Multiple Scattering and EM Physics

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Introduction

- Study of the influence of Multiple Scattering (Msc) on Impact Parameter resolution with the VELO detector and comparison with data.
- Look at occupancy, dE/dx deposition and CALO response differences by altering physics list.
- Even though discussed separately all are inter-related.

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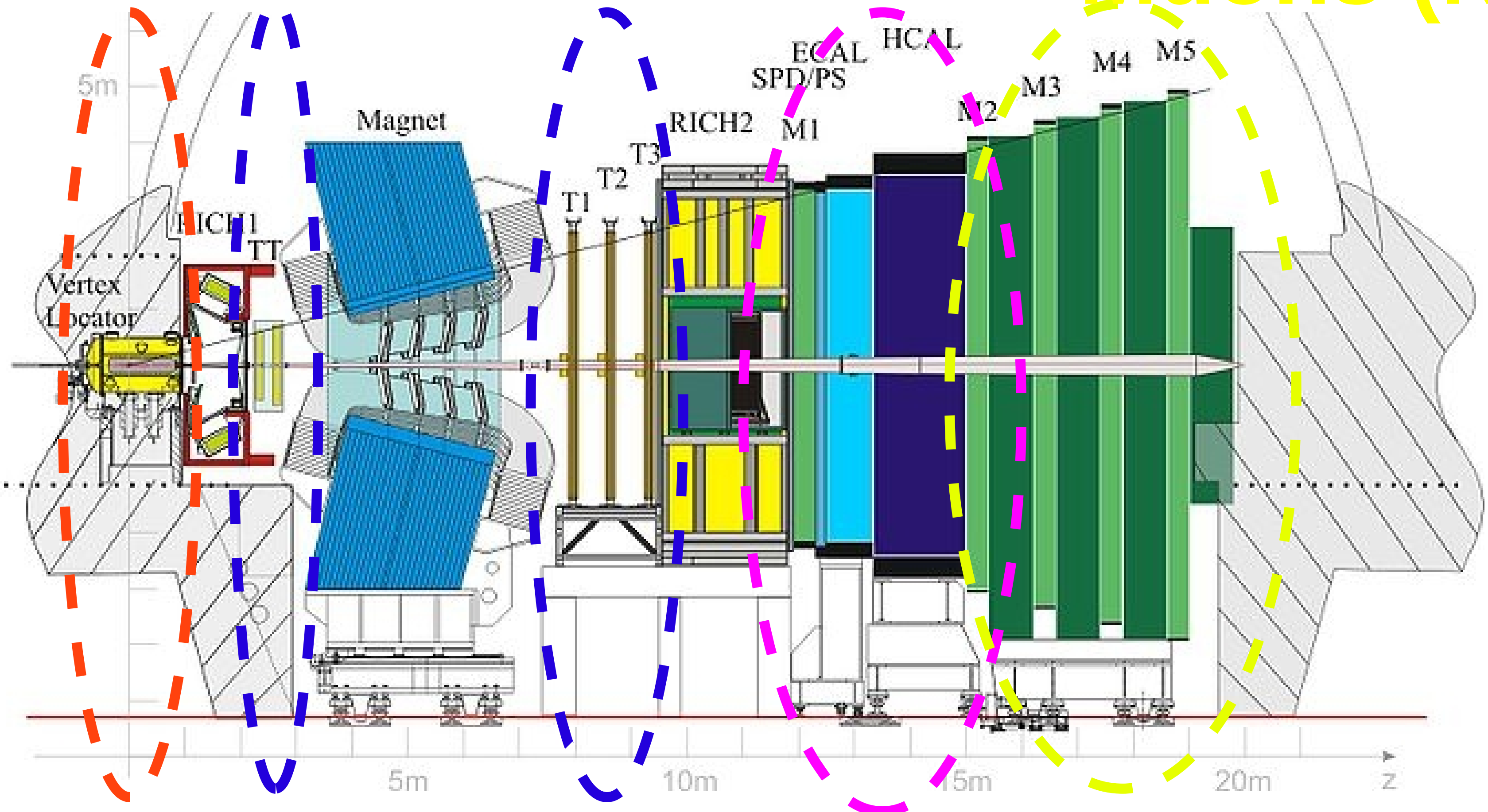
LHCb Detector



Velo IP Resolution Studies

Documented in LHCb notes **LHCb-INT-2011-036, LHCb-INT-2011-034.**
Also the work of Gloria C, Thomas L., David D., Michael A., Silvia B., Chris P., Kazu A., Paula C., Tim G.+…

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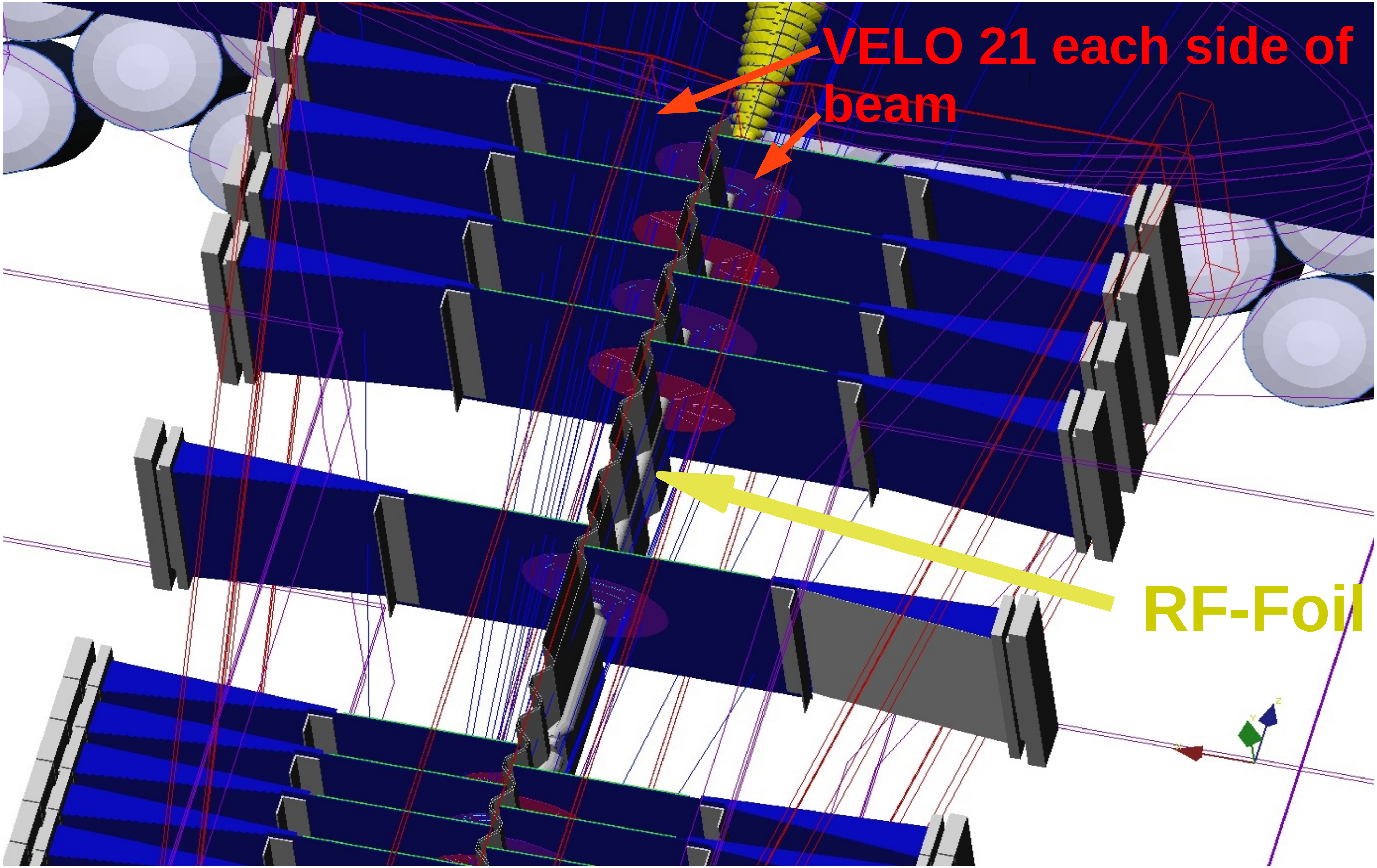
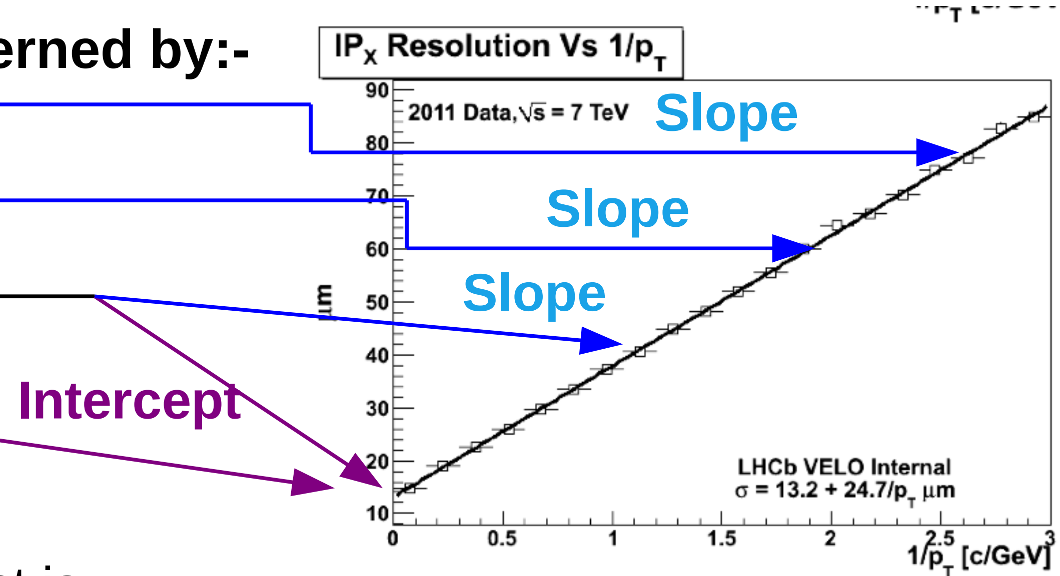
Simulation Of The VELO



