Performance with first LHCb data

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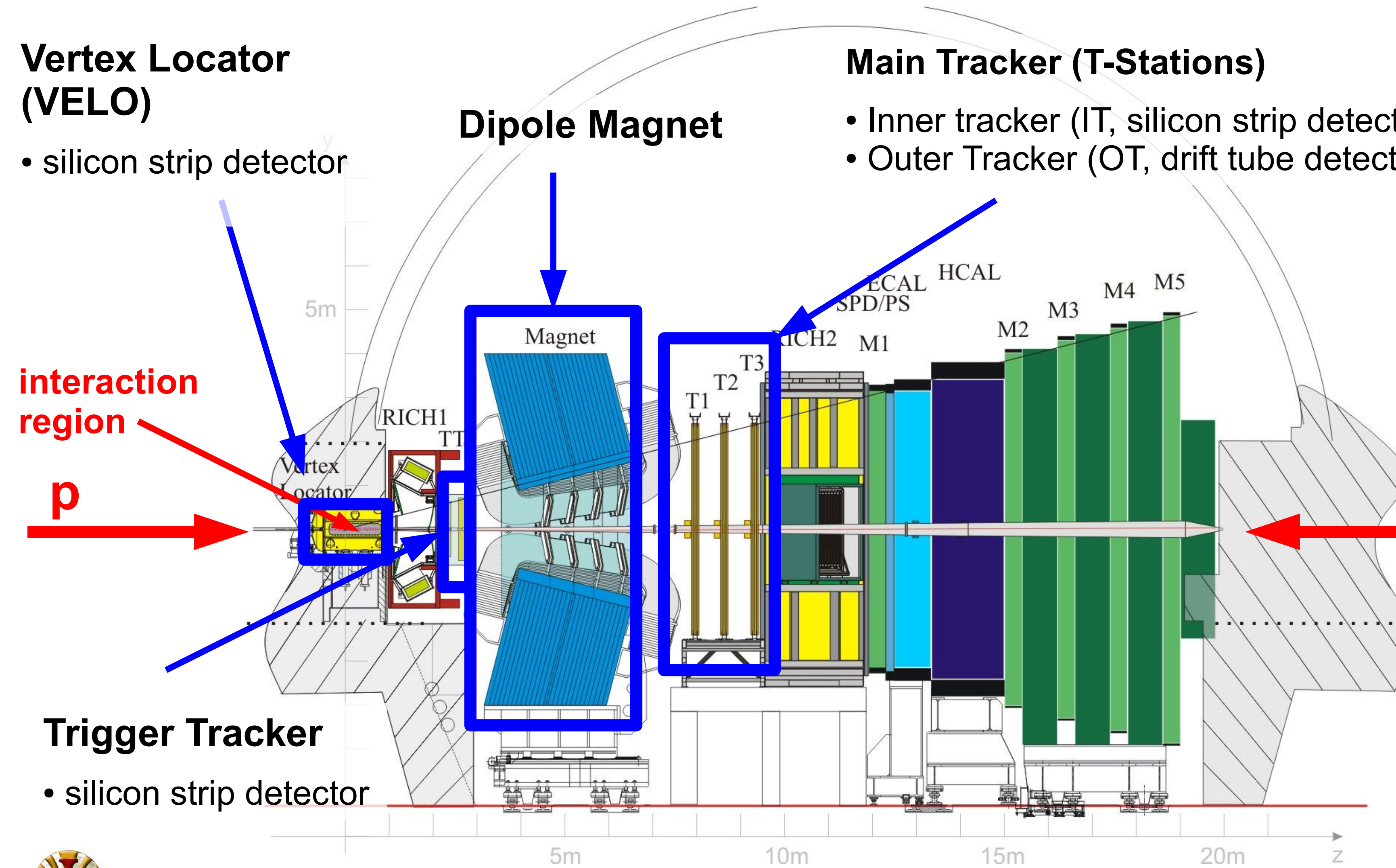
The LHCb Detector

Vertex Locator (VELO)
- silicon strip detector

Dipole Magnet

Main Tracker (T-Stations)
- Inner tracker (IT, silicon strip detector)
- Outer Tracker (OT, drift tube detector)



Trigger Tracker
- silicon strip detector

B field in y direction, tracks are curved in x plane.

