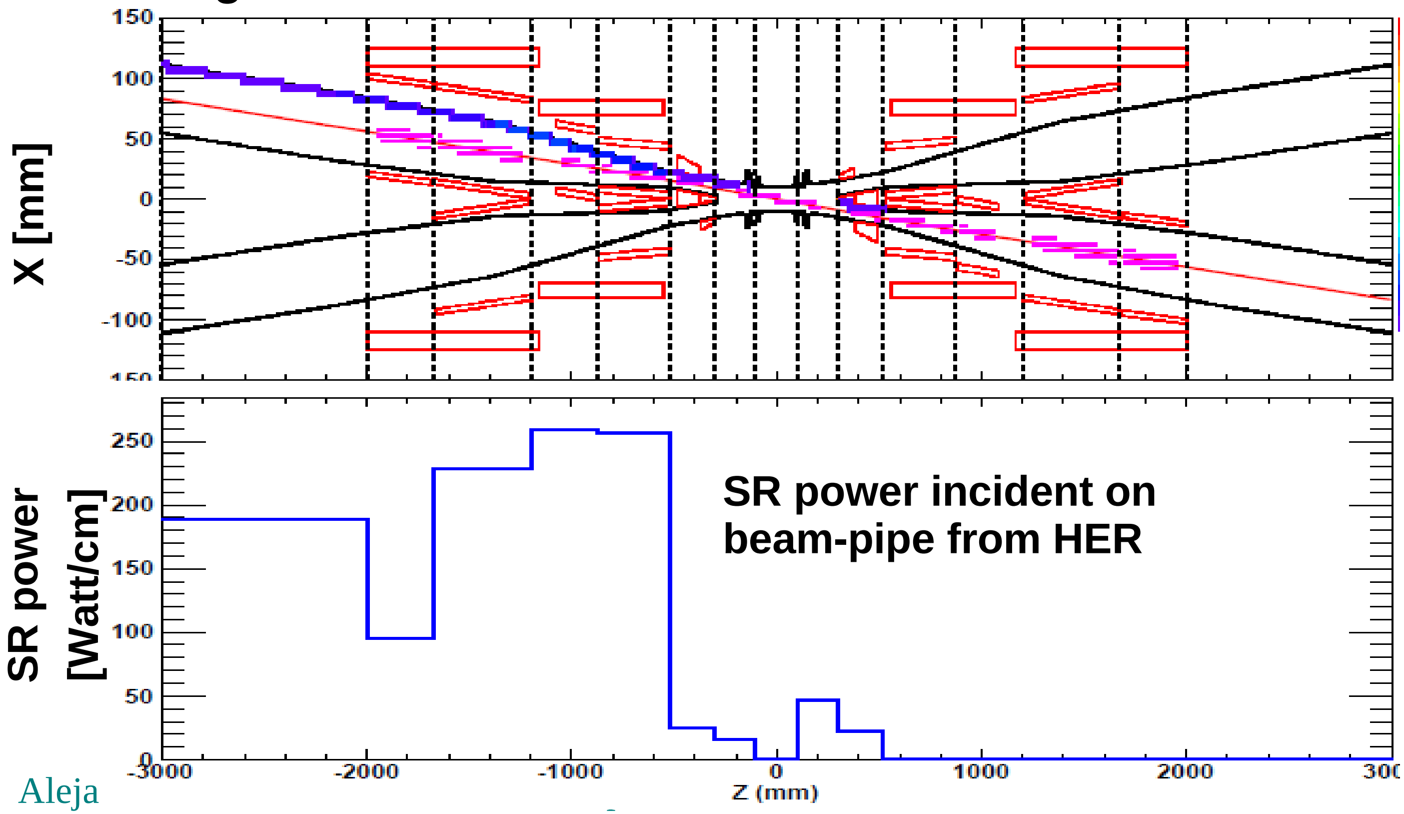
E range (GeV)	Rate (GHz)
0.0 – 1.0	7.863
1.0 – 1.5	2.289
1.5 – 2.0	0.031
2.0 – 2.5	0.007
2.5 – 3.0	0.004
3.0 – 3.5	0.005
3.5 – 4.2	0.003
0.0 – 4.2	10.202

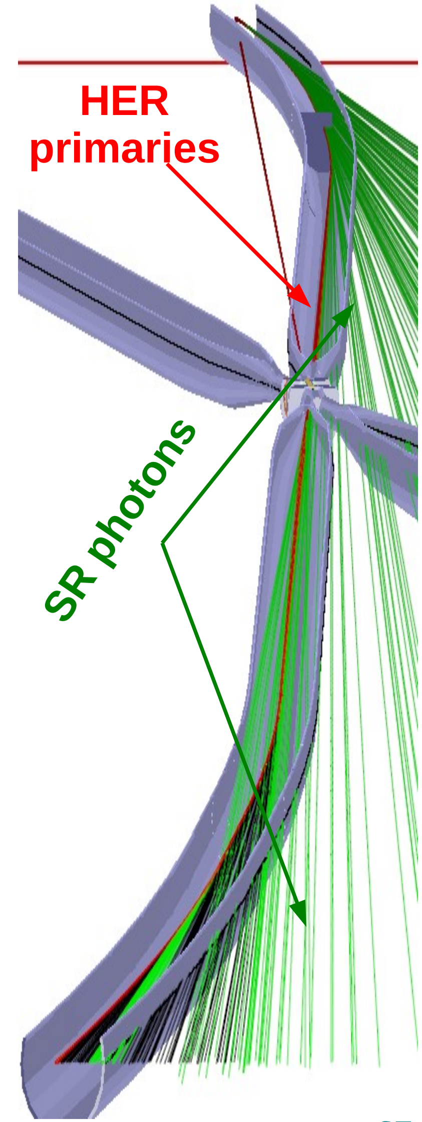
Touschek	HER	LER
No collimators, ε_x with IBS	2.5 GHz	17 GHz
With Collimators, ε_x with IBS	**7 MHz**	**100 MHz**

Coulomb No collimators, ε_x with IBS	11 GHz	25 GHz
Coulomb with collimators, ε_x with IBS	**11MHz**	**36 MHz**
Bremsstrahlung with coll	130KHz	450KHz

Synchrotron Radiation

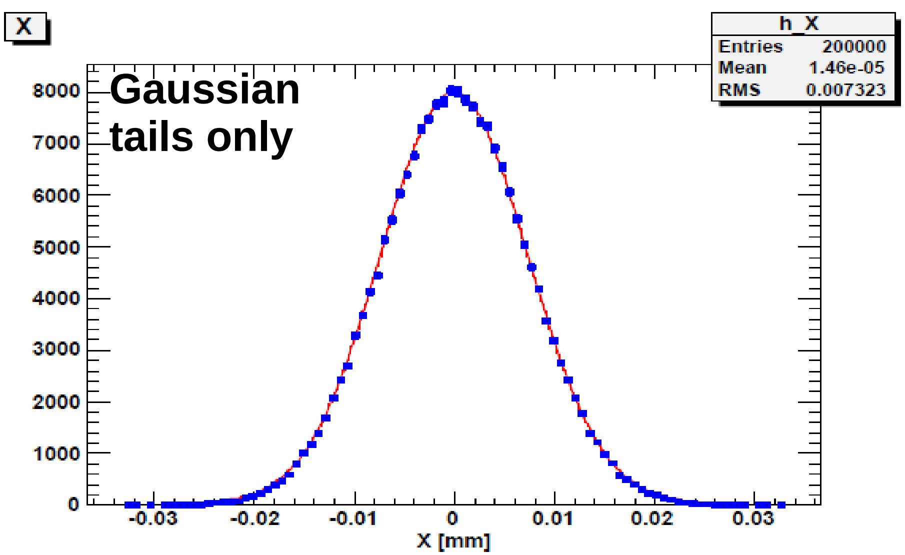
- SR energy spectrum is the soft X-ray, but the rates are huge (hundreds of watts)
- The final focus W-shield should be more than adequate to absorb SR-photons passing through the thin beam-pipe
- The small fraction of the SR radiation that will be reflected and diffused by the inner surface of the pipe eventually hitting the SVT was evaluated with Bruno

