Super*B* Background Picture

E.Paoloni (INFN & Università di Pisa)

for the SuperB Collaboration

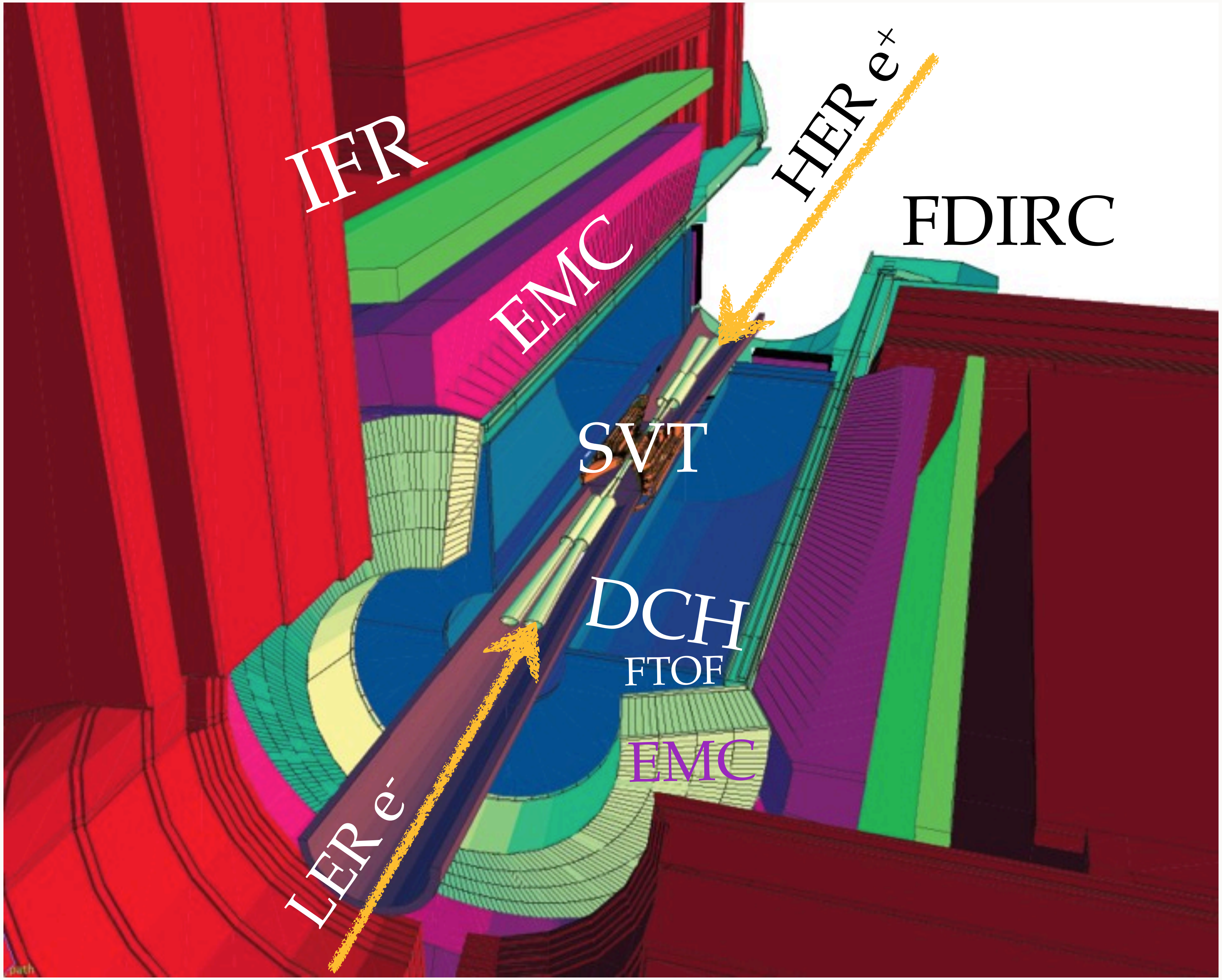
Talk Outline

- The background model in Super*B*:
  - Our Geant 4 simulation tool: Bruno
  - Luminosity scaling backgrounds
    - Radiative Bhabha (beam strahlung) B^3Rem
    - Pairs production (2 photons) : Diag36 + Bruno
  - Intensity scaling backgrounds
    - Touschek scattering: Star + Bruno
    - Beam gas scattering: Star + Bruno
    - Synchrotron radiation

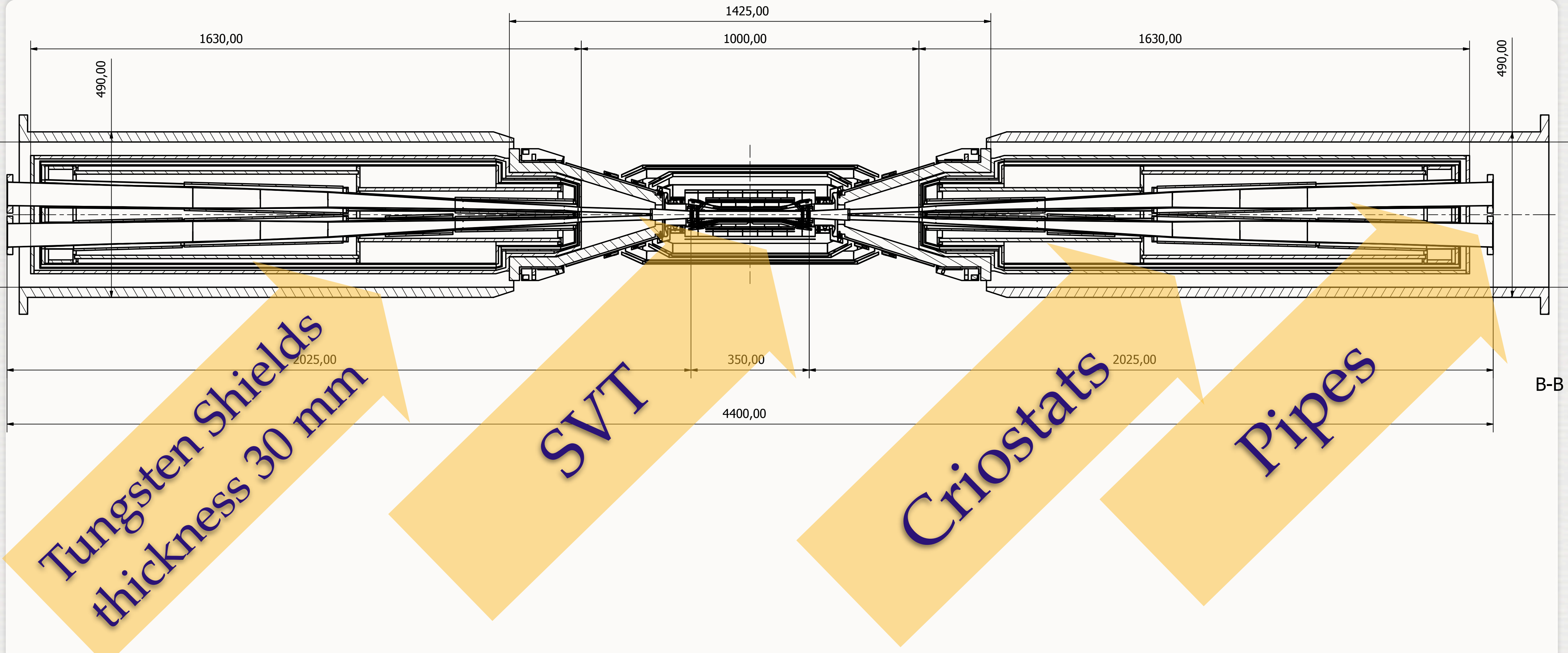
PRIMARIES PROPAGATION

- A Geant4 based program (code name Bruno, from Bruno Touschek) was created to simulate:
  - 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 the dipolar and quadrupolar components of the field
  - the passage of particles trough matter (machine elements)
  - the effect of the secondaries in the detector (energy releases, 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...