Interactions in LHCb Experiment

Beam gas events are collisions from one proton from one of the beams with an atom left in the beampipe vacuum.

Beam 1

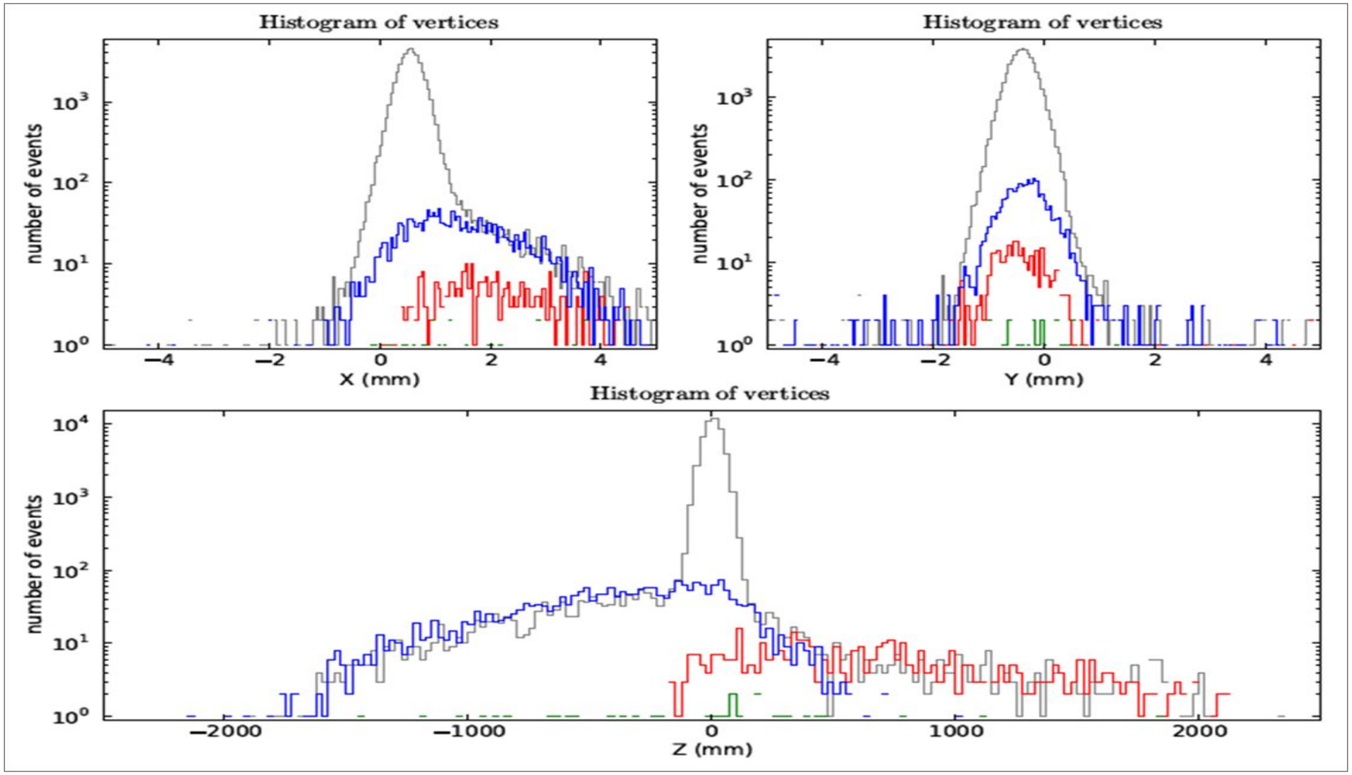
Beam 2

beam – beam Interaction

(between 5-30% beam gas background)