Velo Geometry

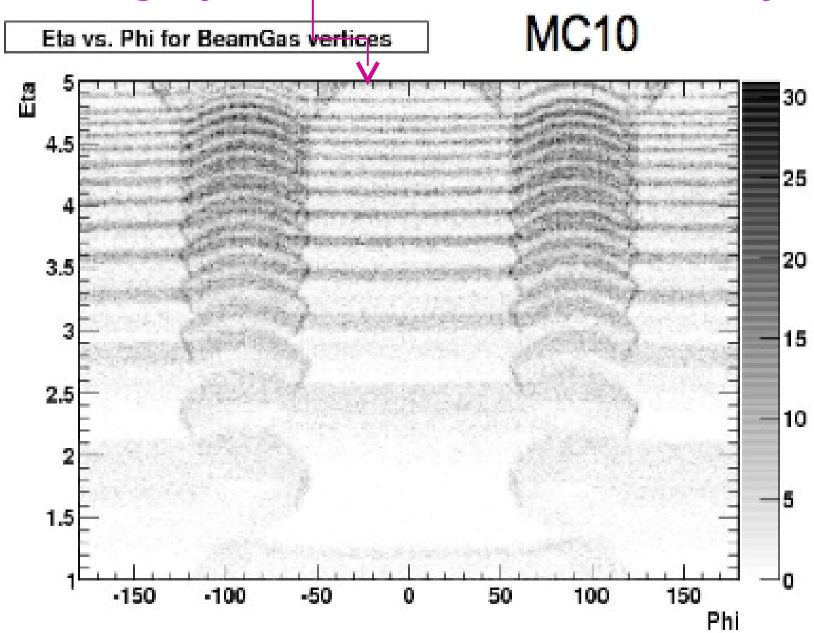
Impact parameter resolution governed by:-

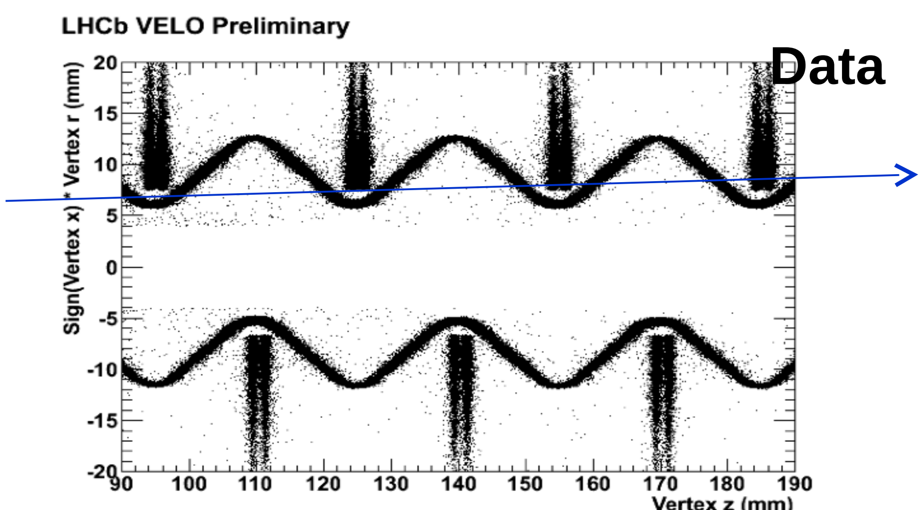
- **Multiple Scattering**
- **Radius of the first measured point**
- **Alignment**
- **Detector Resolution**



Material before first measured point is

Highly non uniform and a very special geometry (many thin planes)



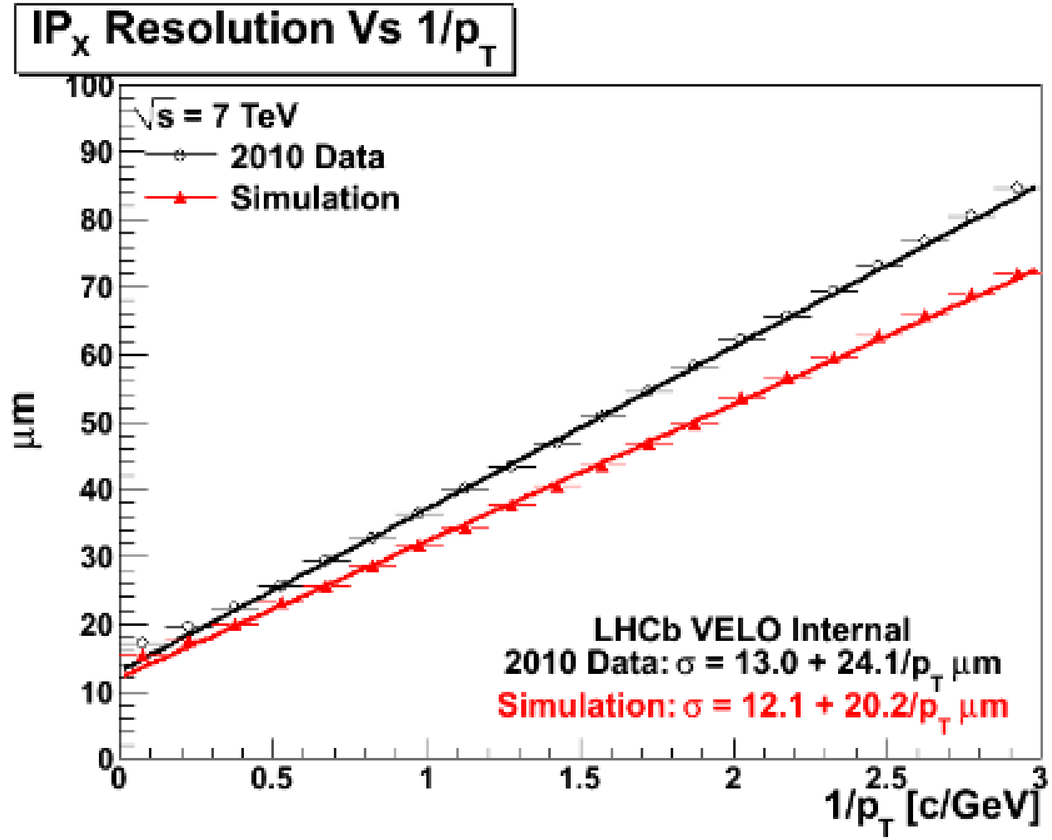


IP Discrepancy Data/MC

- Comparisons for 2010 data and MC10 using Geant4 9.2.p04

- Improved alignment but MC gradient remained ~**20%**

- Geometry description was a good approximation to the real mass of the RF-Foil:



$$(N^{data}_{foil} / N^{MC}_{foil}) / (N^{data}_{sensor} / N^{MC}_{sensor})$$

- Double ratio (determined from hadronic vertices) less than 2 sigma.

Standalone Simulation

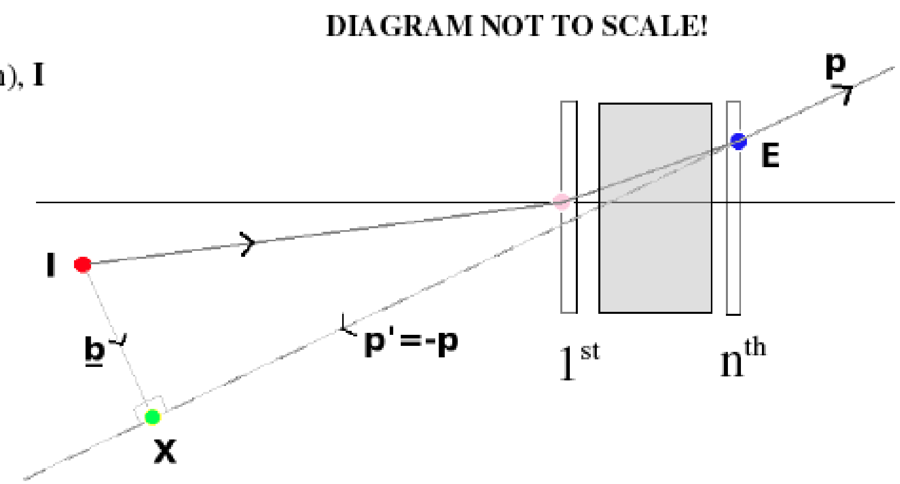
Intended to test sensitivity of our geometry to MS effects Geant4 versions and Physics List (PL):