Bruno Detector Model



Bruno: Machine Material

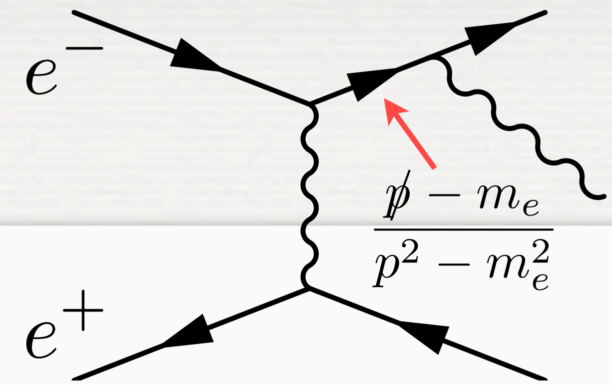


- Detailed model of the beam pipe sizes, cryostats and cold mass
- A 30 mm thick tungsten shield is put around the cryostat to protect the detectors from Radiative Bhabhas and Touschek

BACKGROUND CROSS SECTIONS

	Scattering Cross section	#Evt / crossing	***Scattering*** Rate	
Beam Strahlung	~340 mbarn (Eγ/Ebeam > 1%)	~1400	0.34 THz	Luminosity lifetime driving term
Beam Strahlung	~150 mbarn (Eγ/Ebeam > 10%)	~630	0.15 THz	Losses "near" the IP
e^+e^- production	~7.3 mbarn	~31	7.3 GHz	
e^+e^- production (seen by L0 @ 1.4 cm coverage 300 mRad)	~ 80 μbarn	~0.34	80 MHz	Main SVT L0 Background
Elastic Bhabha	$O(10^{-4})$ mbarn (Det. acceptance)	~420/Million	100 KHz	~L1 Trigger rate
Υ(4S)	$O(10^{-6})$ mbarn	~4.2/Million	1 KHz	Physics

RADIATIVE BHABHA



$$e^+e^- \to e^+e^-\gamma \quad (\gamma \sim\parallel e^-)$$

- Quasi elastic Bhabha of the electron on the positron associated with the emission of a photon
- The virtual photon and the virtual electron are almost on mass shell:
  - the amplitude pinches both poles of the propagator
- The particles in the final states escapes throughs the detector acceptance holes till
  - magnetic field deflect the lepton that radiated the photon
  - the photon or the deflected lepton hit the beam pipe
  - the debris of the electromagnetic shower hit the detector

INCOMING LEPTON GENERATION

- The angular divergence of the beam @ IP ~ $1/\gamma$ and cannot be neglected
- The momenta of the incoming particle and the position of the scattering vertex is generated from first principles
- All the gaussian features @ IP are modeled + Crab Waist as a bonus

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

Radial size @ IP

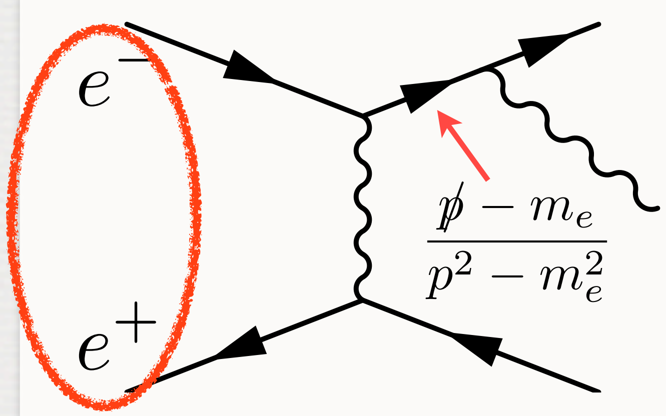
Radial div. @ IP

Vertical size @ IP (with C.W.)

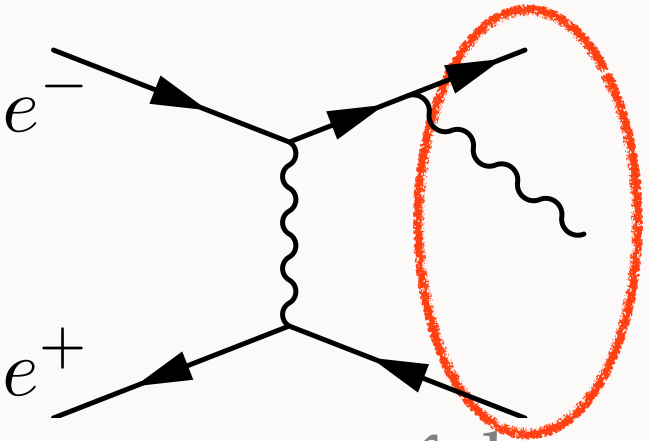
Vertical div. @ IP

Bunch length @ IP

Energy spread @ IP

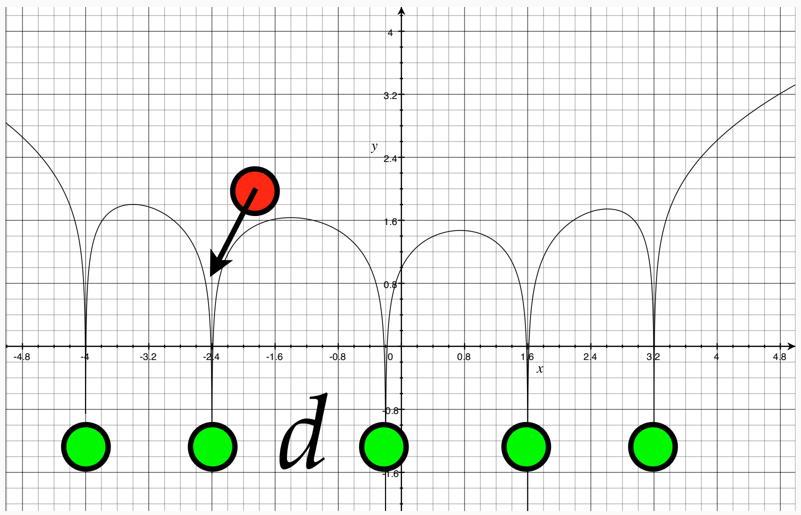


PRIMARIES GENERATION

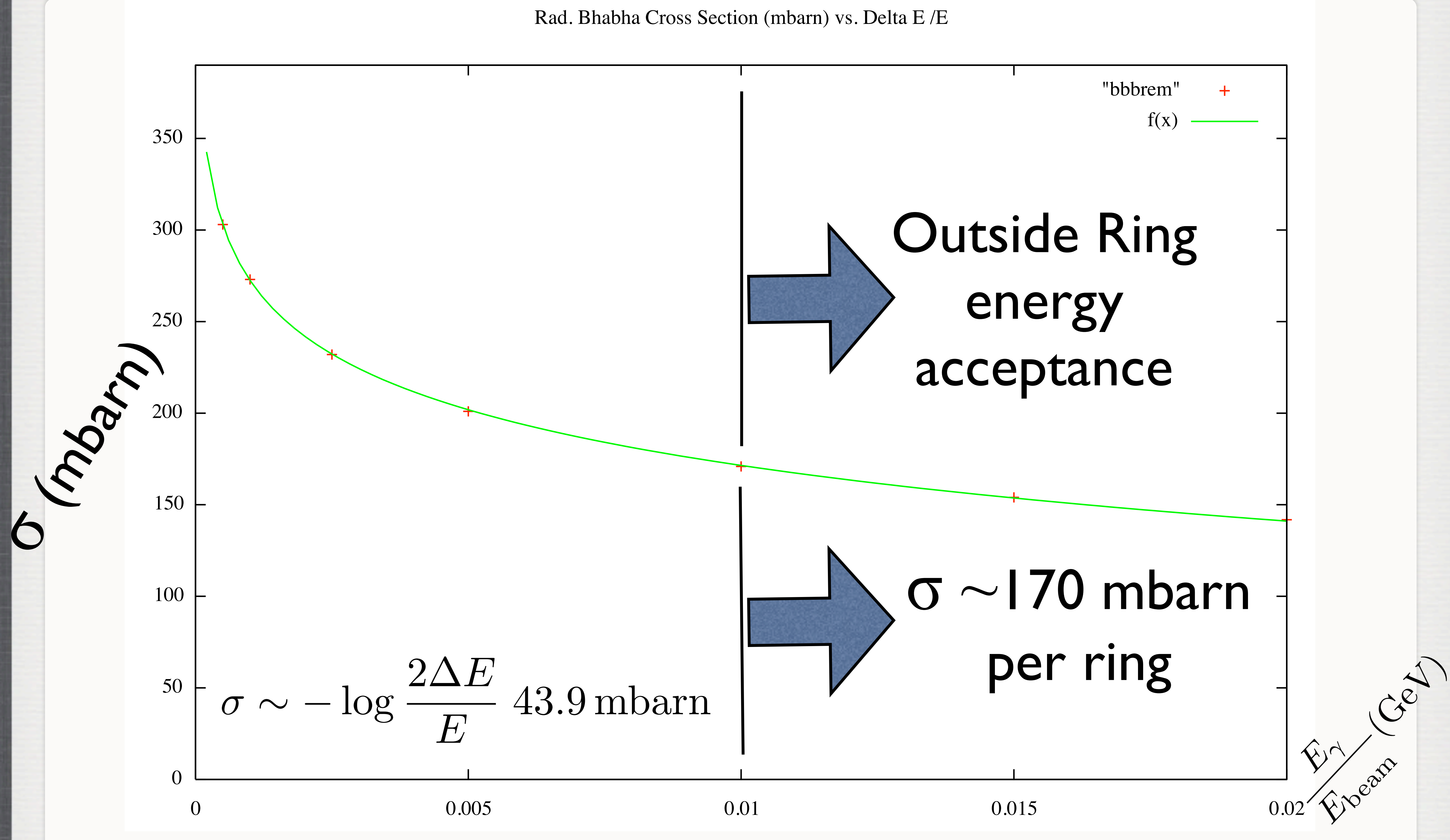


- BBBrem (R. Kleiss, H. Burkhardt) arXiv:hep-ph/9401333
- Only two Feynman diagrams are taken into account out of the eight tree level diagrams
- The electron mass is not "neglected with impunity" , i.e. the angular deflection of the lepton is properly simulated
- Finite density of the bunch is taken into account by an infrared cut-off parameter that fix the minimum momentum transfer