Beam gas can be statistically Substracted

beam gas events are more in forward region and have higher occupancy



Interaction region of proton proton events

Run Summary 6/12/09 – 15/12/09

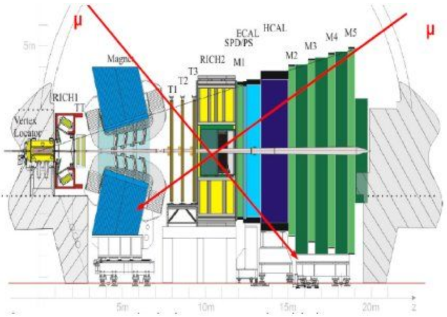
- recorded ~6 μb^{-1} of int. luminosity with “Minimum Bias” trigger
- (L0: “Hadron” -OR- “muon” -OR- “backward VELO”)

- ~260k pp-collision events at 900 GeV (beam gas subtracted) with all detectors ON!
  (about same numbers usable for first analysis)

Date	Number of crossing On disk	Number of beam-beam crossing On disk	Number of beam1-gas crossing On disk	Number of beam2-gas crossing On disk	Estimated Number of pp interaction on disk	pp interaction / (bb-crossing)	Estimated pp interaction rate (t=0) [Hz]	L0 rate (t=0) beam1-gas crossing [Hz]	L0 rate (t=0) beam2-gas crossing [Hz]	Recorded luminosity [μb-1]
Dec 6, 09	994	606	164		278	45.9%	0.5	0.2		0.01
Dec 6, 09	7 762	5 506	889		3 728	67.7%	0.9	0.2		0.09
Dec 8, 09	16 220	11 449	4 298		7 151	62.5%	0.8	0.5		0.18
Dec 9, 09	3 227	2 155	408		1 339	62.1%	0.5	0.1		0.03
Dec 11, 09	75 511	55 478	14 975	48	40 503	73.0%	5.1	1.6	0.01	1.01
Dec 11, 09	2 070	1 424	382	30	1 042	73.2%	2.0	0.8	0.06	0.03
Dec 12, 09	88 819	62 772	17 831	963	44 941	71.6%	6.3	1.7	0.11	1.12
Dec 12, 09	92 776	62 644	20 417	1 301	42 227	67.4%	5.3	1.8	0.14	1.06
Dec 12, 09	84 759	69 889	9 952	878	59 937	85.8%	12.7	1.9	0.17	1.50
Dec 15, 09	23 670	19 581	3 294	2	15 816	80.8%	22.3	4.7	0.01	0.40
Dec 15, 09	63 103	50 412	8 985	597	40 143	79.6%	20.6	4.4	0.28	1.00
	458 911	341 916	81 595	3 819	**257 105**					6. 4

What do we learn from this data?

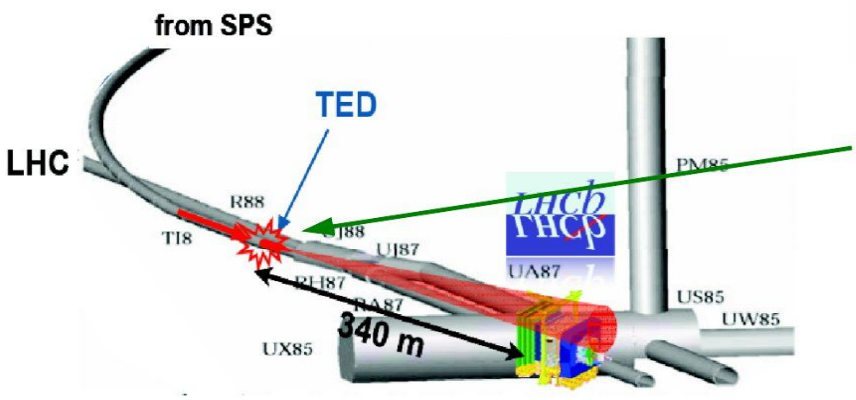
DETECTOR CALIBRATION & PREPARATION FOR DATA TAKING AT HIGH ENERGIES

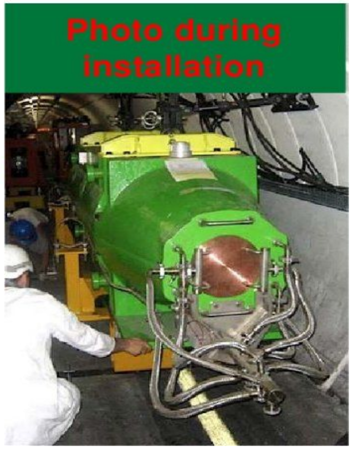


Calibrations taken up to now:

- “some” cosmics for large surface detectors (OT, muon chambers, calorimeters)

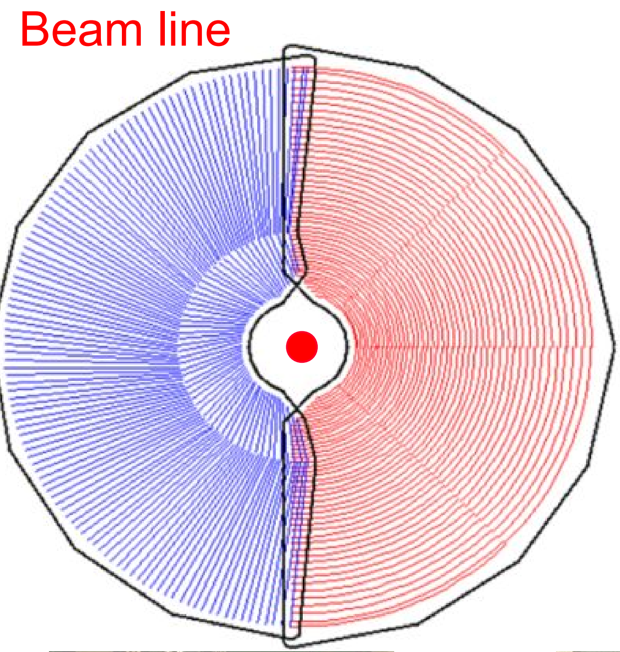
- TED data (tracks parallel to the beam) for small surface detectors (vertex detector, Inner Tracker, Trigger Tracker)





FIRST ANALYSIS AS TRAINING GROUND FOR UNDERSTANDING OF THE DETECTOR, STUDY OF SYSTEMATICS

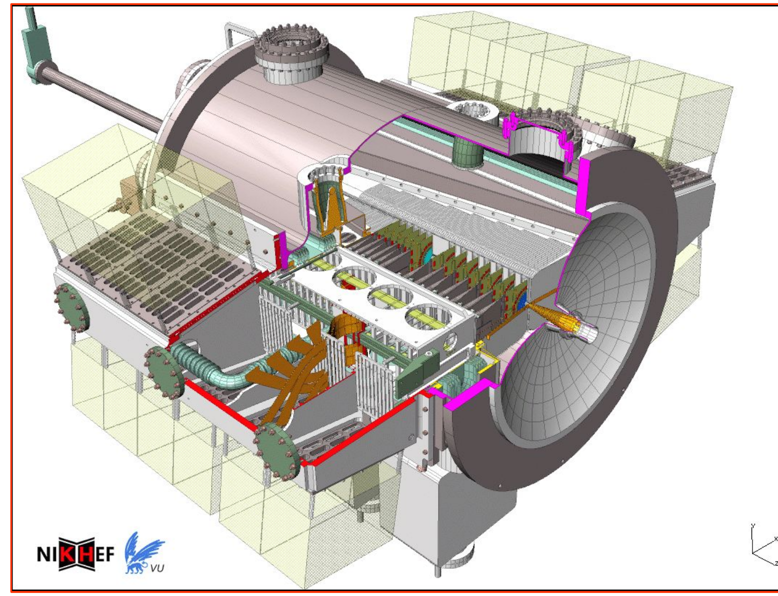
Vertex Locator (VELO)