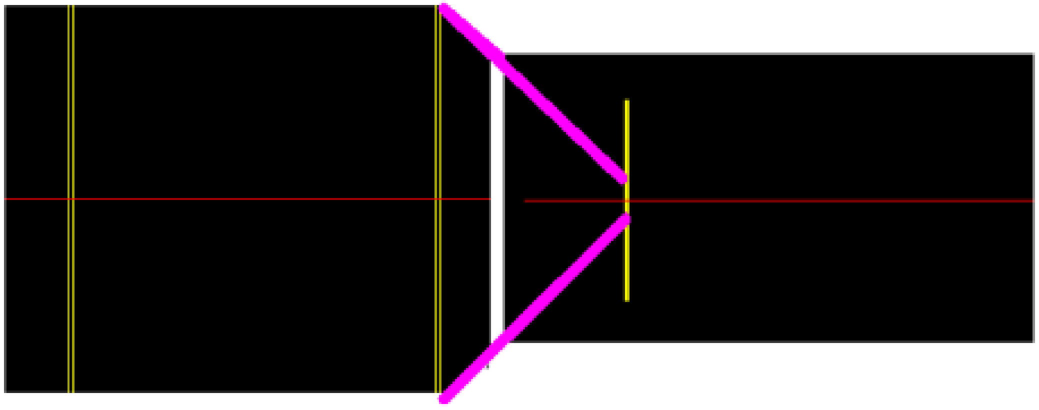
9.2.p04 (Reference) with PL: G4EmStandardPhysics_Option1 => Opt1
9.4.p01 with PL : G4EmStandardPhysics_Option3 => Opt3

Compares the effect of scattering through a single block of Al to many thin layers

Designed to be sensitive to lateral displacement, was thought to be issue

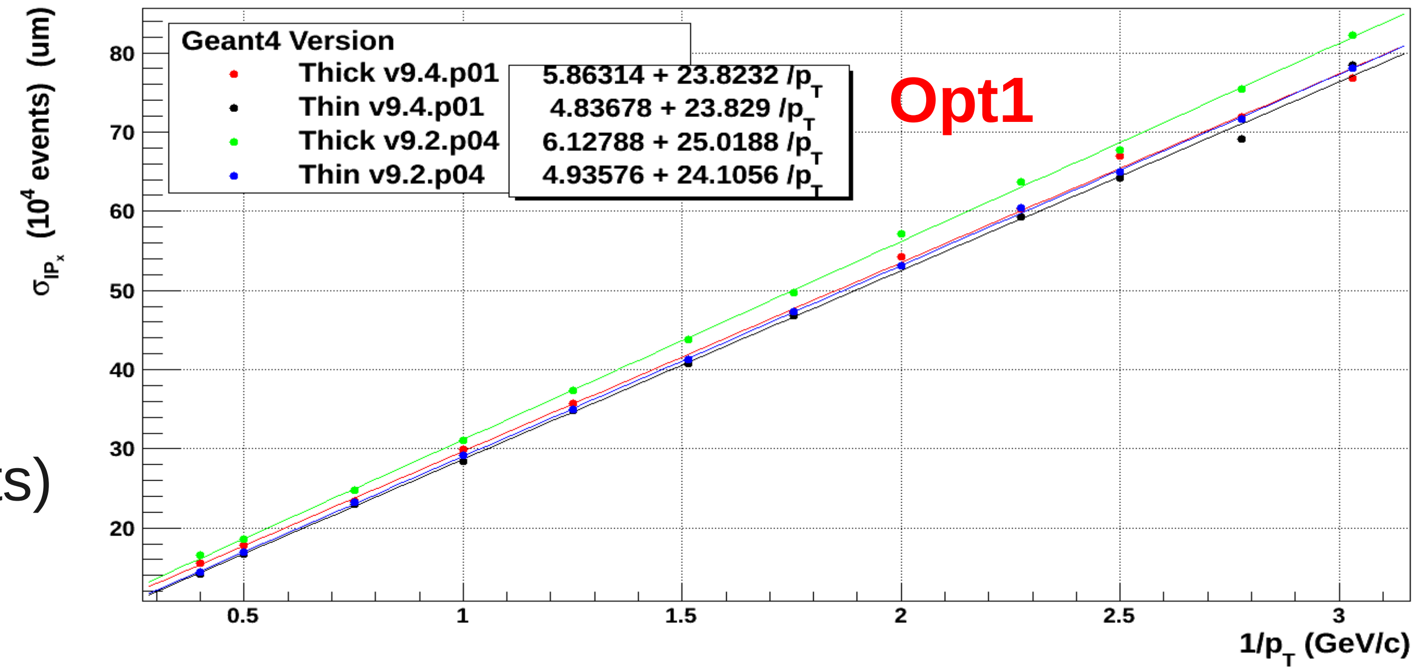
Estimates ideal impact parameter resolution with infinite measurement precision

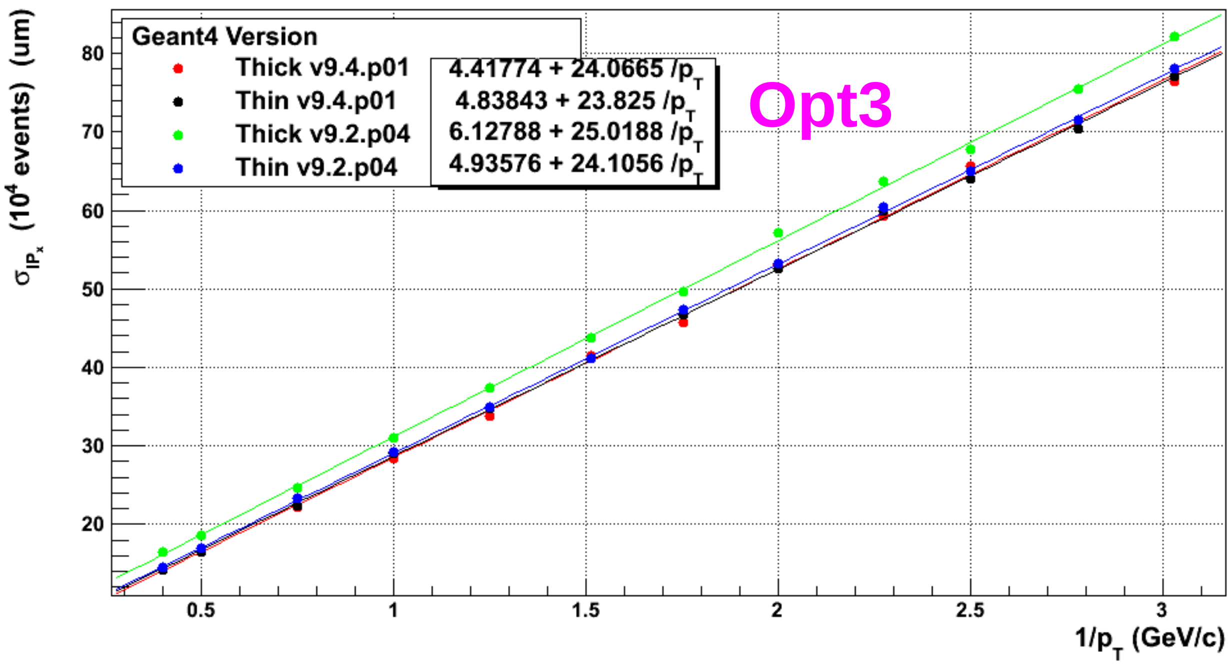




Electrons are Tricky!

- For electrons with Thick@5mm and Thin@500um
- 9.4.p01 has UrbanMsc93 model (lateral displacements)