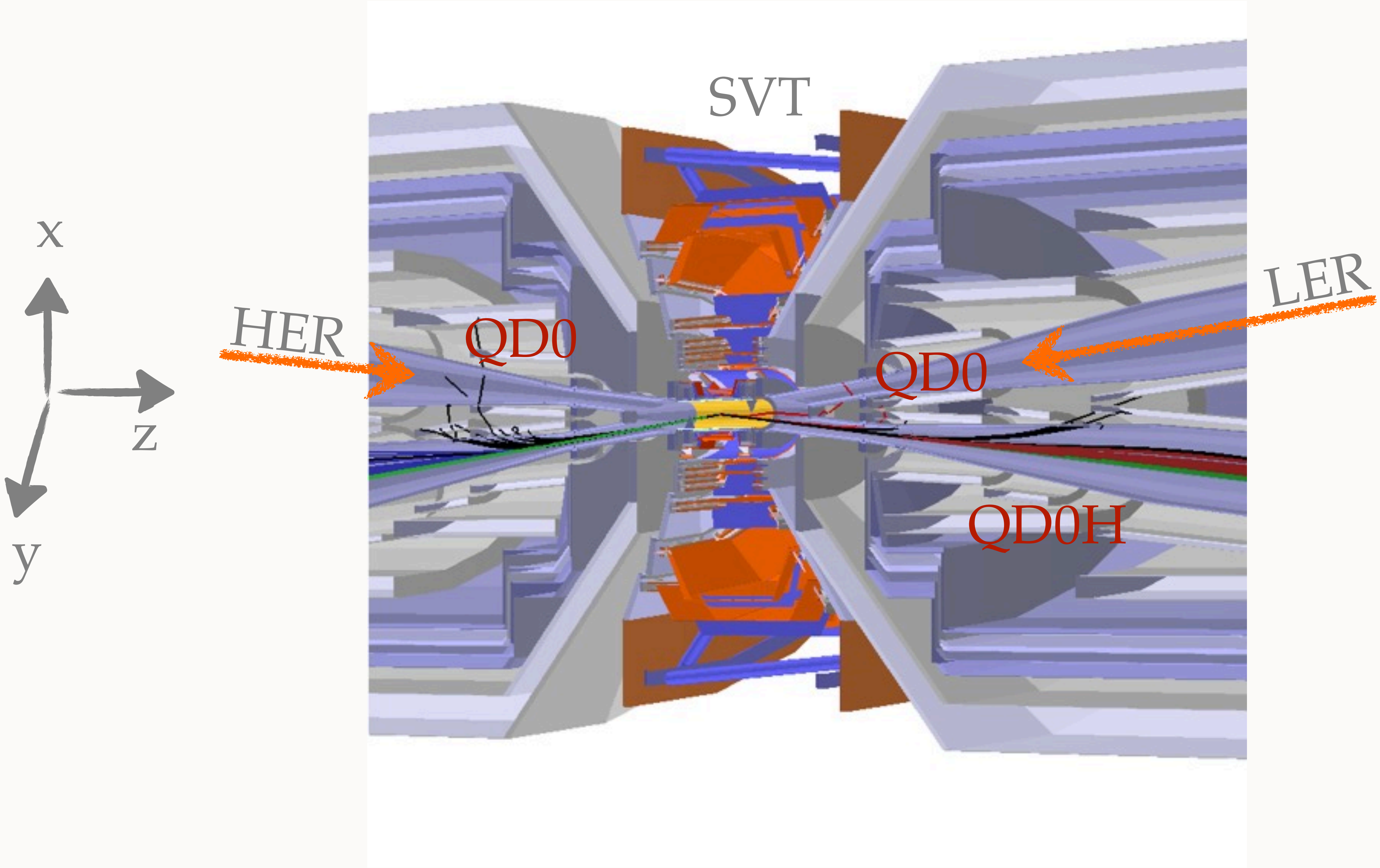
$$p_{min} \sim \hbar\, c / d$$



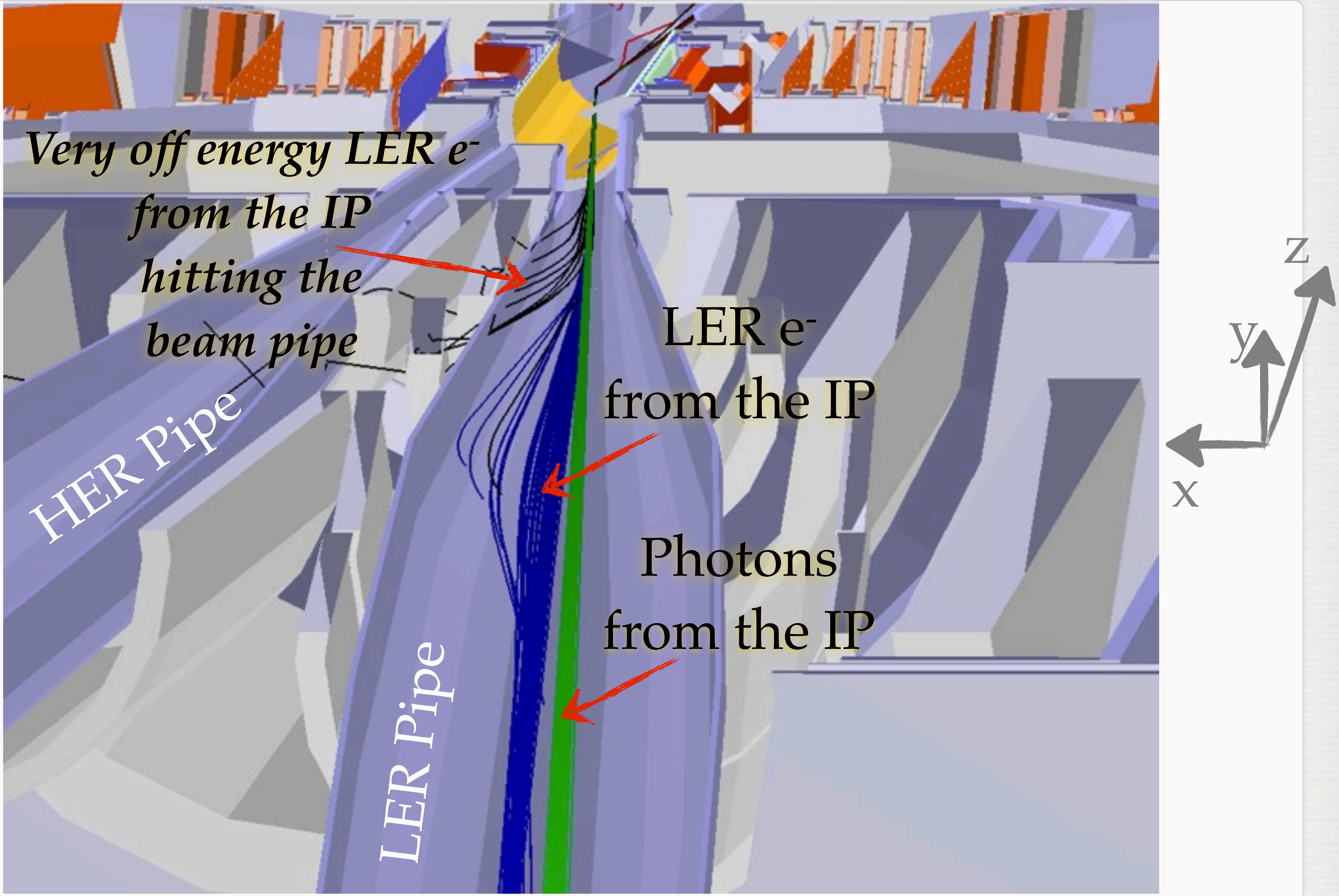
Radiative Bhabha Cross Section



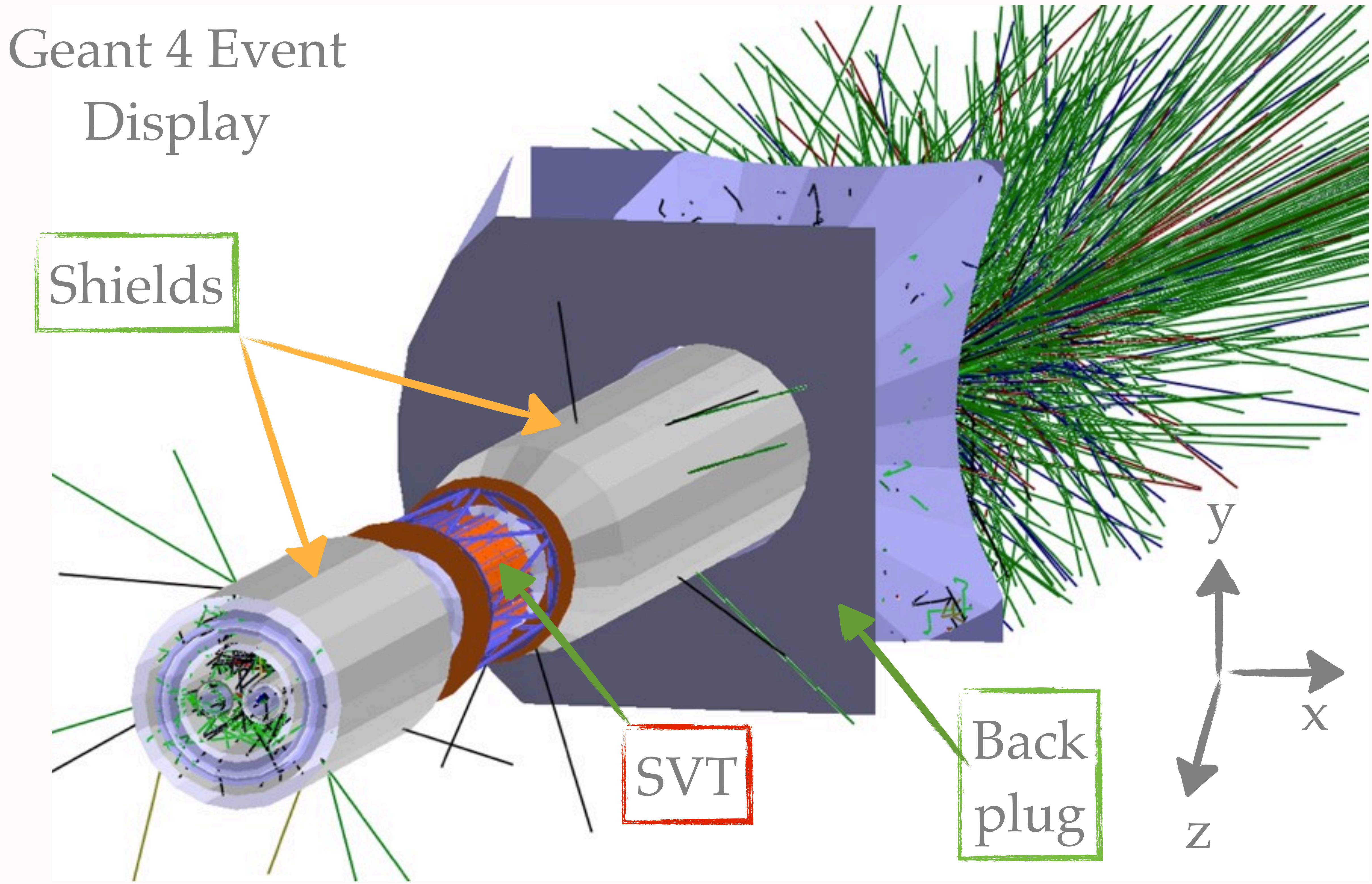
A SINGLE BUNCH CROSSING



RADIATIVE BHABHA: 1 BUNCH XING

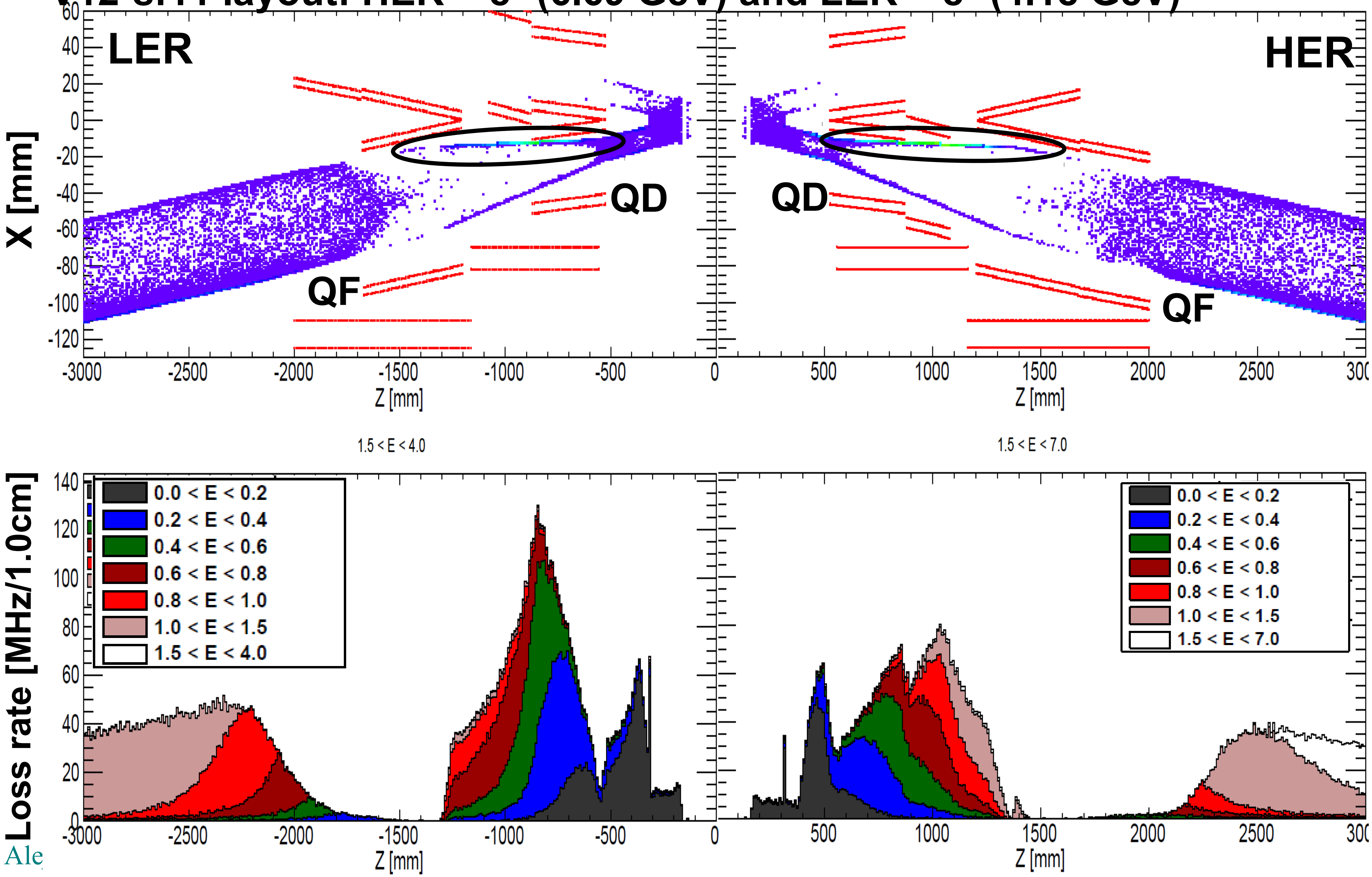


1 Bunch Crossing: Secondaries



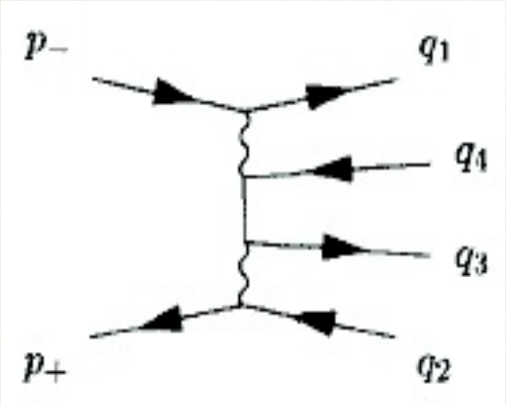
Primaries Loss Rate

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



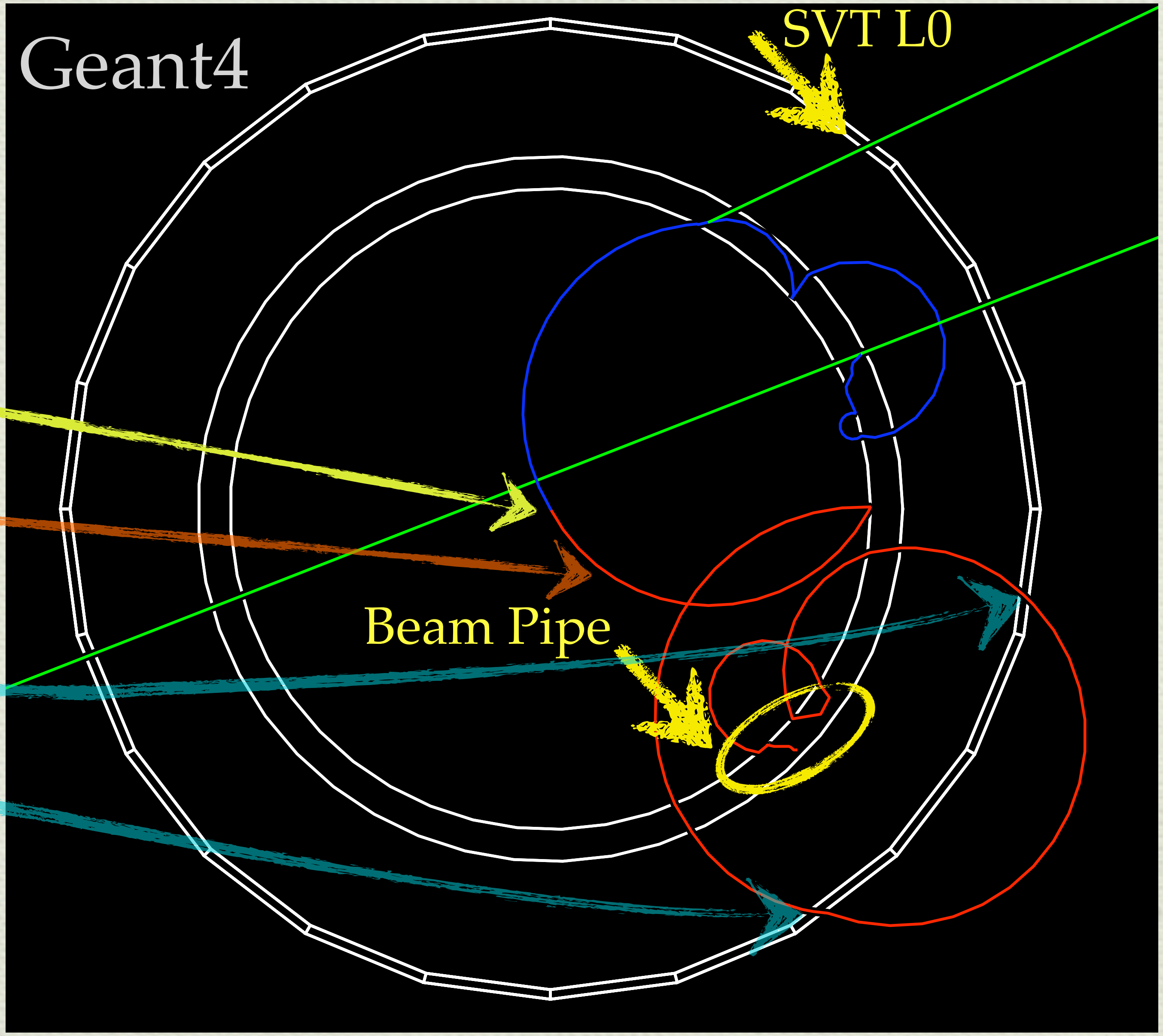
L0 main bkg.: pairs production

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



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

- In this scattering event there is:
- 1 track that hits the L0
- this track fires 2 clusters in the L0
- each cluster will be composed by one or more hits



Definitions

Event rate:

$$\mathcal{R} = \mathcal{L}\,\sigma$$

track rate:

$$\mathcal{R}_{\text{trk}} = \mathcal{R}\,\langle \#trk \rangle_{evt}$$

cluster rate:

$$\mathcal{R}_{\text{clus}} = \mathcal{R}_{\text{trk}} \langle \#clus \rangle_{trk}$$

hit rate:

$$\mathcal{R}_{\text{hits}} = \mathcal{R}_{\text{clus}} \langle \#hits \rangle_{clus}$$

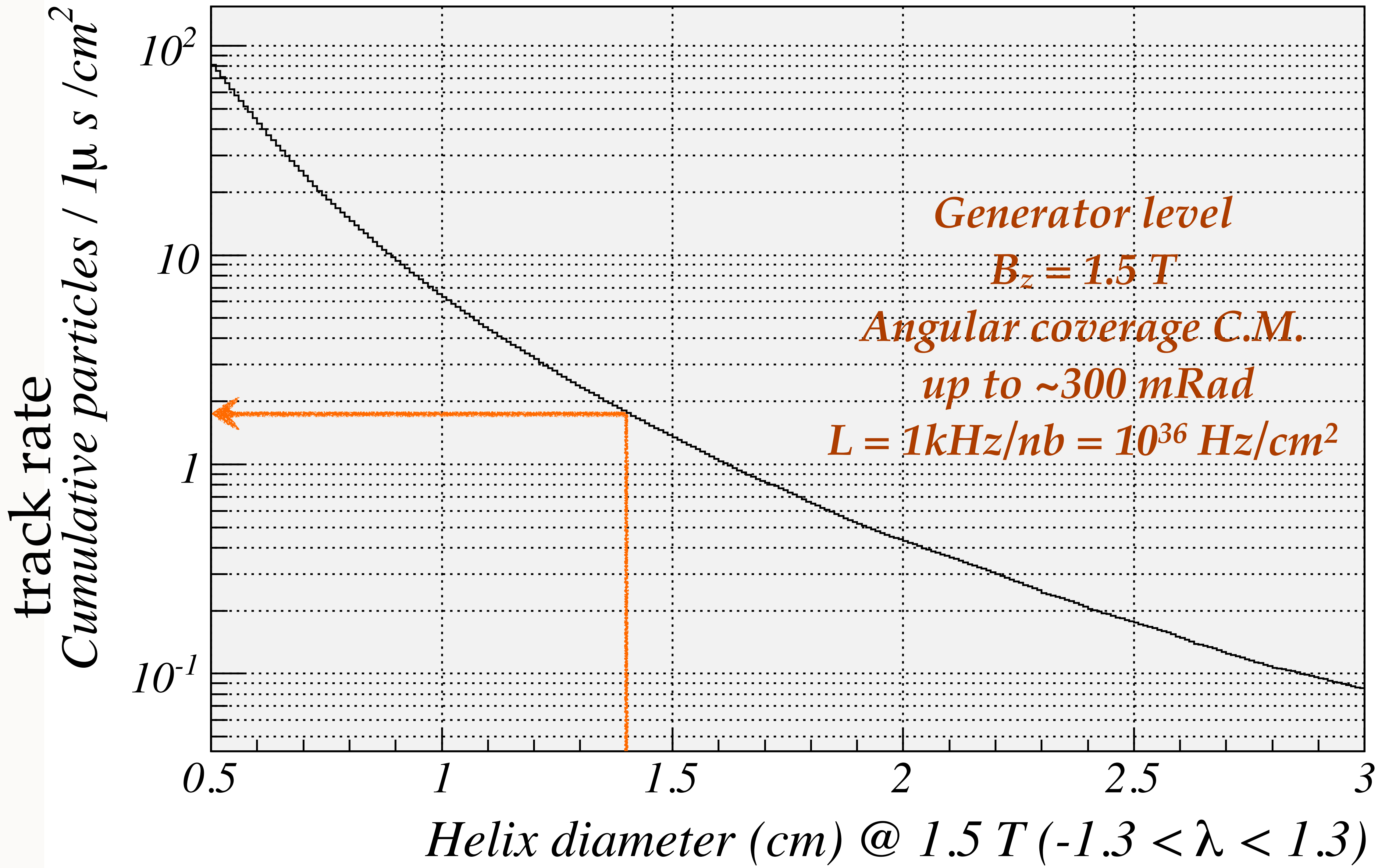
SIMULATION STRATEGY

- Primaries generated with DIAG36 then
- Bruno simulates the effects of primaries on detector

DIAG36

```
C-----ALL THE FEYNMAN DIAGRAMS CONTRIBUTING IN LOWEST ORDER----------
C-----(IPROC=1  6 DIAGRAMS, IPROC=2 12 DIAGRAMS, IPROC=3 12DIAGRAMS,--
C----- IPROC=4 12 DIAGRAMS, IPROC=5 36 DIAGRAMS)--------------------
C-----ARE TAKEN INTO ACCOUNT----------------------------------------
C-----THE KINEMATICS IS TREATED EXACTLY----------------------------
C-----THE PROGRAMS GENERATES EVENTS EFFICIENTLY UNDER----------------
C-----NO- OR SMALL ANGLE TAGGING CONDITIONS-------------------------
C
C*******************************************************************
C*                                                                 *
C*    AUTHORS : F.A. BERENDS, P.H. DAVERVELDT, R. KLEISS           *
C*                                                                 *
C*              UNIVERSITY OF LEIDEN                               *
C*              INSTITUUT-LORENTZ VOOR THEORETISCHE NATUURKUNDE    *
C*              NIEUWSTEEG 18                                      *
C*              2311 SB LEIDEN                                     *
C*              THE NETHERLANDS                                    *
C*                                                                 *
C*                                                                 *
C*    INSTALLATION DATE :                                          *
C*    LAST UPDATE       : 8 FEBRUAR 1985                           *
C*                                                                 *
C*******************************************************************
C
C FOR DETAILED INFORMATION ON THE CALCULATION OF THE MATRIX ELEMENT
C SQUARED AND ON THE PROCEDURE USED FOR THE EVENT GENERATION WE REFER
C TO THE PAPER :
C "COMPLETE LOWEST ORDER CALCULATIONS FOR FOUR-LEPTON PROCESSES IN E+
C E- COLLISIONS"
C NUCL. PHYS. B253 (1985) 441
C
C THIS PROGRAM RUNS IN DOUBLE PRECISION FORTRAN H-EXT.
```