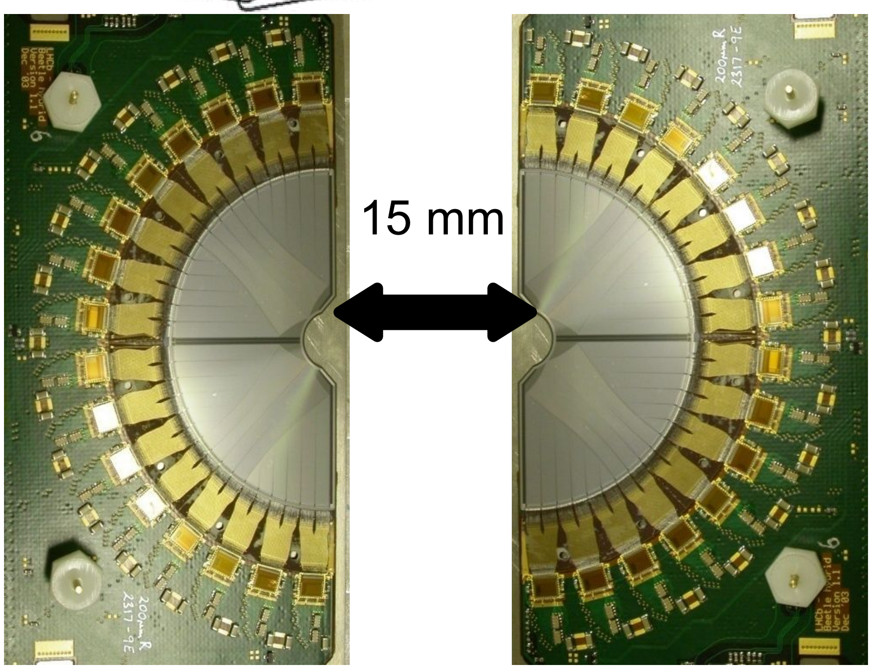
Velo can be opened when beam is Injected and closed for stable beam

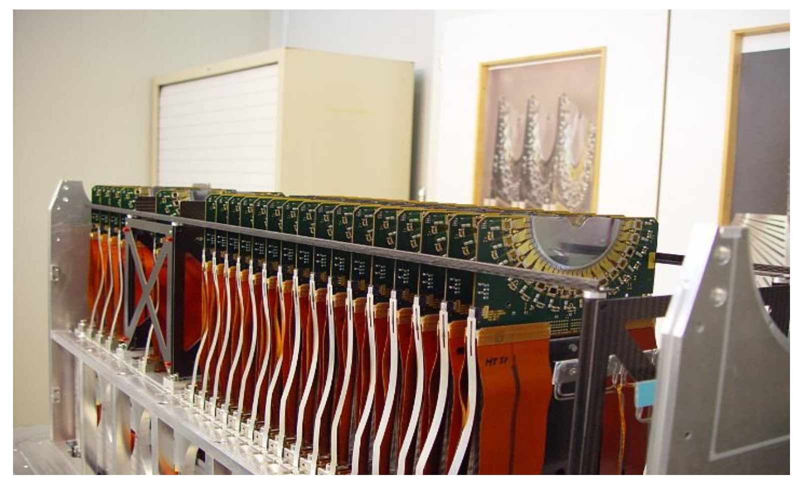
Uncertainty on position 10 μm, reproducibility 3 μm

In current data, 15 mm wide open

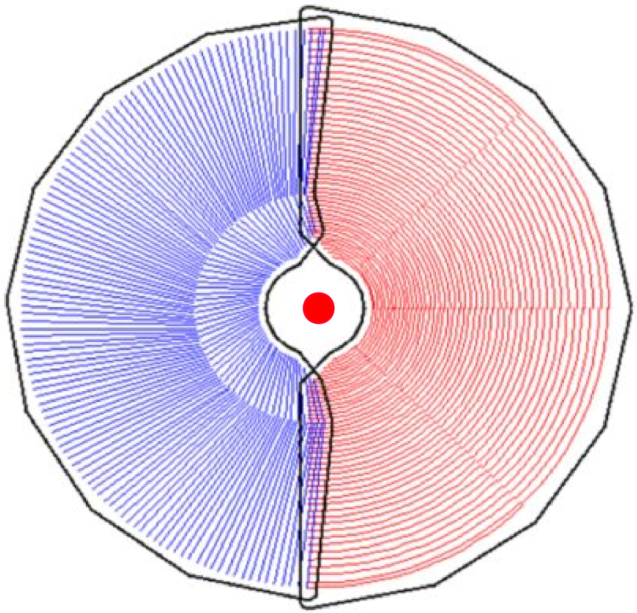


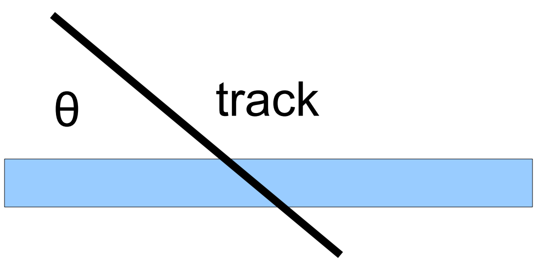
21 stations of Silicon wafer pairs with R and Φ strip readout