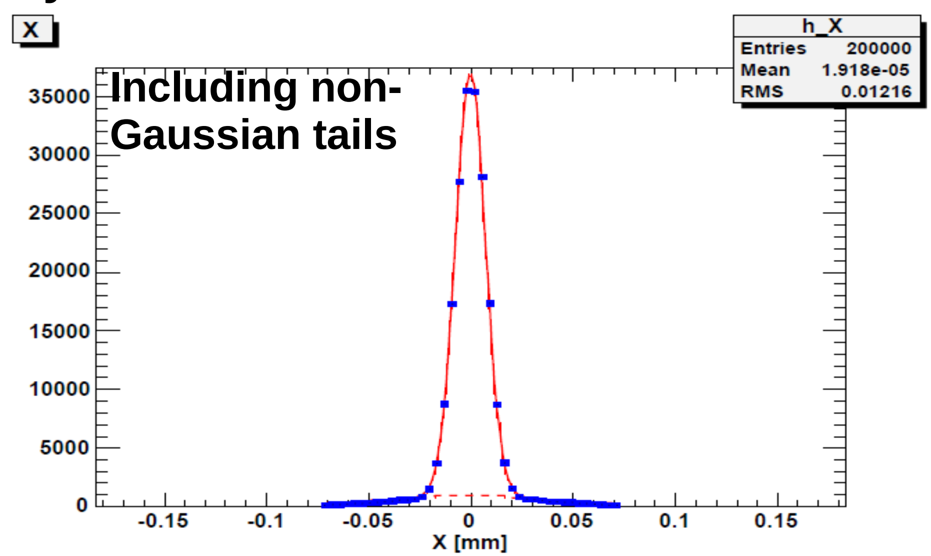




Synchrotron Radiation: strategy

- **3 stages code:**
  - Stage 1: use the IP parameters of the beams to generate primaries for HER/LER. Invert momentum and charge and backtrack particles up to the 2^{nd} dipoles upstream the beam-line
  - Stage 2: at this point re-invert the momentum and charge and foward-track the particles turning-on the Synchrotron radiation
  - Stage 3: use as primaries for the simulation those photons that eventually hit the beam pipe
- **Can include non-gaussian tails from Touschek/Beam-Gas by adding 2 gaussian functions: core + tails. Can also move the location of the IP**
- **Only managed to simulate synchrotron radiation with gaussian tails, obtaining a negligible effect on all subsystems**

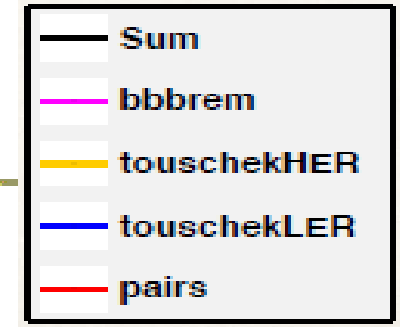




Machine backgrounds on the SuperB detector

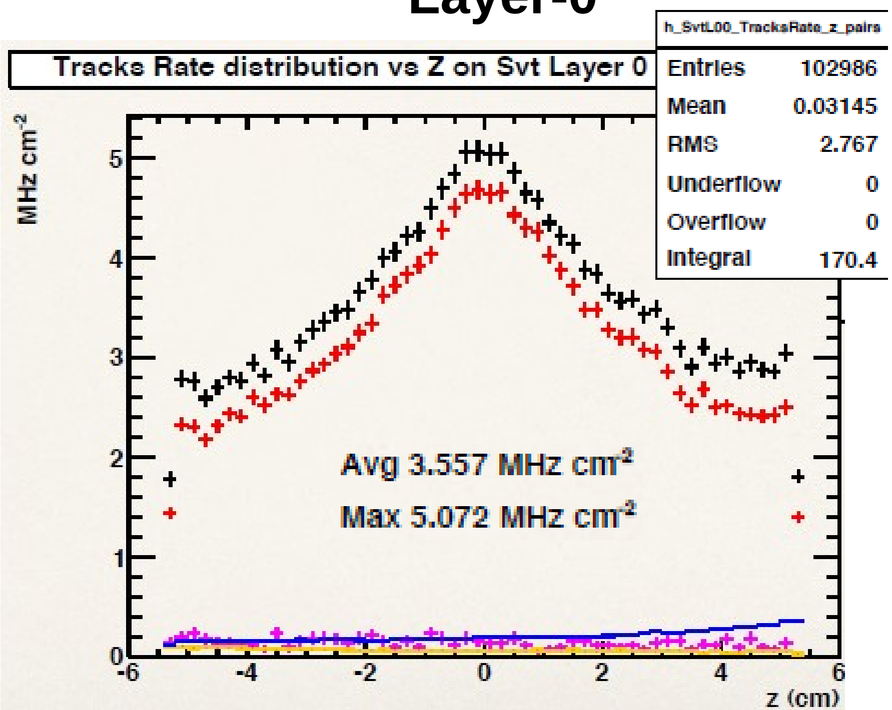
R. Cenci

SVT

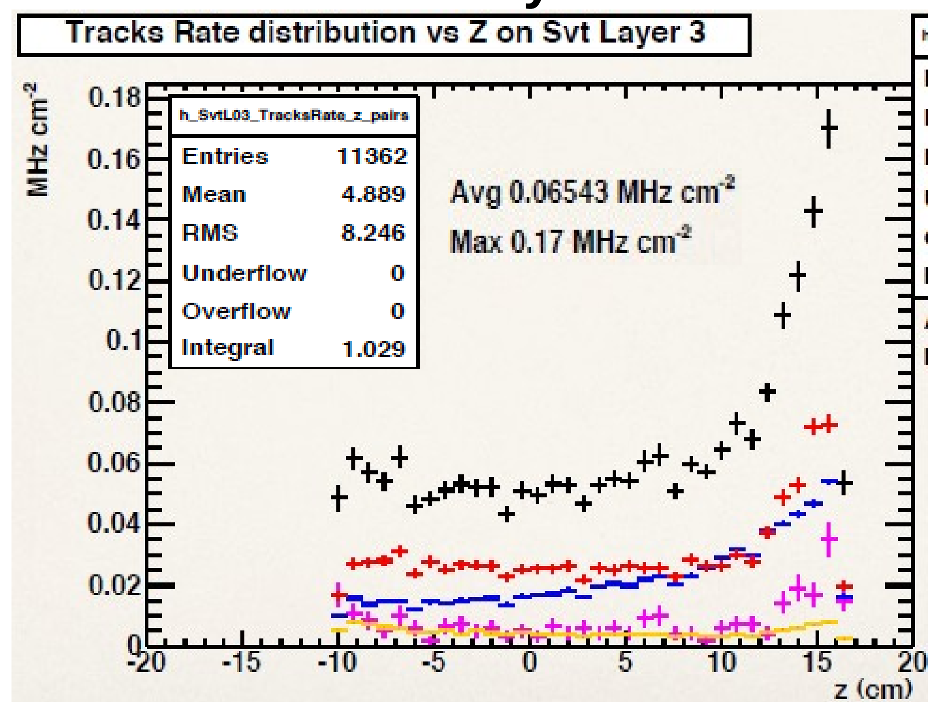


- **Instantaneous rate of charged particles for SVT vs Z (sum over ϕ)**
- **Track rate (multiple crossing not considered):**
  - L0: main contribution from 2-photon (mostly coming from IP)
  - L3: Touschek-LER comparable to 2-photon