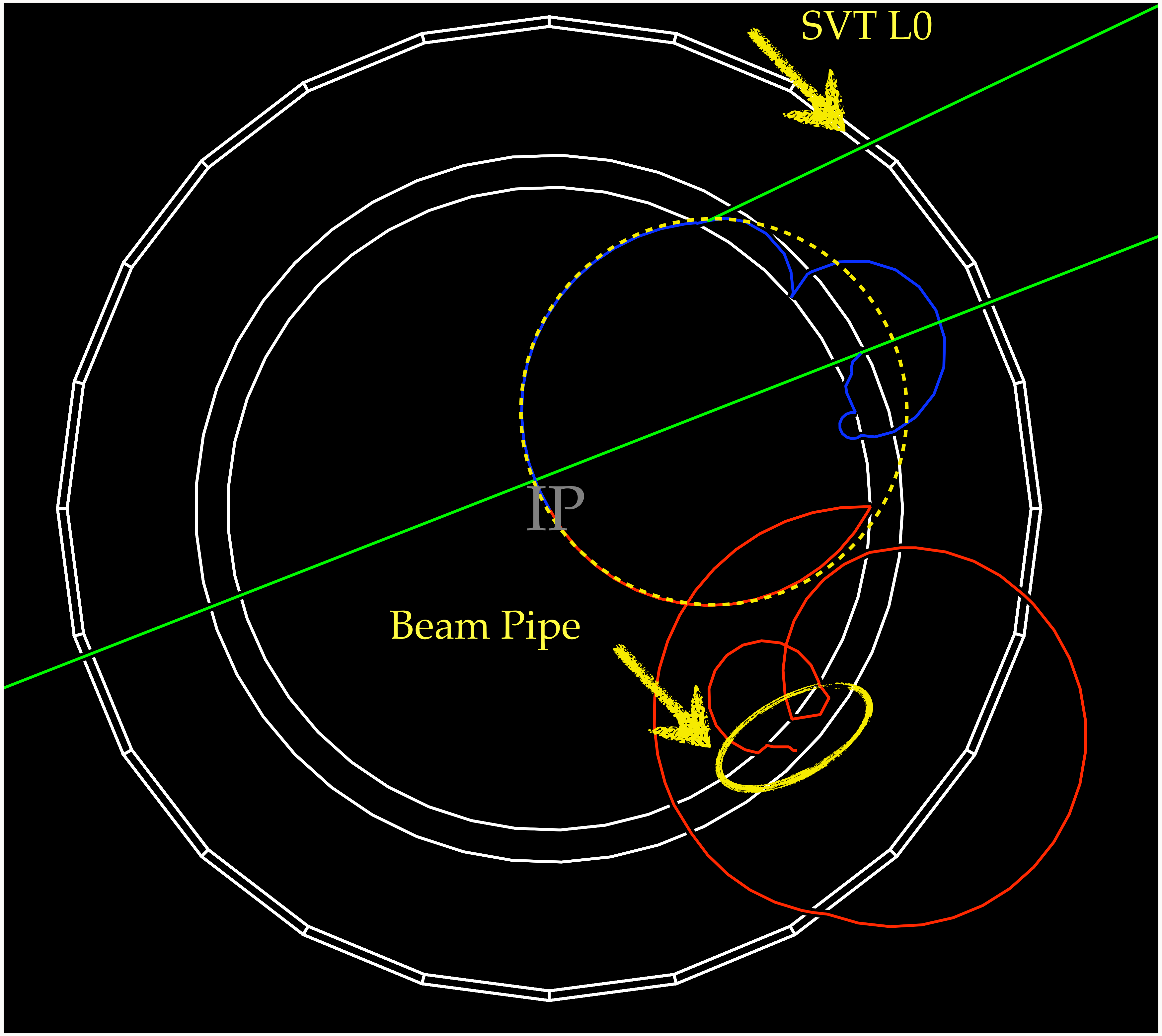
DIAG36 TRACK RATE EVALUATION



Why We Need Bruno?

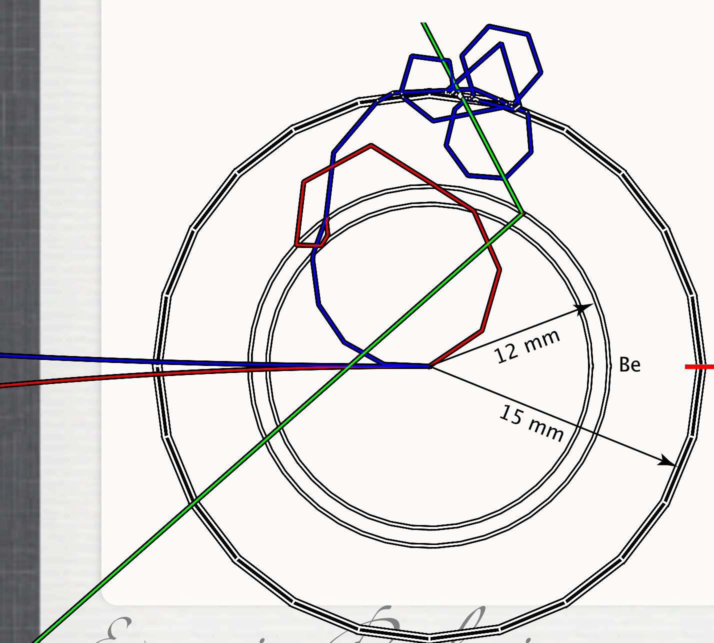
Primaries are very soft ~ few MeV
Multiple Coulomb scattering and dE/dx are not negligible

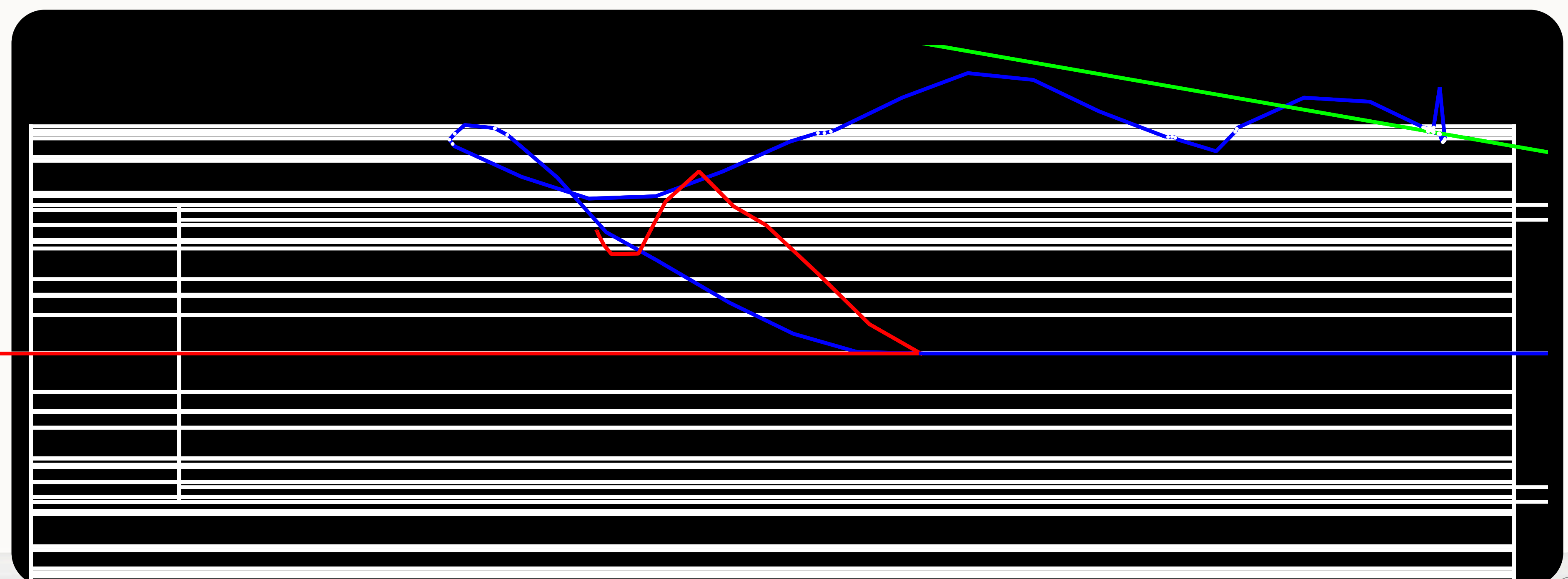
Particles with $p_t < 3.5$ MeV/c can still hit the pipe and the Coulomb scattering can increase p_t at expense of the long. momentum