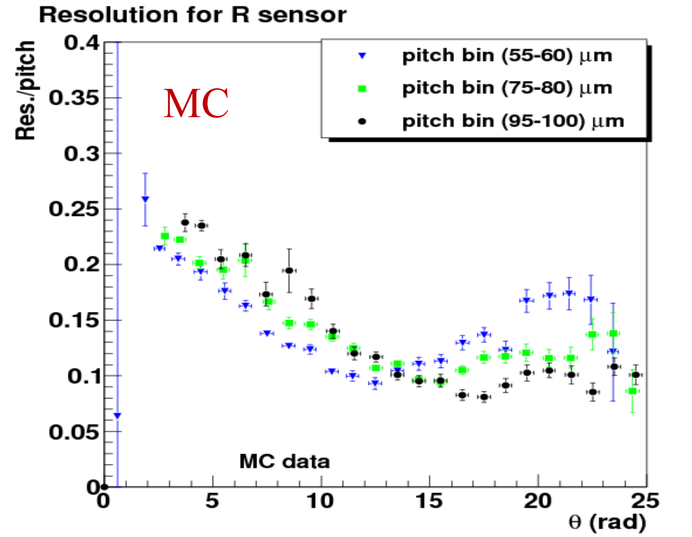


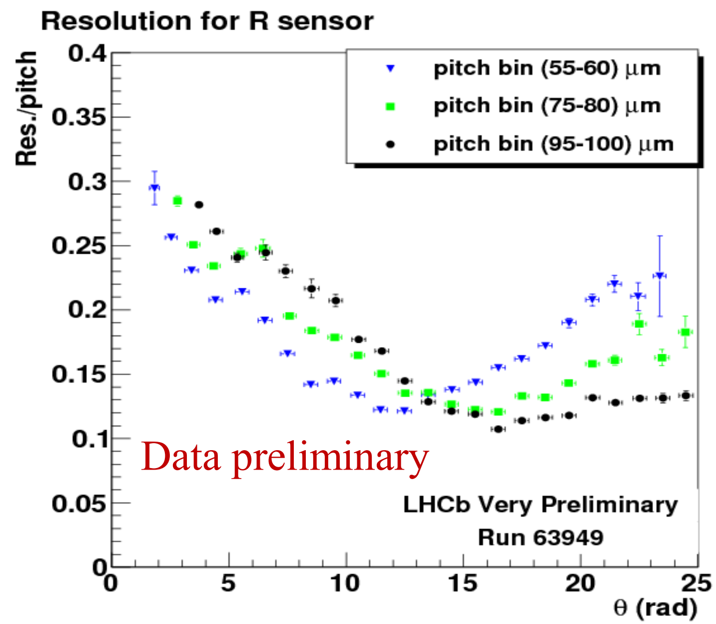


Vertex Locator (VELO)