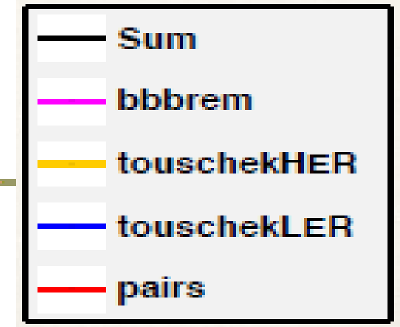
Layer-0



Layer-3

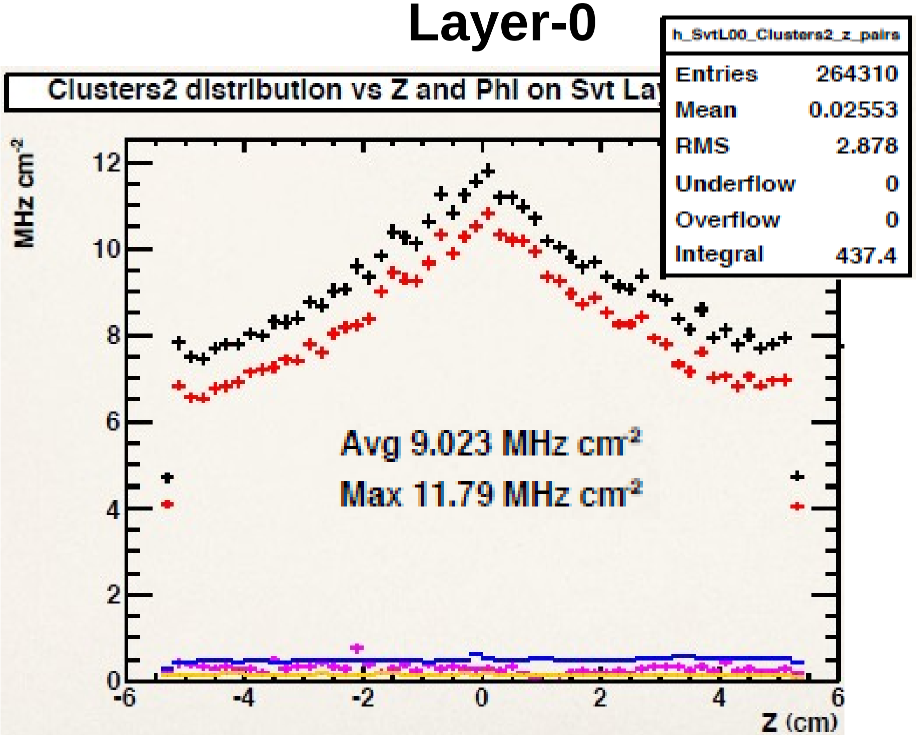


SVT

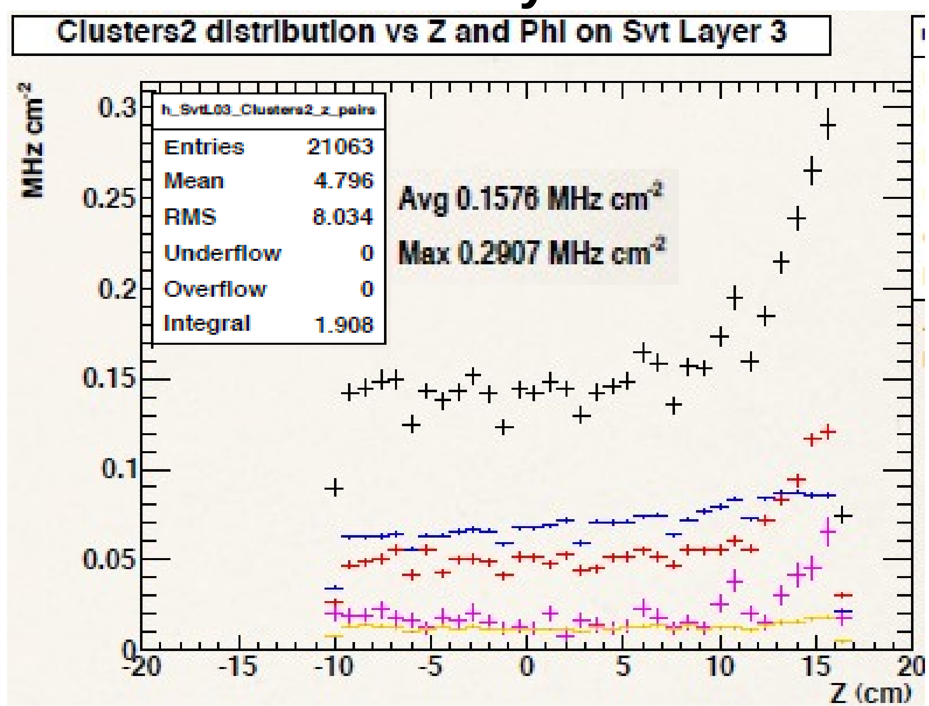


- **Instantaneous cluster rate for SVT vs Z (sum over ϕ)**
- **Track rate (multiple crossing not considered):**
  - L0: average # of cluster/track ~2.6
  - L3: average # of cluster/track ~2.4
  - Additional factor due to # hits per cluster (pixel/strip), pitch/thickness dependent: average up to ~5