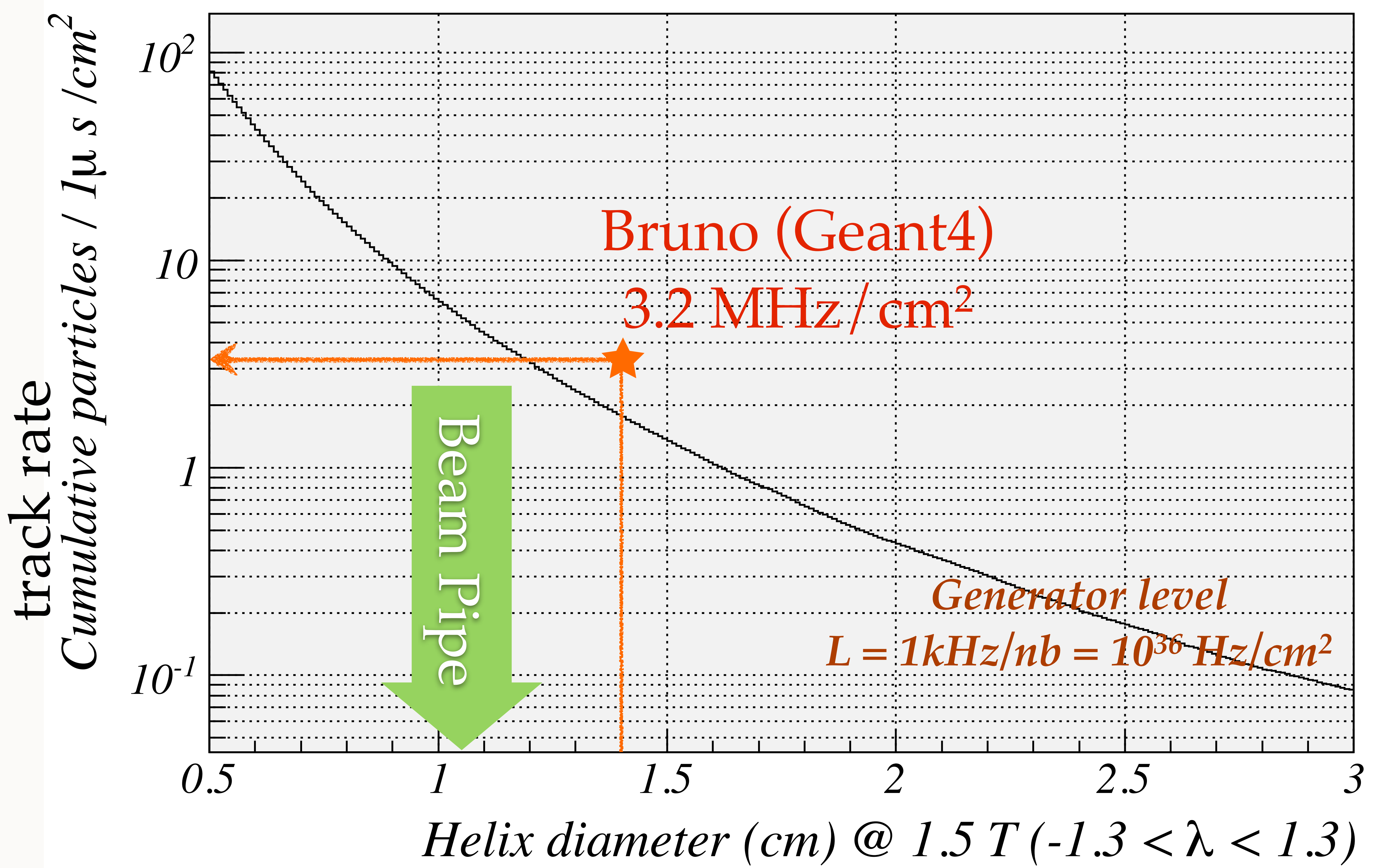
PAIR PRODUCTION

- Particles from this process can have enough transverse momentum to enter directly into the detector acceptance
  - The detector solenoidal field is the main trap for particles with small p_t
  - Non trivial effects from the interactions with the beam pipe





Bruno Evaluation Example



CLUSTER MULTIPLICITY

- In our model 1mm thick Be Beam Pipe + 3 µm Au @ r = 10 mm
- SVT L0 mean radius 14mm
  - track rate = 3.2 MHz/cm^2
  - Average cluster multiplicity per track 2.5
  - Cluster Rate 8.2 MHz/cm^2
  - Average hit multiplicity per cluster 4 - 5 depending on the view

INTENSITY DEPENDENT BKG.

- Touschek scattering and beam-gas scattering generates non gaussian tails in the bunch transverse profile
- The finite aperture of the beam pipe and the large β functions at the final focus doublet 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 STAR (M.Boscolo)
- Bruno simulates the interaction of these particles crossing the beam pipe near the IP to predict the effects on the detector

PRIMARY LOSS RATES

Modif. V12 **Conclusions (1): Lifetime summary**

	HER	LER
Touschek lifetime	τ_{TOU} (min)	τ_{TOU} (min)
No collimators, nominal ε_x (no IBS)	26.3	7.4
No collimators, ε_x with IBS	26	10.2
With Collimators, ε_x with IBS	22	7.9

Coulomb	76min	39 min
Bremsstrahlung	72 hrs	77 hrs

M. Boscolo, December 14th 2011

Loss Rate At the IP

Modif. V12 Conclusions (2): **IR rates** summary

|s|<2 m

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

M. Boscolo, December 14th 2011

Touschek vs Rad. Bhabha

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

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

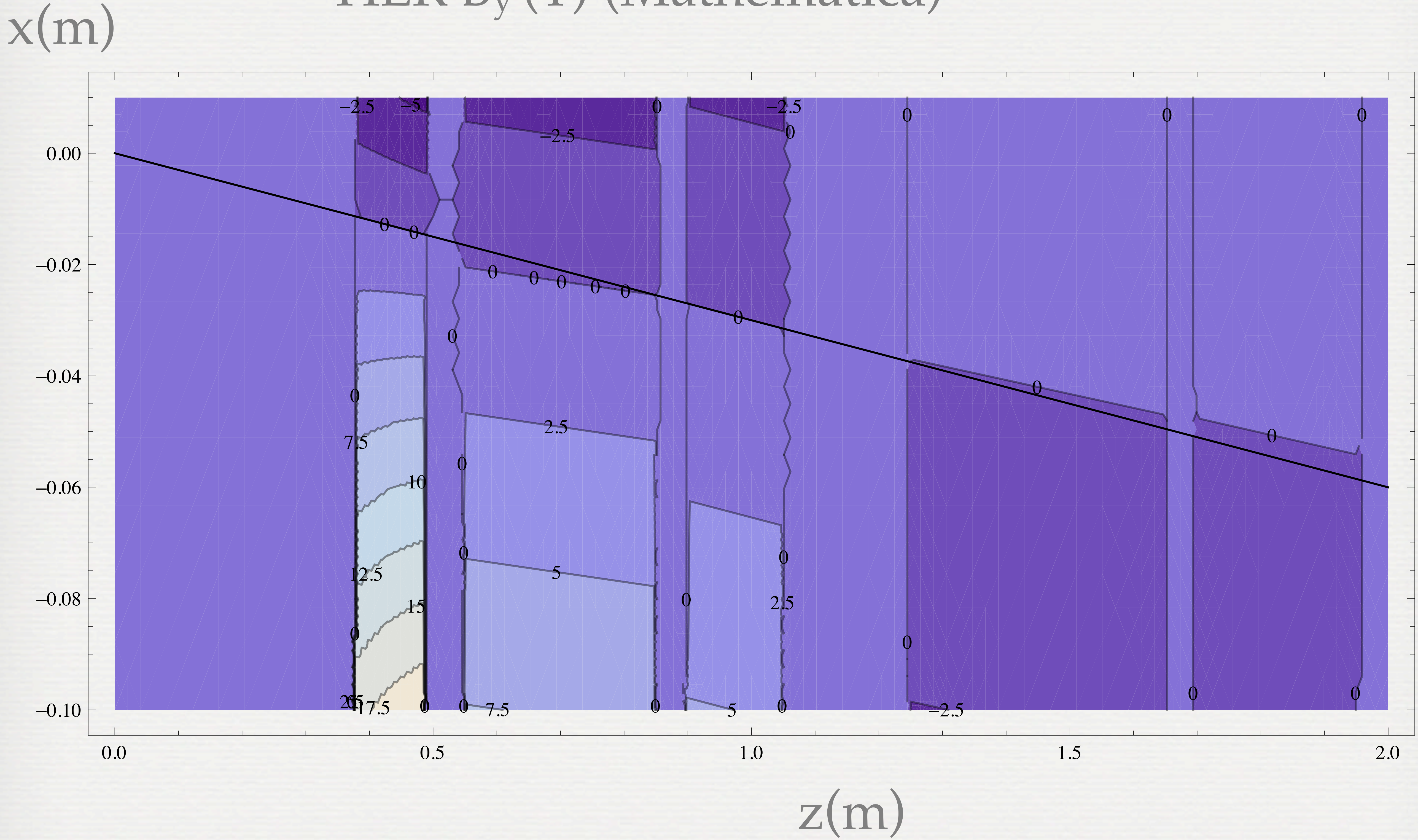
Conclusions

- SuperB developed (in my humble opinion) a fairly good set of tools to understand and predict the backgrounds features
- The discrepancy in the pairs background rate is probably a byproduct of lack of communication between the 2 collaborations
- The beam pipe material play a significant role in the pairs background