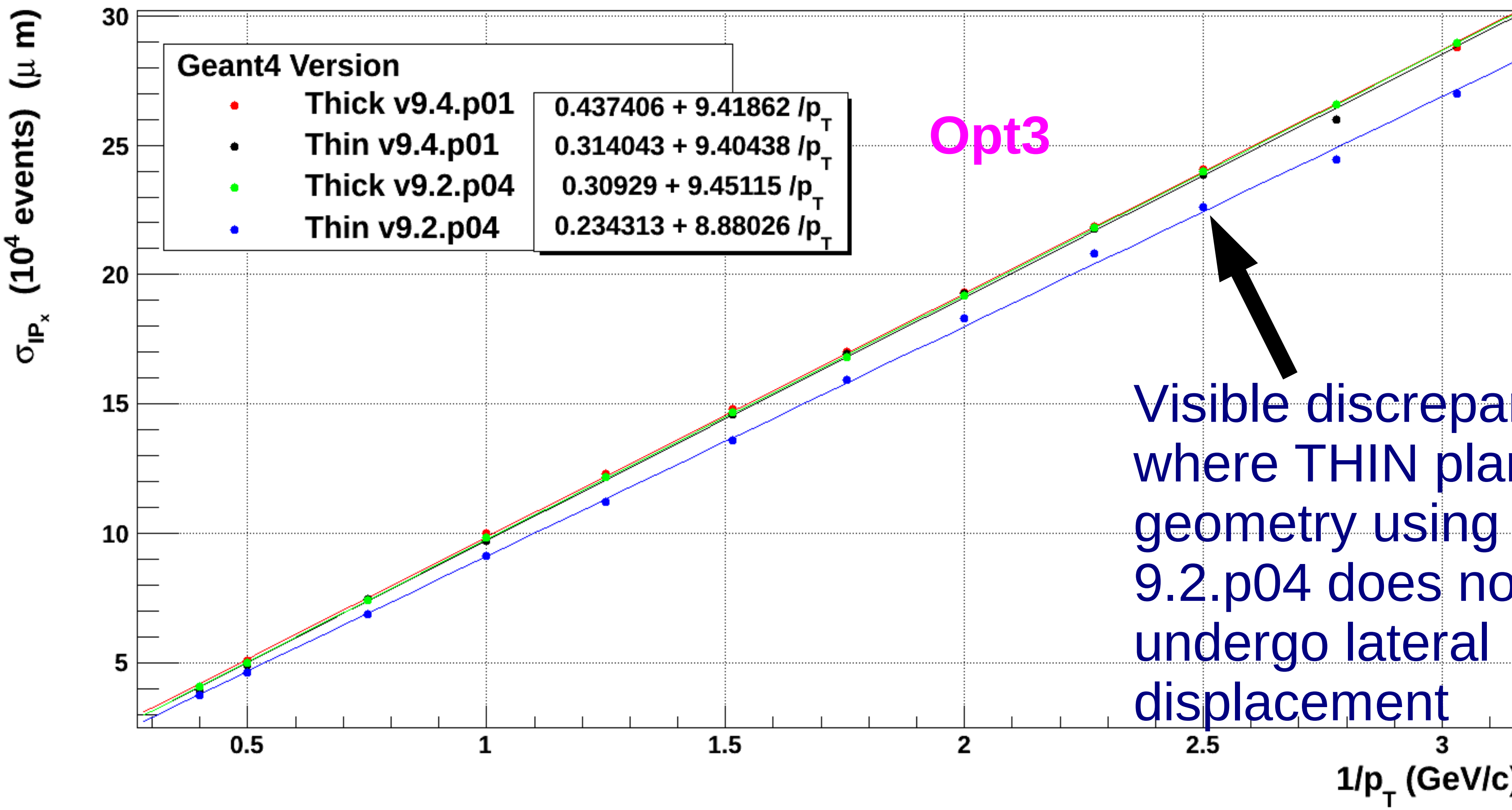




1) **Opt 1 - v9.2.p04** does not converge green/blue
2) **Opt3 – v9.4.p01** does not increase resolution for e-. red/black CONVERGE!

Muons Look Promising

- Thick@1mm and Thin@100um using new physics list Option3
- Result! (Thick/Thin)94p01 overlap with Thick92p04, leaving Thin92p04



Visible discrepancy where THIN plane geometry using version 9.2.p04 does not undergo lateral displacement

Small enhancements to the effect are given by reducing step size

Analysis Of Physics Lists (PL)

In MC productions so far used version 9.2.patch04 with known issue for lateral scattering in thin planes

Concentrate on differences on two predefined **P**hysics **L**ists (**PL**) in newer version 9.4.patch01 to try to identify best options for all particles

G4EmStandardPhysics_option1 (MC10)

G4EmStandardPhysics_option3

Main differences:

Electrons: Use of **fU**se**D**istanceTo**B**oundary (**fUDB**) + different G4UrbanMscModel (Lewis theory for charged particle propagation, applicable at any energy)

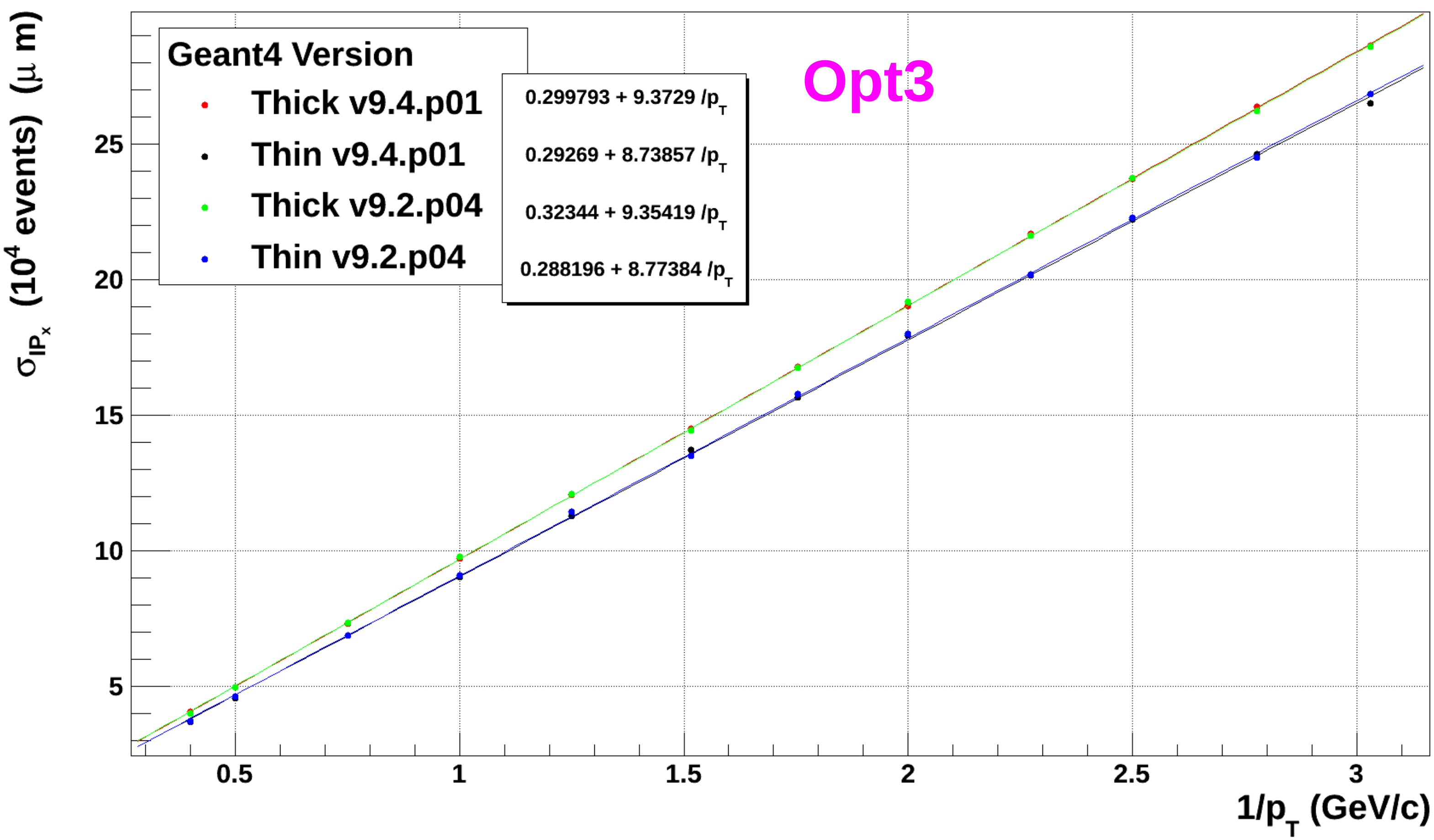
Muons: Does not use **fUDB**; uses combination of UrbanMSc and Wentzel (Msc for small angles, Coulomb scattering for large angles) in 9.4.p01 (9.2.p04 uses Wentzel only). Ionisation Class has StepFuntion applied.

Hadrons: same models in both versions, does not use **fUDB**

Applied Cuts: Switched on by default in the latest versions (5mm production cuts in LHCb).

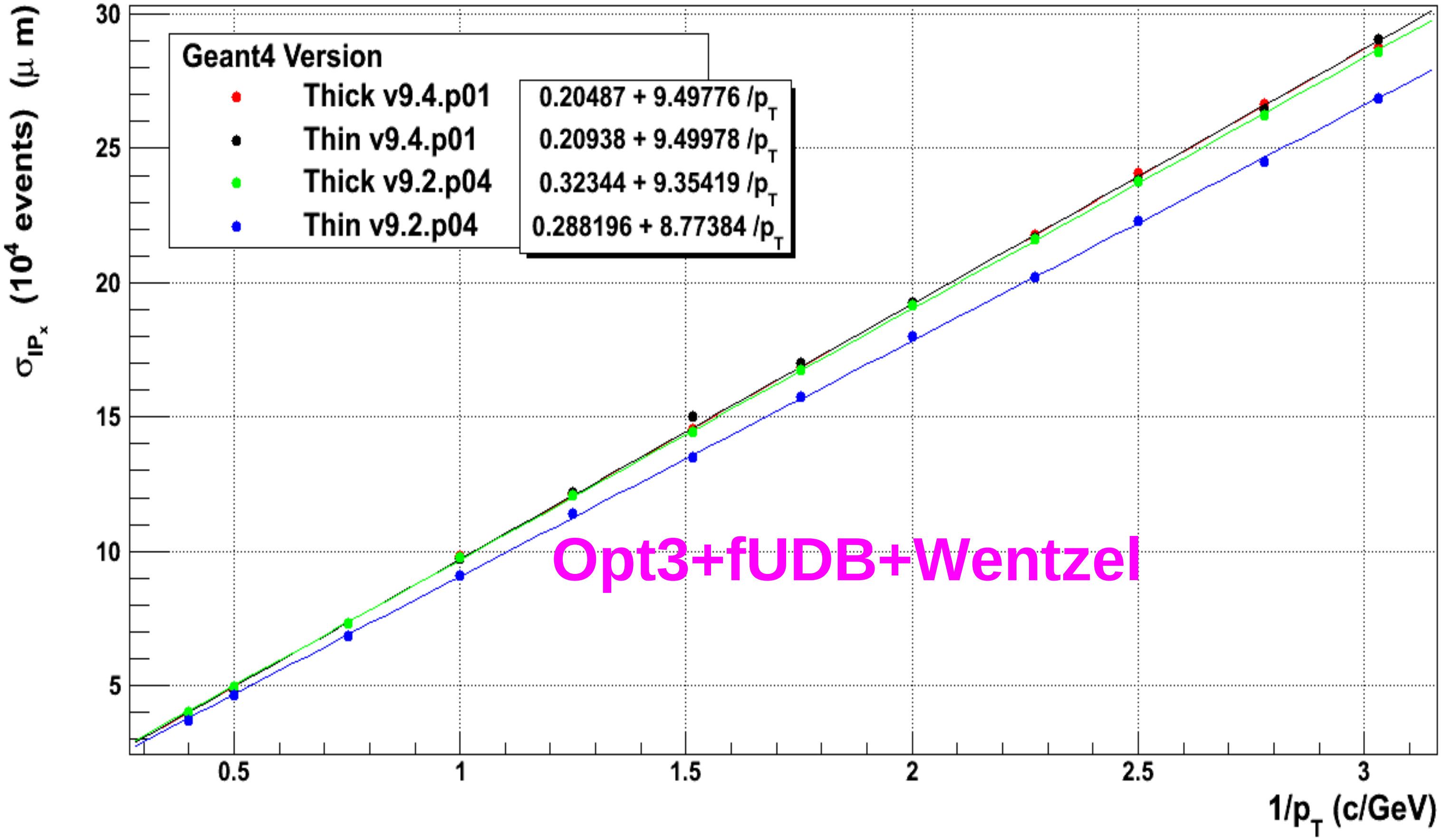
Pions: No change in either 9.2.p04 or 9.4.p01with EmStandard physics lists