Layer-0



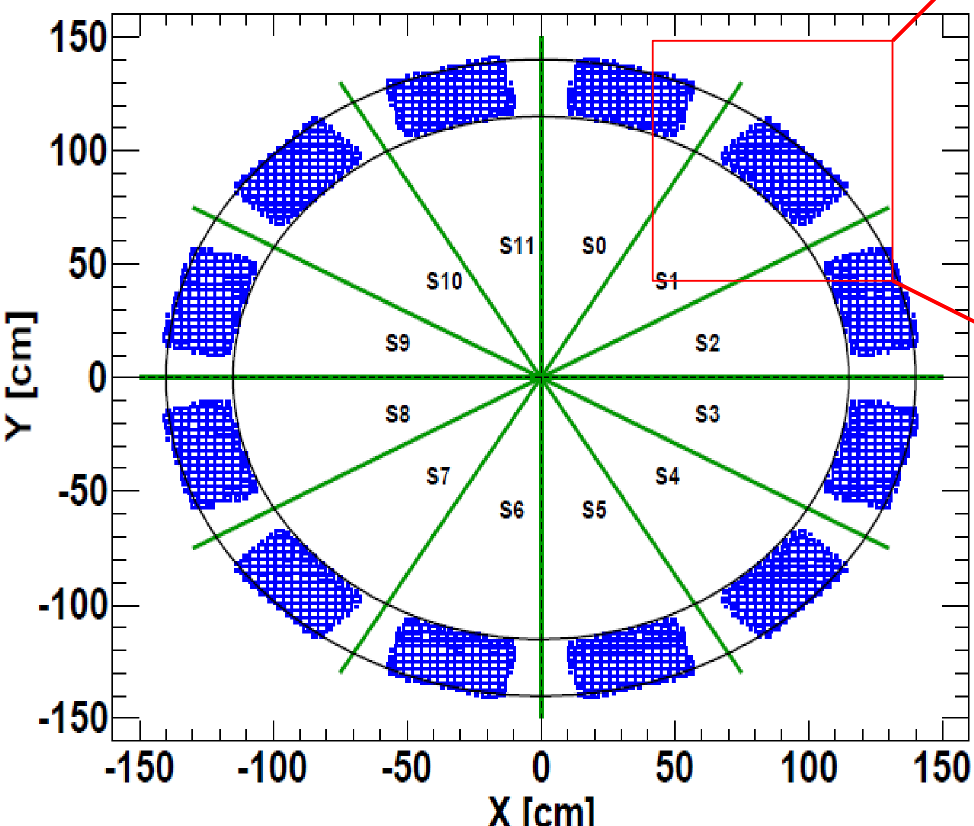
Layer-3

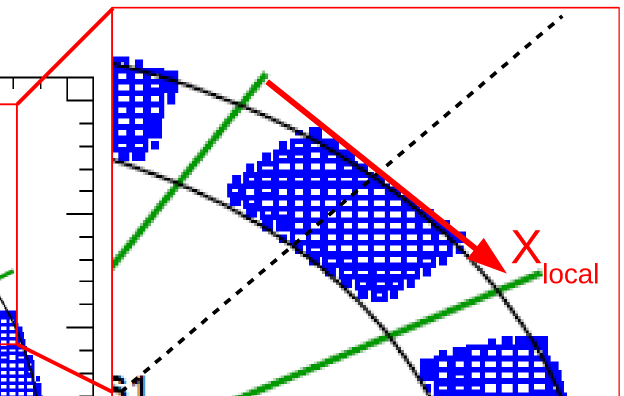


FDIRC

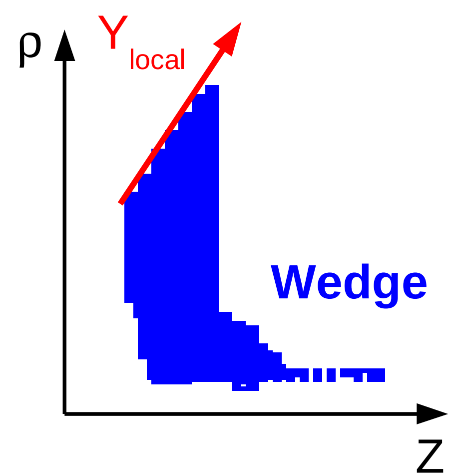
- **Determine the photo-electron (p.e.) rates per pixel for every sector and for all background sources ⇒ background optical-photons map**
- **Use background map to superimpose on signal Cerenkov cone projection to estimate effect on Cerenkov angle resolution**

Hits location for Rad-bhabha





X_{local}:
From -width/2 up to width/2

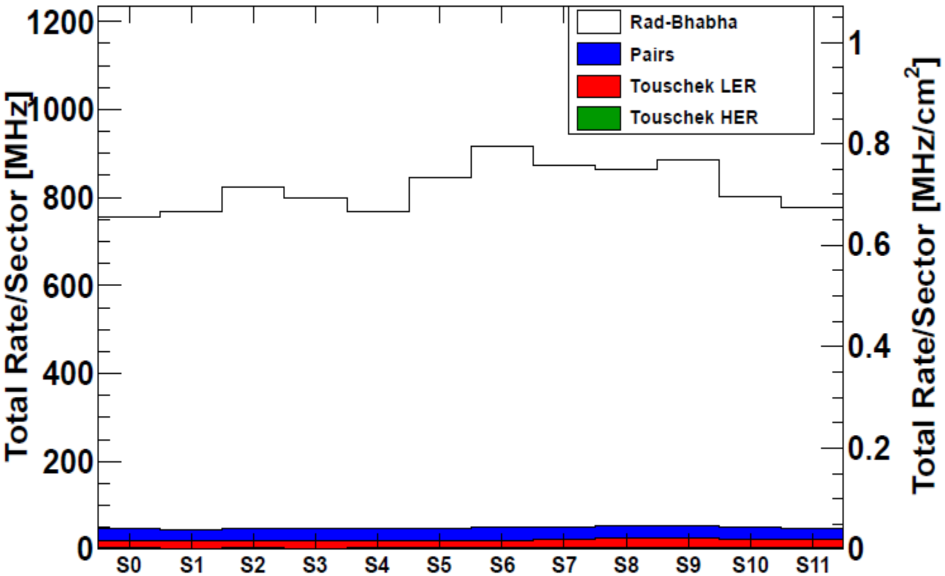


Y_{local}:
From 0.0 up to Length

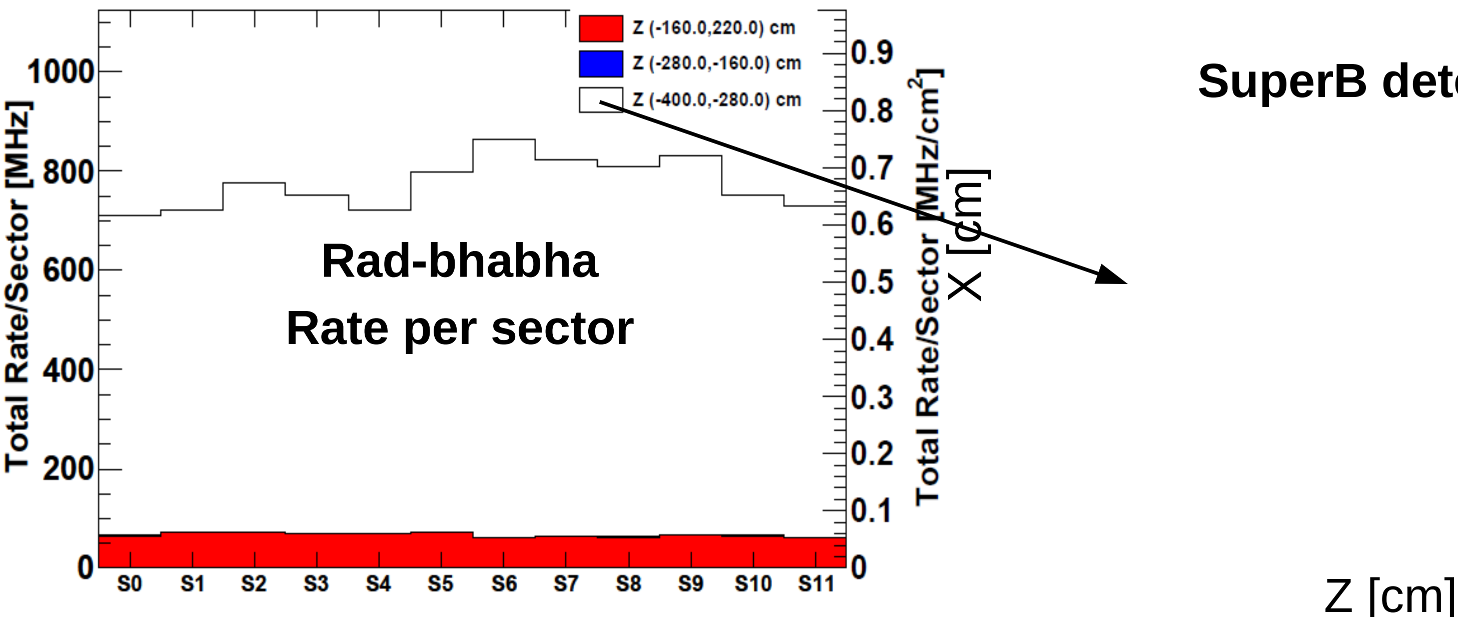
A. Pérez

FDIRC

- **Rad-Bhabha is the main background source by at least one order of magnitude**
- **Rad-bhabha:** main Cerenkov photons contribution for tracks passing through Photo-camera