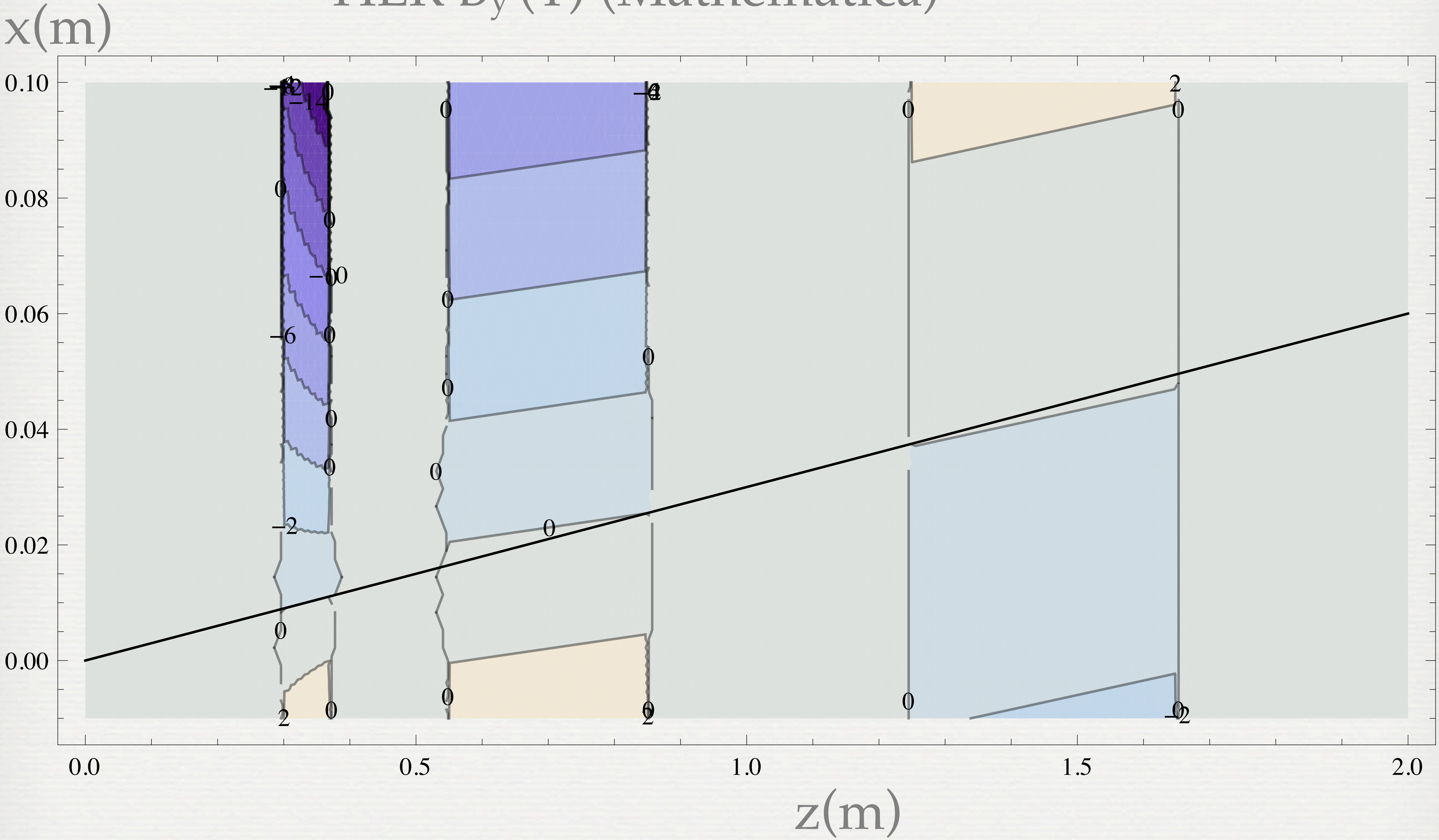
Thank you

For your Attention

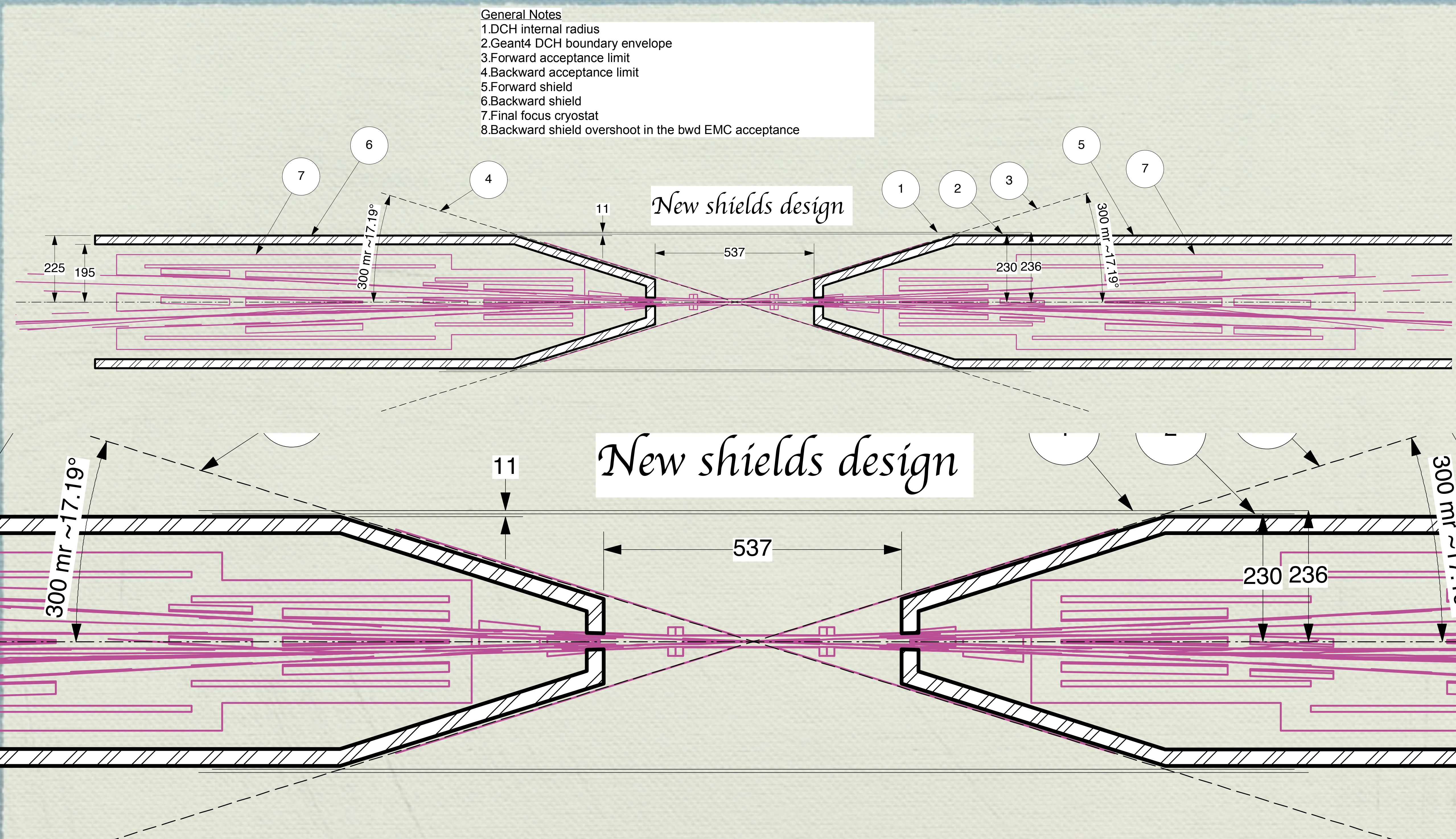
HER B_y (T) (Mathematica)



HER B_y (T) (Mathematica)



Mechanical interface: boundaries



Generator Level Comparison