- For Pions with Thick@1mm and Thin@100um using new physics list Option3
- **Pions most abundantly produced in pp collision** and clear bug present.



Pions: With Modified Physics List

- Papers by Geant4 EM group suggested Wentzel can be used for Pions
- For Pions with Thick@1mm and Thin@100um using new physics list Option3 + fUseDistanceToBoundary + WentzelVI
- Result! (Thick/Thin)94p01 overlap with Thick92p04, leaving Thin92p04



Pions

- In an attempt to quantify the result, below shows the increase in gradient for thin planes, using the new version of G4 over the old

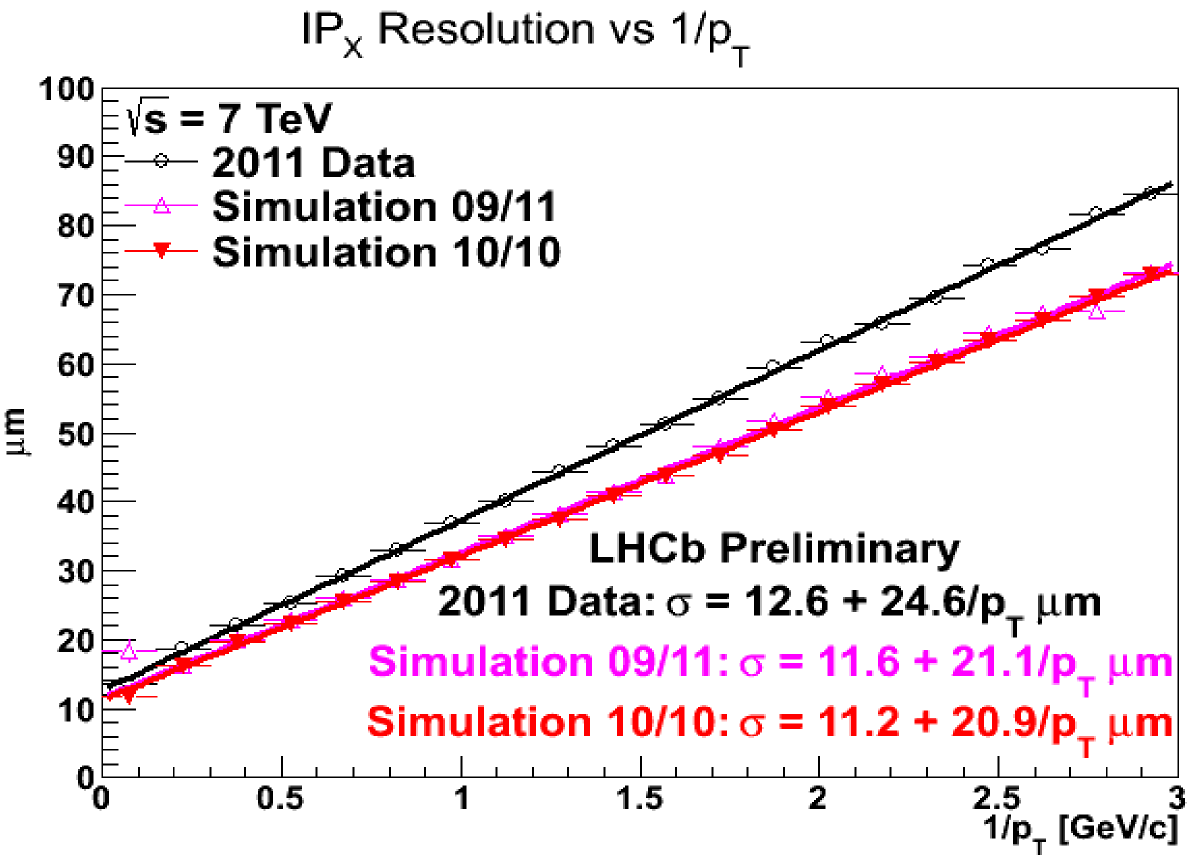
Plane Thickness (um)	Thin v9.2p04	Thin v9.4p01	~ Percentage increase
100	8.77384	9.49978	8.2%
200	13.038	13.6371	4.6%
300	16.3265	16.9393	3.8%
400	19.3062	19.6202	1.6%

~RF-Foil Thickness

- AGAIN, not comparable to the **20% needed** to match data. HOWEVER, this is **TRUE IP**, without detector hits and associated errors (assumed perfect).

MC2011 Validation to start soon

Received a physics list from G4, based on discussion of results of standalone simulations



We observe a 1% increase in IP resolution

Couple more ideas for PL: ionization StepFunction, addition of fUDB and finally apply to all Hadrons.

Why Is There Still A Discrepancy?

- Not fully understood. Fantastic opportunity as resolution so good, study impact of material approximations.
- RF-Foil Surface is constantly changing in many directions. Would need someone INSANE and with years on their hands.
- Difficult with current Boolean combinations of volumes
- Simulation would be slower (Large # of tiny volumes)
- **BACKUP SLIDES FOR THOSE INTERESTED IN GEOMETRY**

Multiplicity, dE/dx & CALO Studies

Some studies based on Geant 9.2p.03
"Silvia M, Matthew N, Nigel W, Alexandra M S, Patrick R, + ..."

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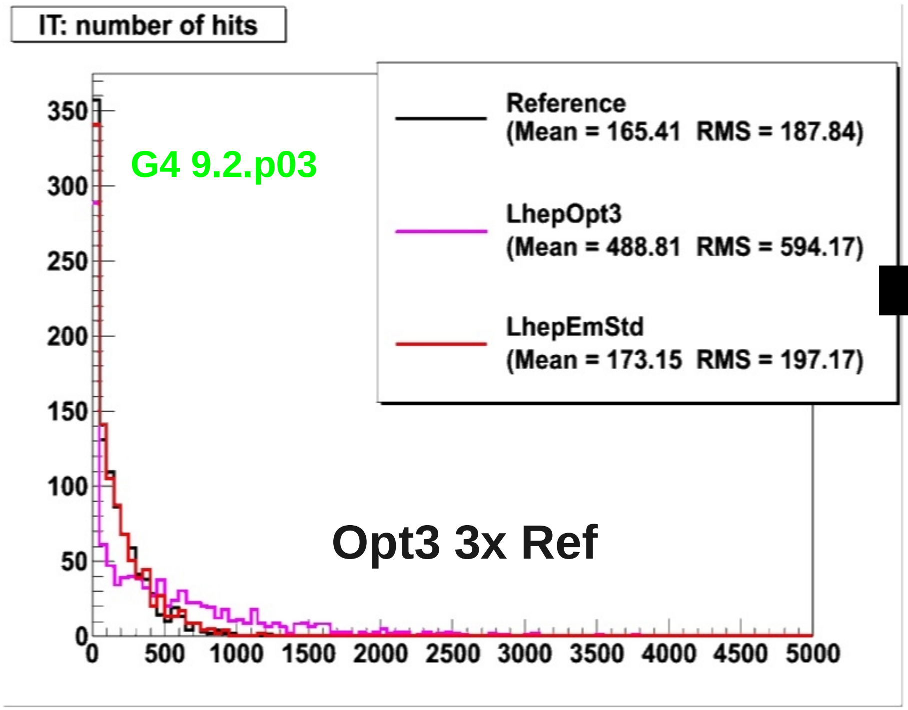
Silicon - Trackers