SuperB detector X-rays



A. Pérez

FDIRC

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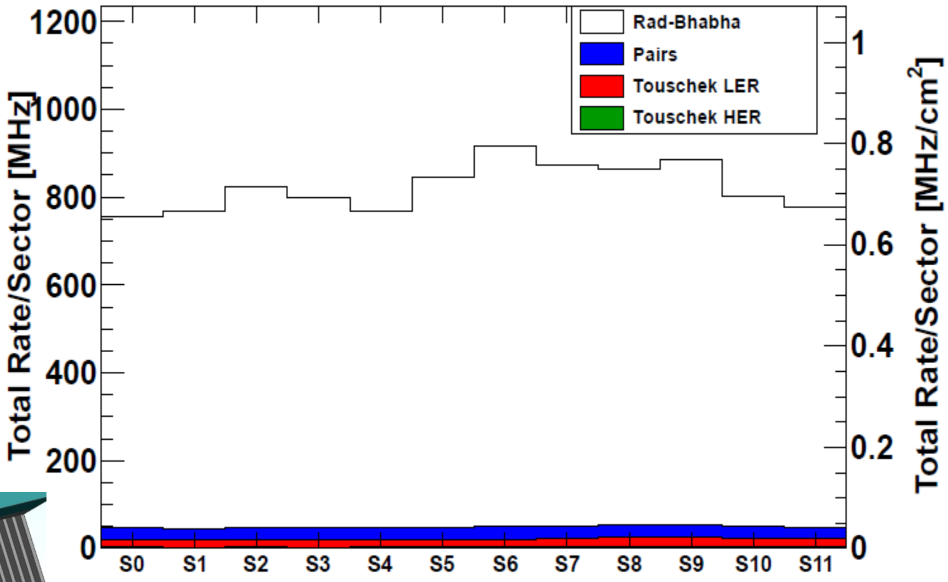

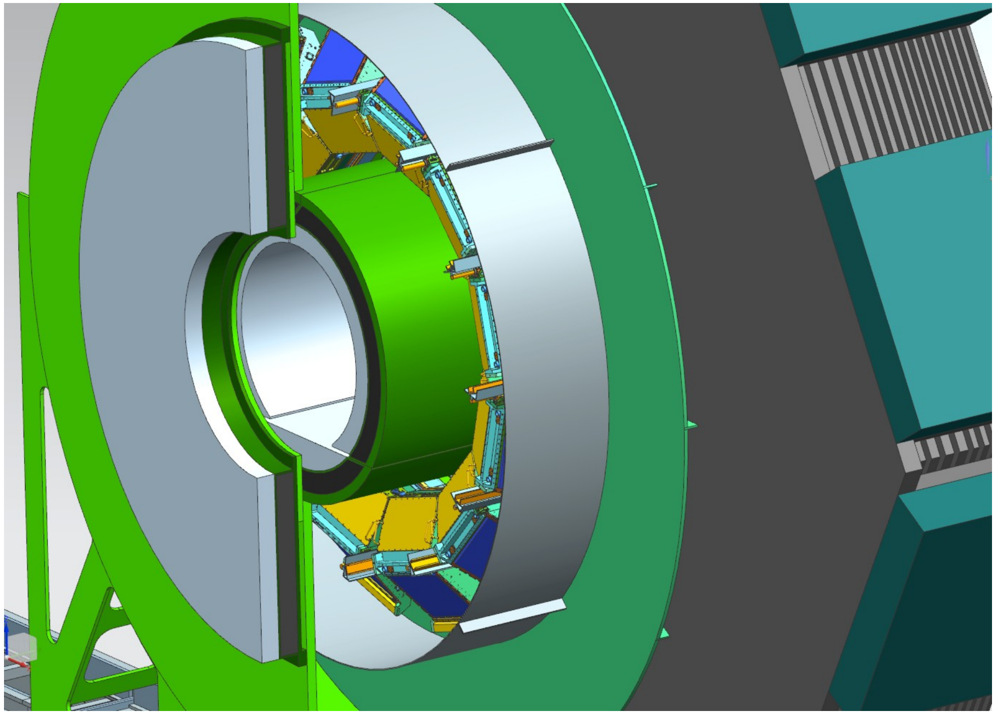

- **Include a new shield (lead-steel-polyethylene sandwich):** reduces background by a factor of ~10

FDIRC

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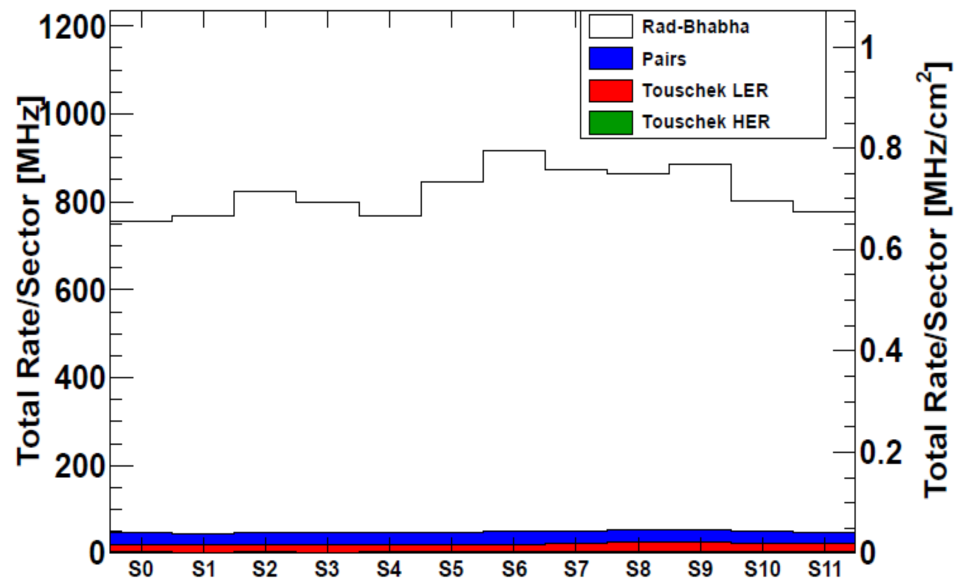
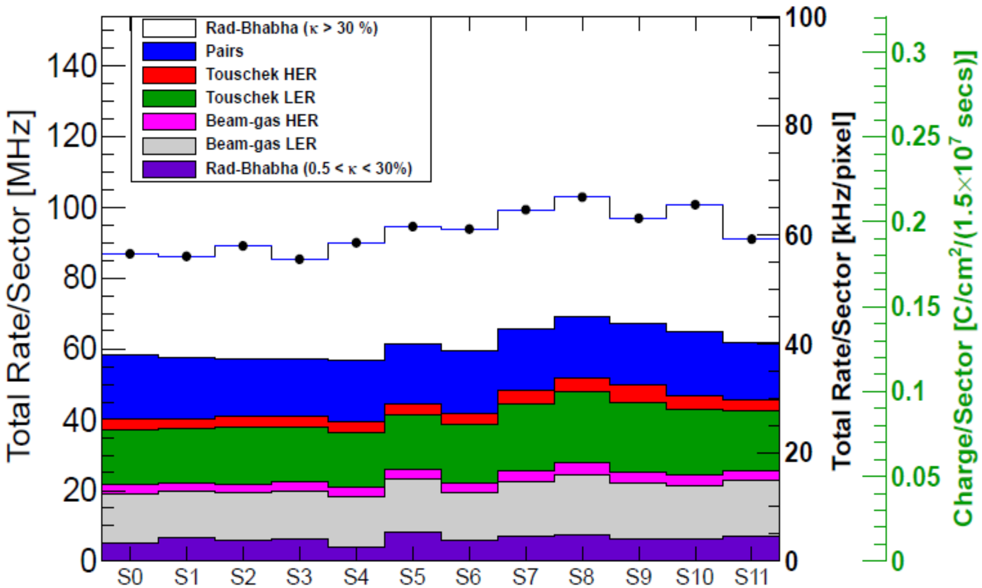




- **Include a new shield (lead-steel-polyethylene sandwich):** reduces background by a factor of ~10

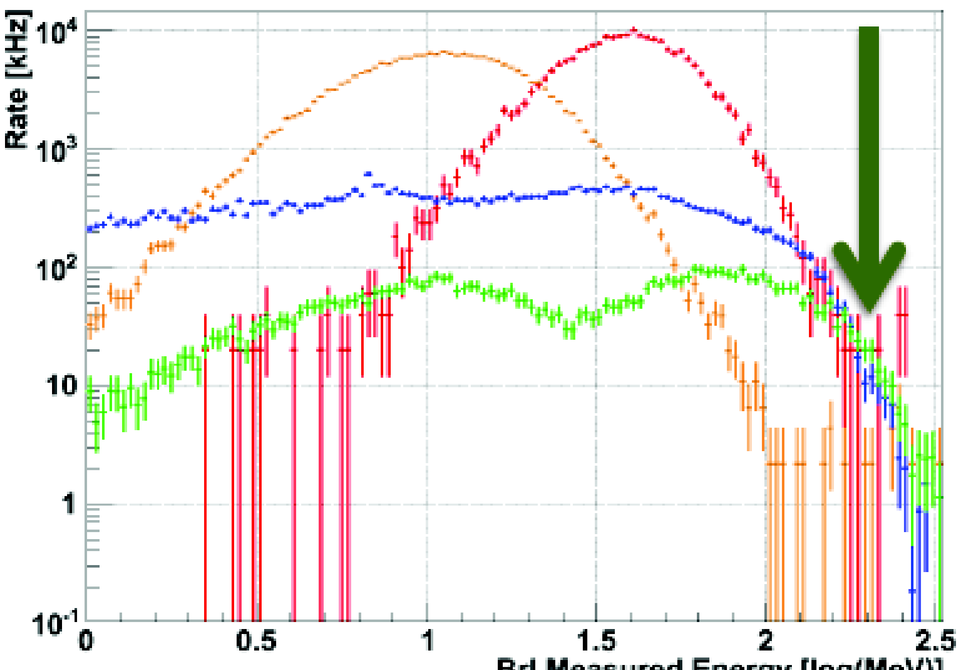
S. Germani

EM Calorimeter (EMC)

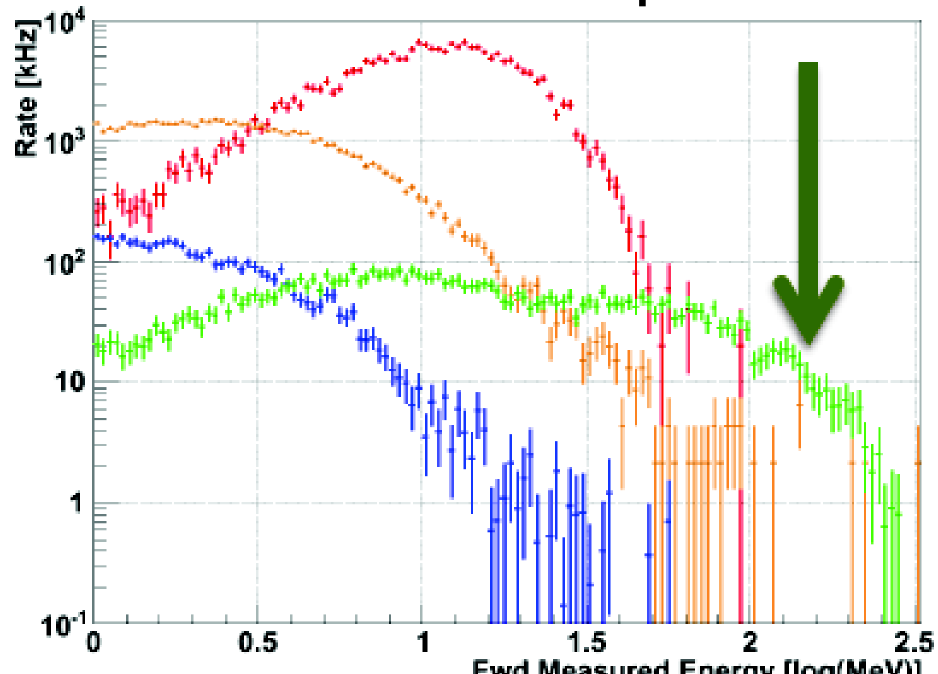
- Rad-bhabha
- 2-photon
- Touschek-LER
- Touschek-HER

- **Rate of energy deposited in the whole calorimeter**
- **No globally dominant background source**
  - Main contribution is Rad-bhabha
  - But there are some geometric/kinematic regions where other sources dominate (e.g. Touschek-HER at high energy)
  - Need to include all background sources for performances studies