MCHit corresponds to a hit in sensitive detector volume

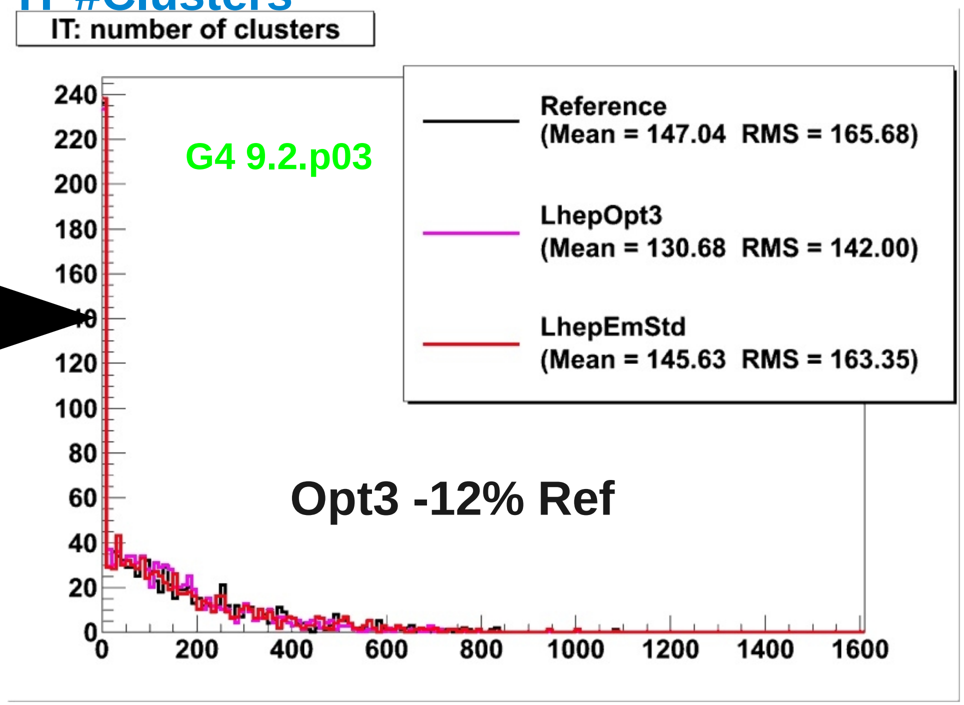
Simulation -> Digitisation -> Reconstruction

OPT3 use of fUDB setting forces 3 steps within a geometric volume

IT #MCHits



IT #Clusters



EmOpt3 #of MCHit a factor 3 (for all Trackers). Increased MCHit multiplicity

Lower Cluster multiplicity @ Inner Tracker (IT). More steps so more steps fewer clusters forming.

Energy Deposition Si – Tests 2011

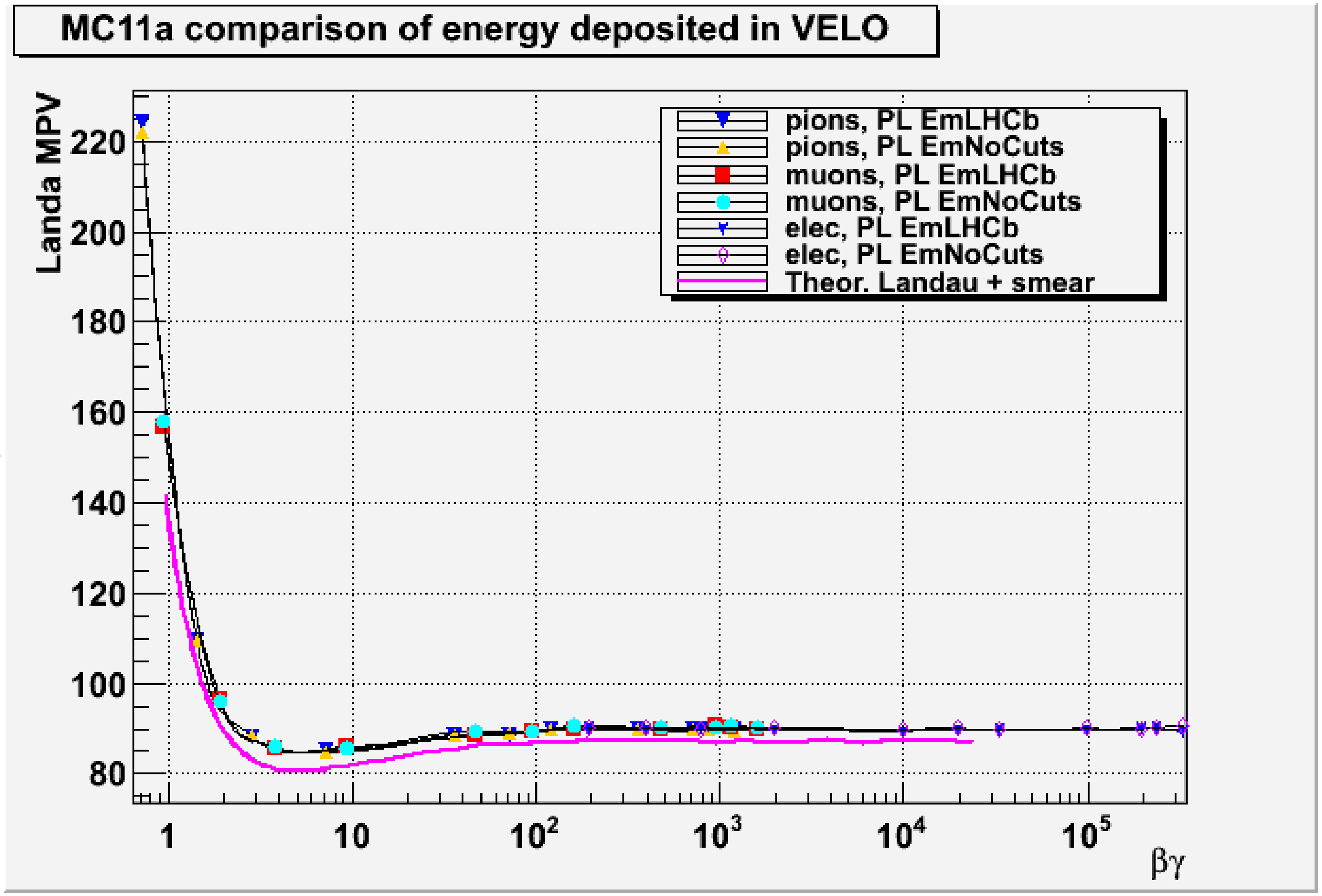
- **No (unphysical) significant differences by particle type**
- **No distinction found between EM options**

G4 9.4.p01

Option1 + NoCuts

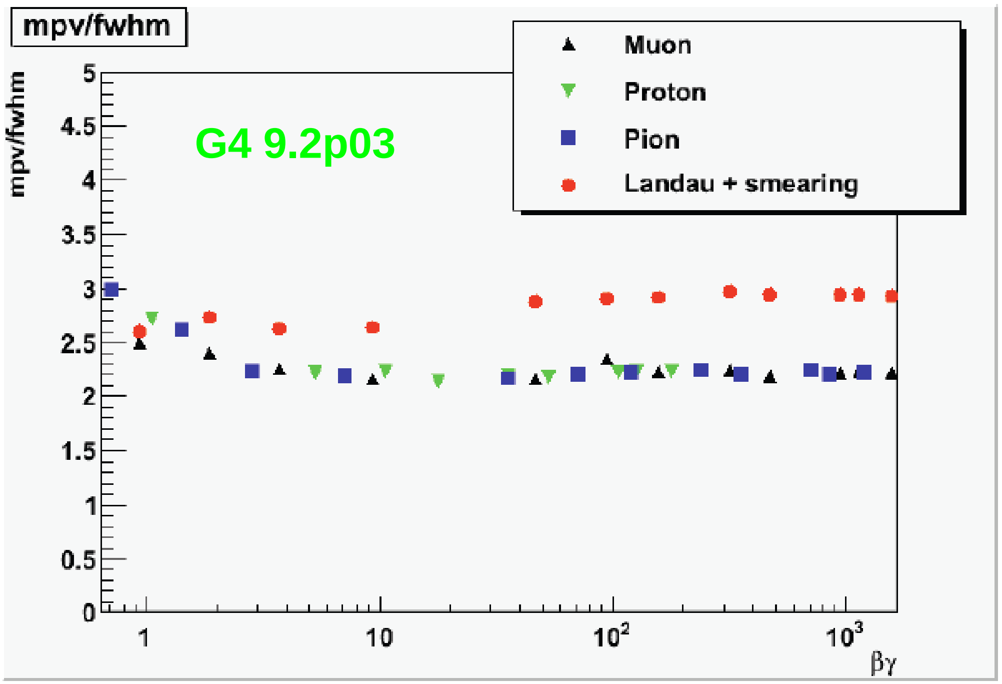
OptionLHCb+Cuts

- **In the past there were differences**



Energy Deposition in Si

- **Different particles with common EM PL (MC10)**



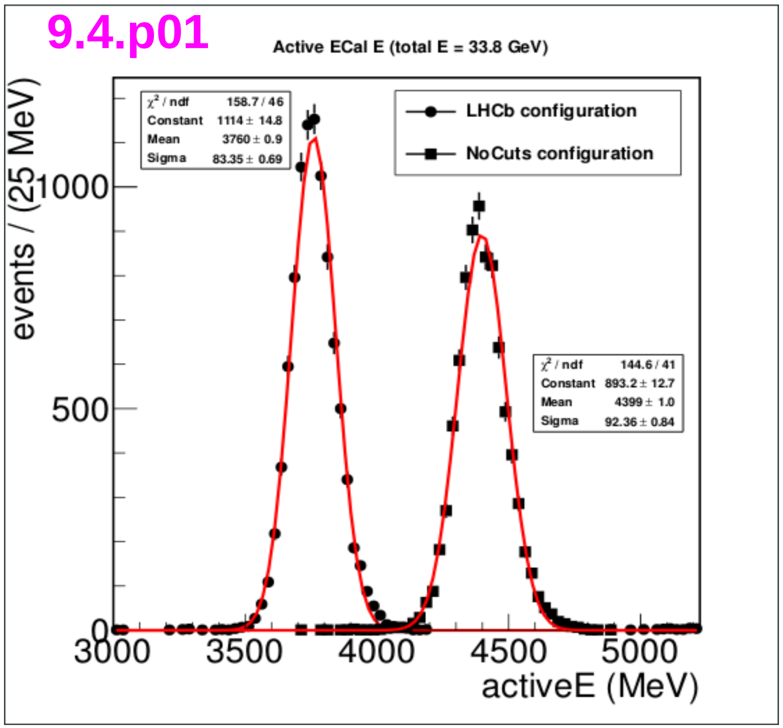
Similarly, for ratio of MPV/FWHM, test width of Landau

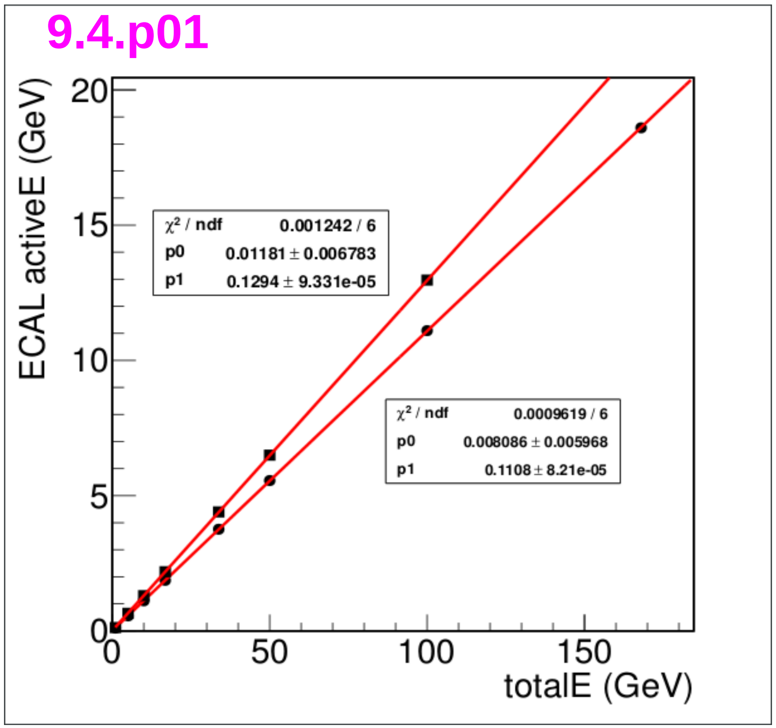
	Opt1/expected			Opt3/expected			Std/expected		
P (Gev)	1	10	100	1	10	100	1	10	100
mpv	1.02	1.07	1.03	1.02	1.07	1.03	1.02	1.07	1.03
mpv/ fwhm	0.82	0.81	0.76	0.81	0.80	0.75	0.82	0.81	0.77

- **For different PL this distribution is the same (small effect in changing PL)**
- **Widths relative to MPV increased slightly in 9.4.p01 vs 9.2.p03; but more stable**

Calorimeter – 2011 Validation w/wo AppliedCuts

- To do study below “switch off” LHCb detector except CALO, examples below look at **photons in ECAL**.
- Evis/Ebeam expected to change by ~ 15% in G4 9.4.p01 for our current choice (EmOpt1) from studies by Andrea D. using simplified LHCb calorimeter model.





- Changes observed in LHCb calorimeters simulation **as expected!**
- Consequence of our 5mm production cut and the application of **“ApplyCut”** option.

[study by A. Sanchez]

Physics List for Calo

- Options:

  1) Disable "ApplyCut" completely in Simulation. Keep simulated energy scale unchanged, ~same calibration

  2) Leave **"ApplyCut" active**, re-tune value to find more stable value for us. Different physics models corresponds to different approximations of the real phenomena.

Conclusions

Standalone study indicates unwanted discrepancies in simple geometries, using old Geant version. New models introduced to compensate.

Physics lists are a delicate symphony. Changes to one aspect might improve one aspect of simulation, but problems may arise elsewhere.

As detectors continue to improve on accuracy and sensitivity we must be able to describe detectors accurately in MC

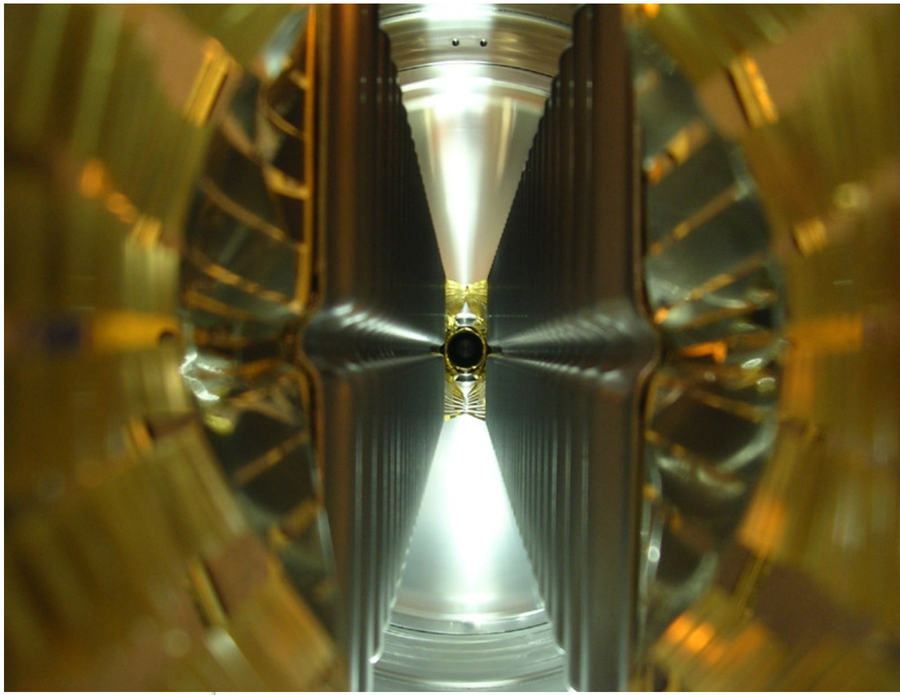
Gone are the days where close approximations are good enough

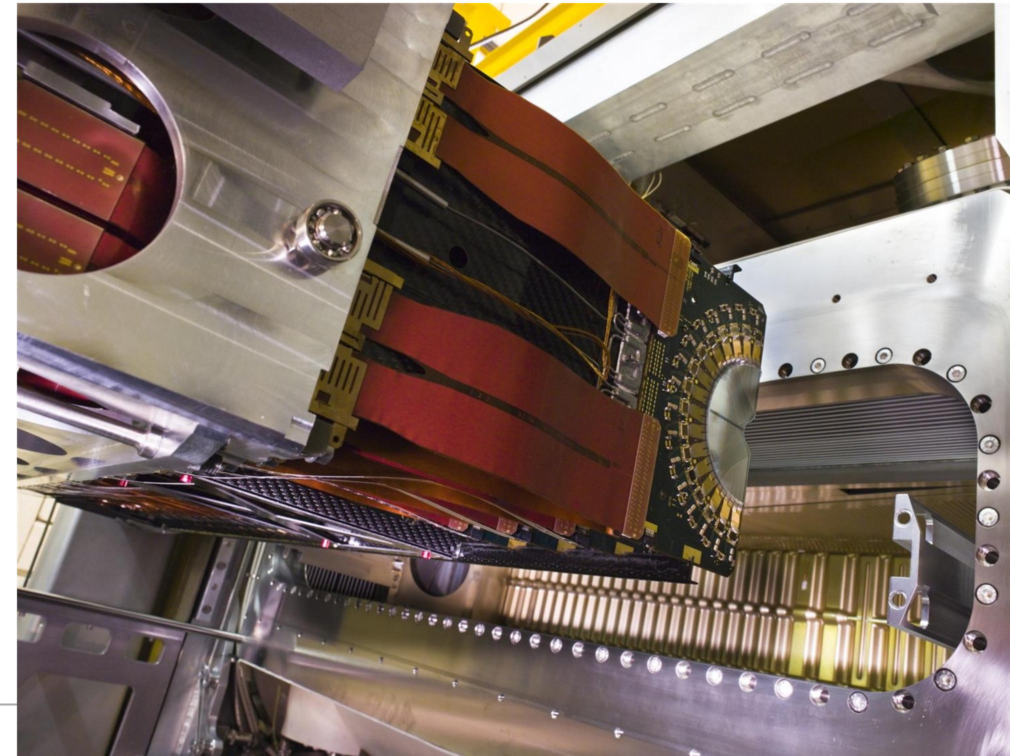
Calo re-calibrations needed dependent on our choice of EM-PL “*To ApplyCuts or not to ApplyCuts*”