Barrel

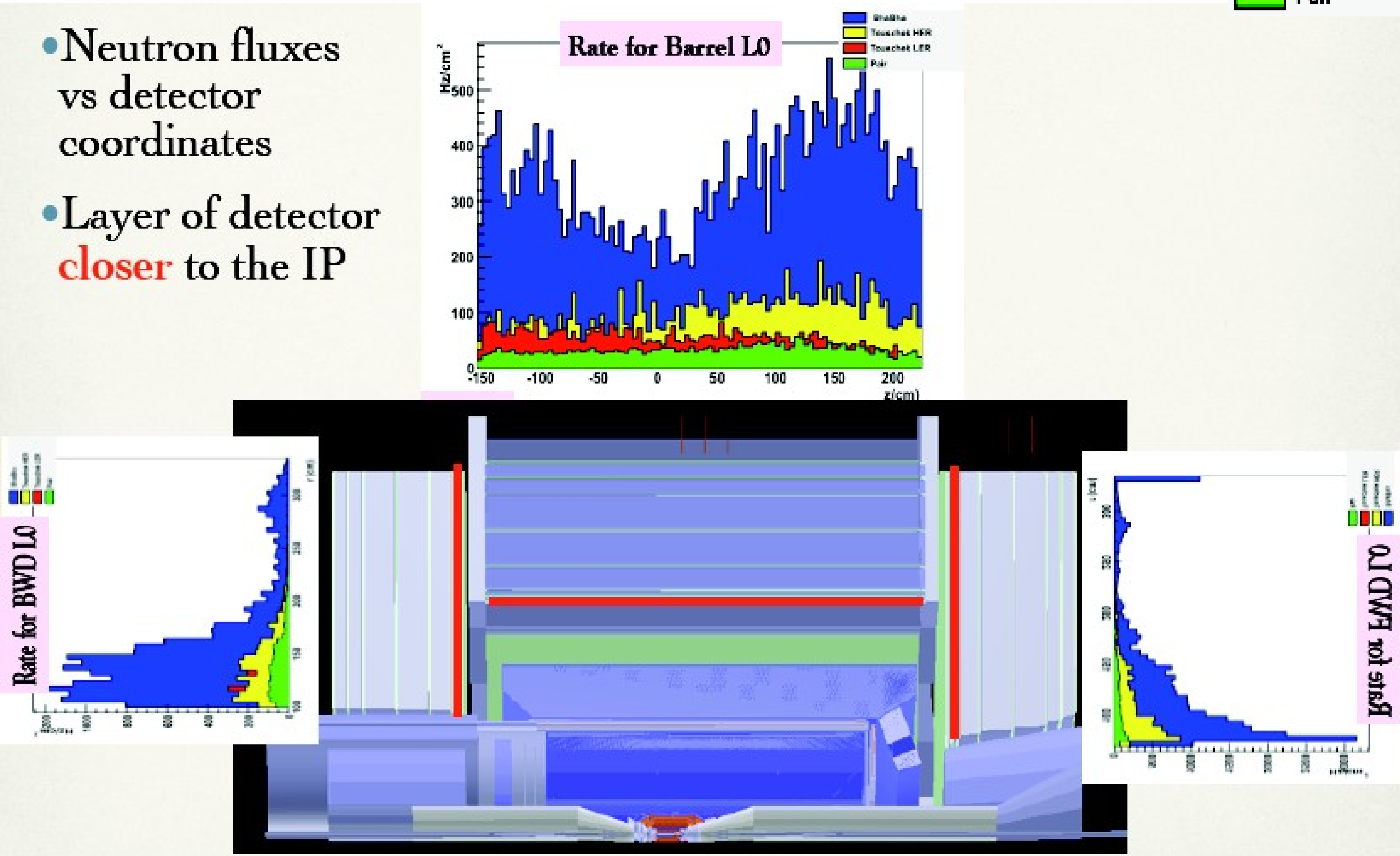


Fwd-end-cap

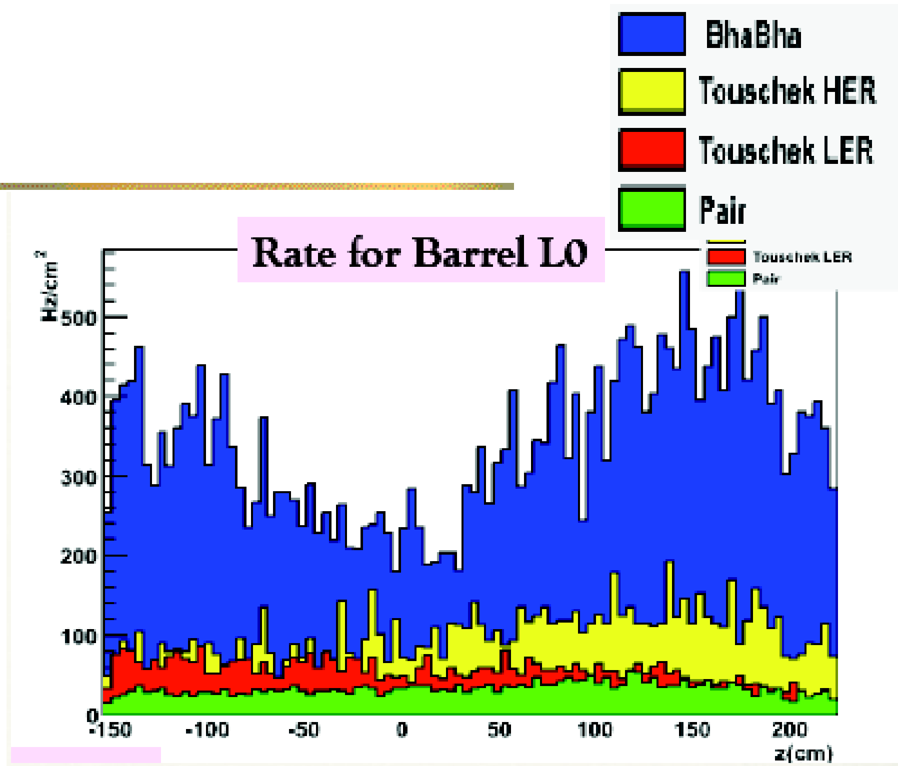


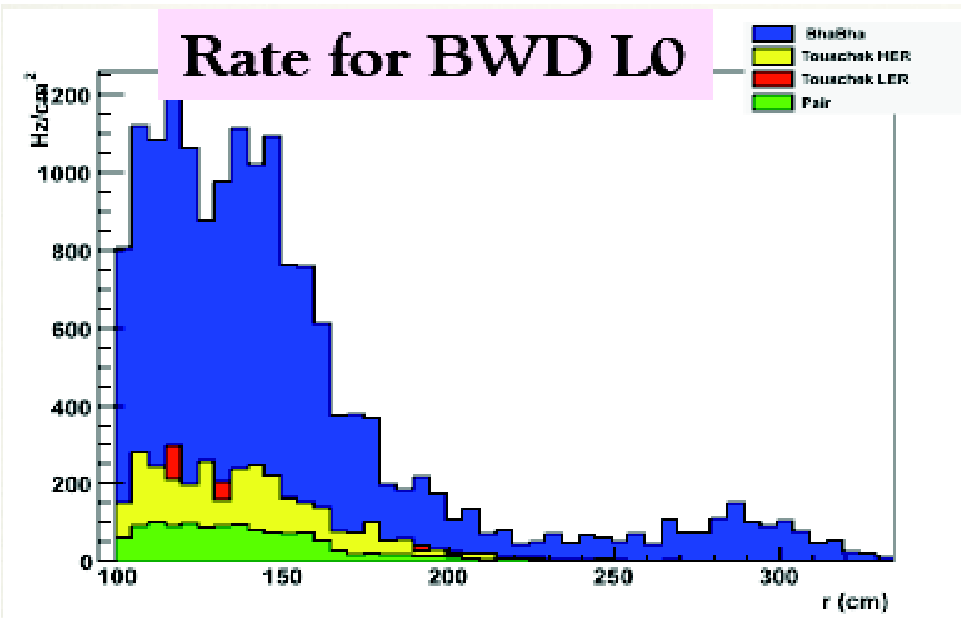
IFR

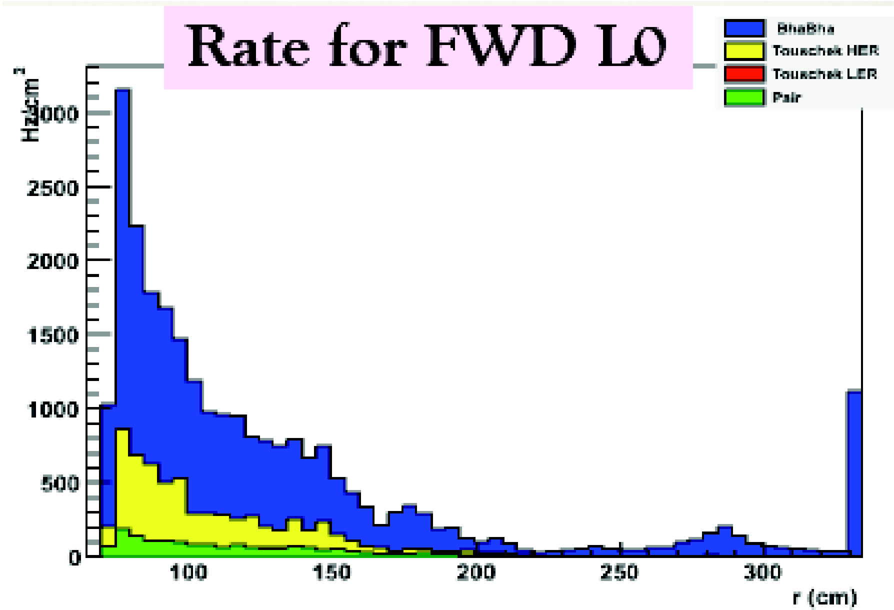
- Neutron fluxes vs detector coordinates
- Layer of detector closer to the IP