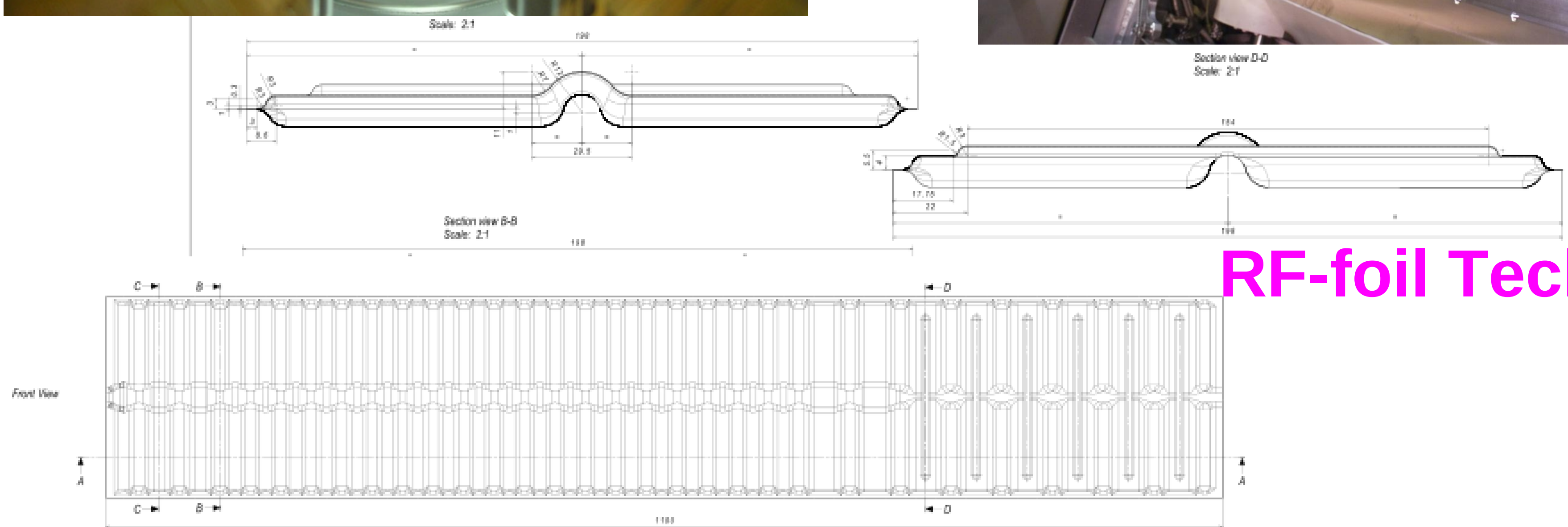
Multiplicities change with EM-PL

Backup Slides I

Downstream view of the Velo

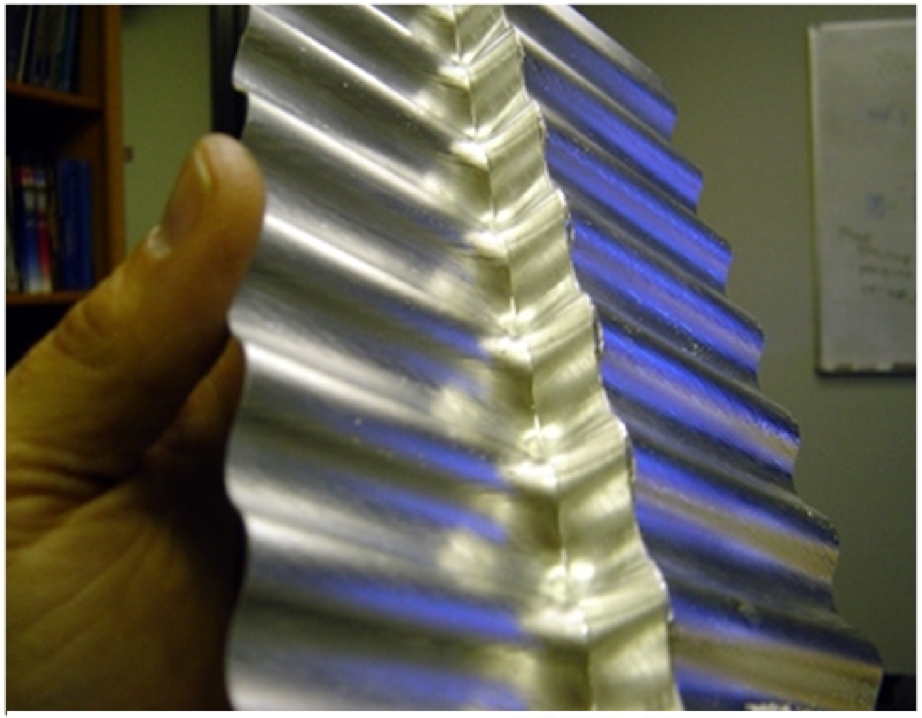




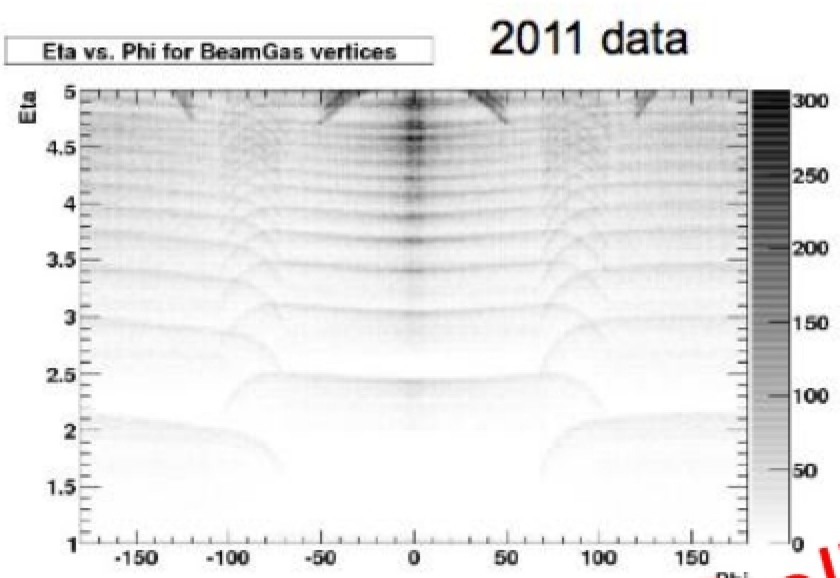


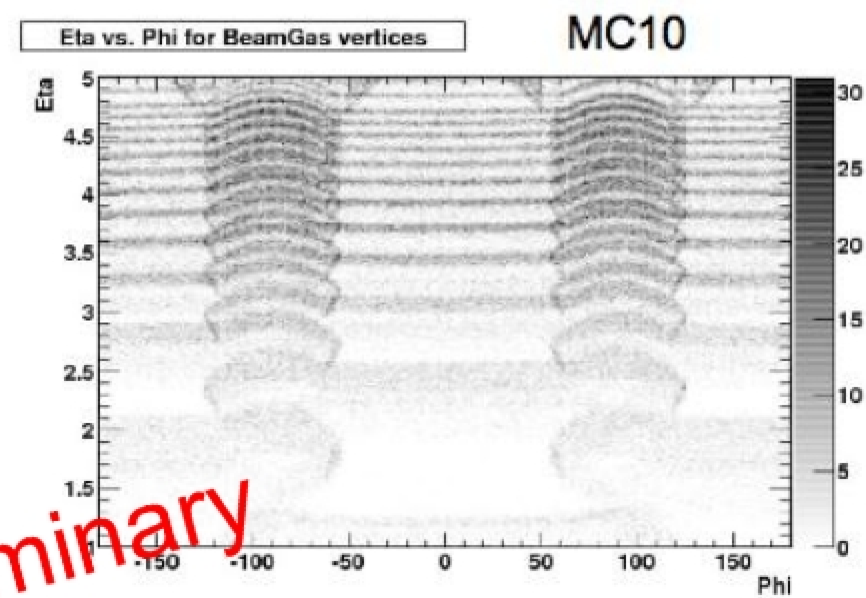
RF-foil Tech Drawing

Backup Slides II



Even more complicate RF-Foil in the proposed LHCb Upgrade





Very Preliminary

Step Size Effects

% Change to gradient (100 μm planes)			
1 (μm)	30 (μm)	fUDB	50 (μm)
7.5 %	7.0%	6.5%	5.8%

Table 4 Comparing the differences in slopes for the IP resolution for thin planes at 100μm. The percentages a made by varying the new version of geant4 simulation and comparing to the ol

By “New Version” I refer to G4 9.4.p04 and by “old” I mean G4 9.2.p04. These results suggest improvements can be made by reducing step size but this would cost valuable CPU for little to no gain.

References

[1] "*Geant4 models for simulation of multiple scattering", V N Ivanchenko, O Kadri, M Maire, and L Urban,2010 J. Phys.: Conf. Ser. 219 032045.* (*http://iopscience.iop.org/1742-6596/219/3/032045*)

[2] "*Geant4 electromagnetic physics for the LHC and other HEP applications", A Schaicke, A Bagulya, O Dale, F Dupertuis, V N Ivanchenko, O Kadri, A Lechner, M Maire, M Tsagri, and L Urban.* (*https://indico.cern.ch/getFile.py/access?contribId=1&resId=0&materialId=slides&confId=127566*)

[3] "*Geant4 Impact Parameter Preliminary Results", M M Reid. (https://indico.cern.ch/getFile.py/access?contribId=10&resId=0&materialId=slides&confId=139392)*

[4] "*Geant4 Collaboration, Physics Reference Manual", v9.4, 17 December, 2010 . (http://cern.ch/geant4/UserDocumentation/UsersGuides/PhysicsReferenceManual/fo/PhysicsReferenceManual.pdf)*