- **Neutron rates vs detector coordinate for Fwd, Barrel and Bwd**
- **Rates are really high in regions close to the pipes:** dangerous for SiPM ⇒ additional shields (under study)
- **Main contribution is Rad-bhabha**







Summary and outlook

- **Summary**
  - e+e- machines a complementary experimental probe to discover NP effects
  - Machine induced background understanding are crucial for the design of future experiments
  - I gave a short summary of a very complex work addressing many requests from subsystems designers
  - SuperB developed (in my humble opinion) a fairly good set of tools to understand and predict the background features
  - No absolute dominant background
    - Depends on the sub-system (e.g. Pairs for SVT and Rad-bhabha FDIRC)
    - For a given subsystem, depends on the geometric/kinematic region
- **Outlook**
  - Belle-II could use a hand for machine background estimations using the SuperB tools
  - Future e+e- colliders could use it too (ILC)

Backup

Flavour and NP energy scale: an example

- **Consider MSSN with generic squark mass matrices as an illustration of SUSY**
  - Simple model general enough to illustrate the issue
  - Model is being constrained by LHC

- Similar structure for $M^2_{\tilde{u}}$
- Δ's are related to NP mass scale

LHCb, SuperB

$$M^2_{\tilde{d}} \approx \begin{pmatrix} m^2_{\tilde{d}_L} & m_d(A_d - \mu\tan\beta) & (\Delta^d_{12})_{LL} & (\Delta^d_{12})_{LR} & (\Delta^d_{13})_{LL} & (\Delta^d_{13})_{LR} \\ & m^2_{\tilde{d}_R} & (\Delta^d_{12})_{RL} & (\Delta^d_{12})_{RR} & (\Delta^d_{13})_{RL} & (\Delta^d_{13})_{RR} \\ & & m^2_{\tilde{s}_L} & m_s(A_s - \mu\tan\beta) & (\Delta^d_{23})_{LL} & (\Delta^d_{23})_{LR} \\ & & & m^2_{\tilde{s}_R} & (\Delta^d_{23})_{RL} & (\Delta^d_{23})_{RR} \\ & & & & m^2_{\tilde{b}_L} & m_b(A_b - \mu\tan\beta) \\ & & & & & m^2_{\tilde{b}_R} \end{pmatrix}$$

LHC, ILC - HE frontier

- In many NP scenarios the energy frontier experiments (LHC) will probe the diagonal elements of mixing matrices
- Flavour experiments are required to probe off-diagonal elements

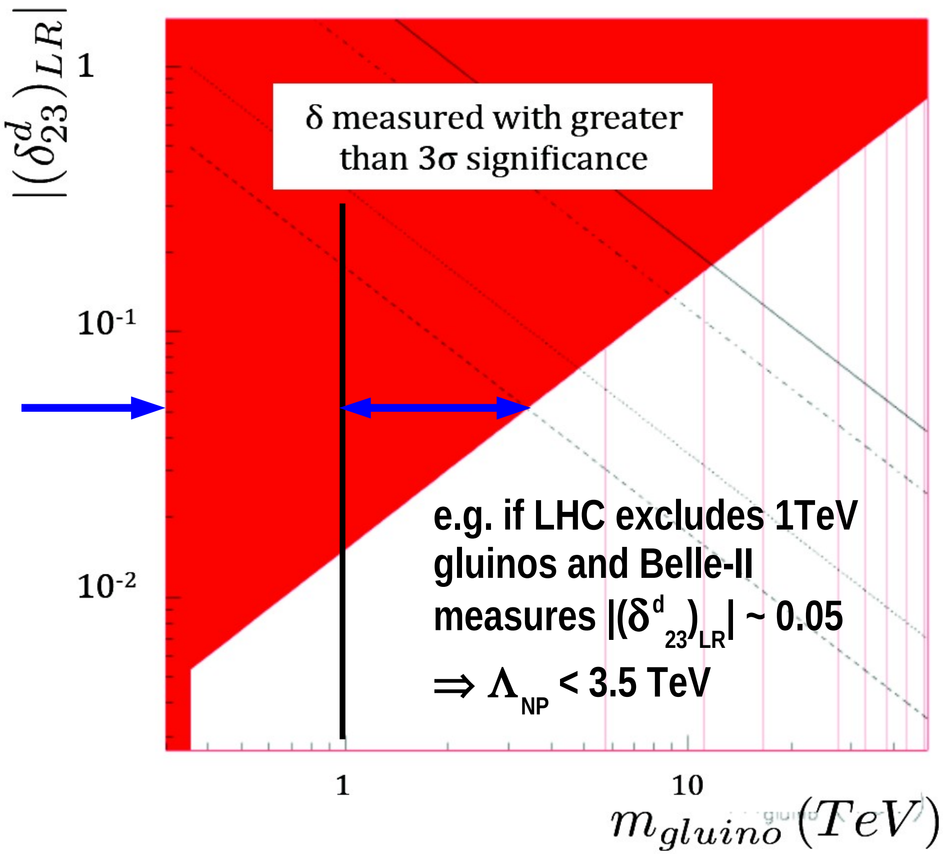
Flavour and NP energy scale: an example

- **Consider MSSN with generic squark mass matrices as an illustration of SUSY**
  - Simple model general enough to illustrate the issue
  - Model is being constrained by LHC
  - Use mass insertion approx. with $m_{\tilde{q}} \sim m_{\tilde{g}}$ to constrain couplings:

$$(\delta^q_{ij})_{AB} = \frac{(\Delta^q_{ij})_{AB}}{m^2_{\tilde{q}}}$$

  - LHC constraints on gluino mass mean couplings are non-zero, and SuperB can provide an upper bound on Λ_{NP}
  - Can constrain the $(\delta_{ij})^q_{AB}$'s using

$$\mathcal{B}(B \to X_s \gamma)$$
$$\mathcal{B}(B \to X_s \ell^+ \ell^-)$$
$$\mathcal{A}_{CP}(B \to X_s \gamma)$$



Hall et al., Nucl Phys. B 267 415-432 (1986)
Ciuchini et al., help-ph/0122397

A New Idea

- Pantaleo Raimondi came up with a new scheme to attain high luminosity in a storage ring:
  - Change the collision so that only a small fraction of one bunch collides with the other bunch
    - Large crossing angle
    - Long bunch length
  - Due to the large crossing angle the effective bunch length (the colliding part) is now very short so we can lower β_y^* by a factor of 50
  - The beams must have very low emittance - like present day light sources
    - The x size at the IP now sets the effective bunch length
  - In addition, by crabbing the magnetic waist of the colliding beams we greatly reduce the tune plane resonances enabling greater tune shifts and better tune plane flexibility
    - This increases the luminosity performance by another factor of 2-3

F. Bianchi 24