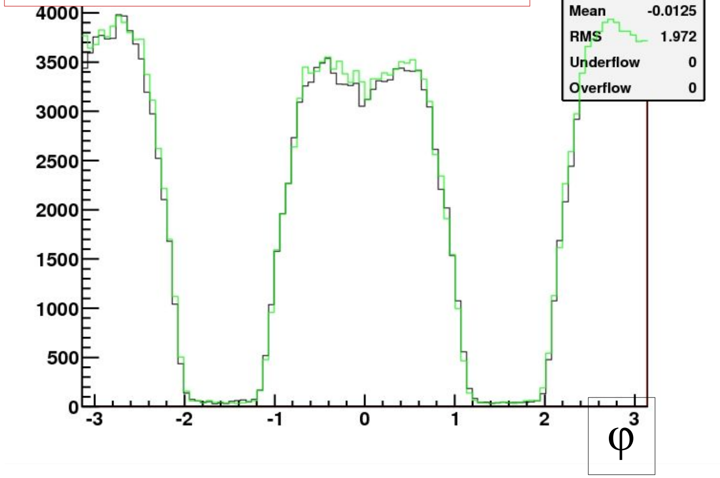




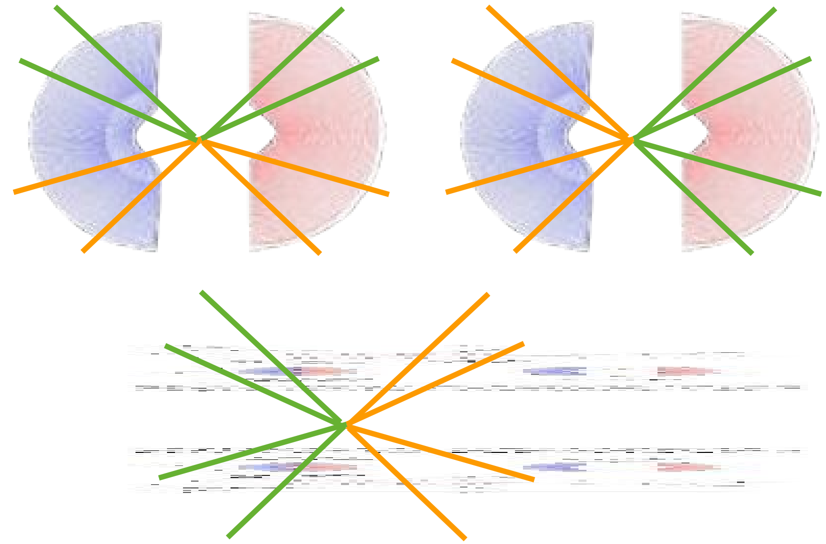
Expect 7 micron alignment resolution

Vertex resolution with partially open VELO

VELO tracks vs. φ

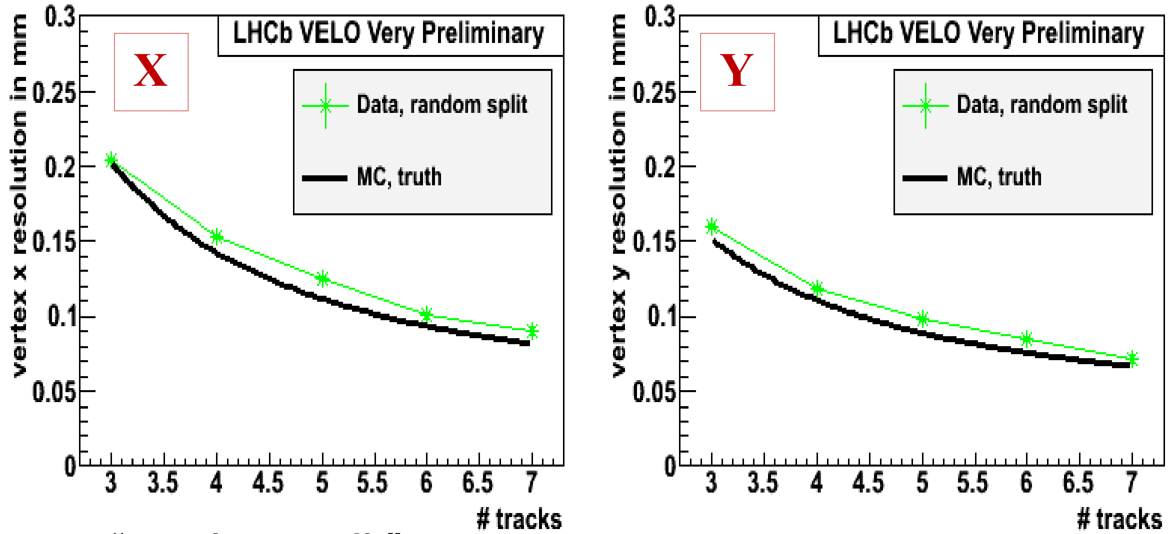


data
MC



Area data and MC normalized to same number of entries
“open velo” clearly visible

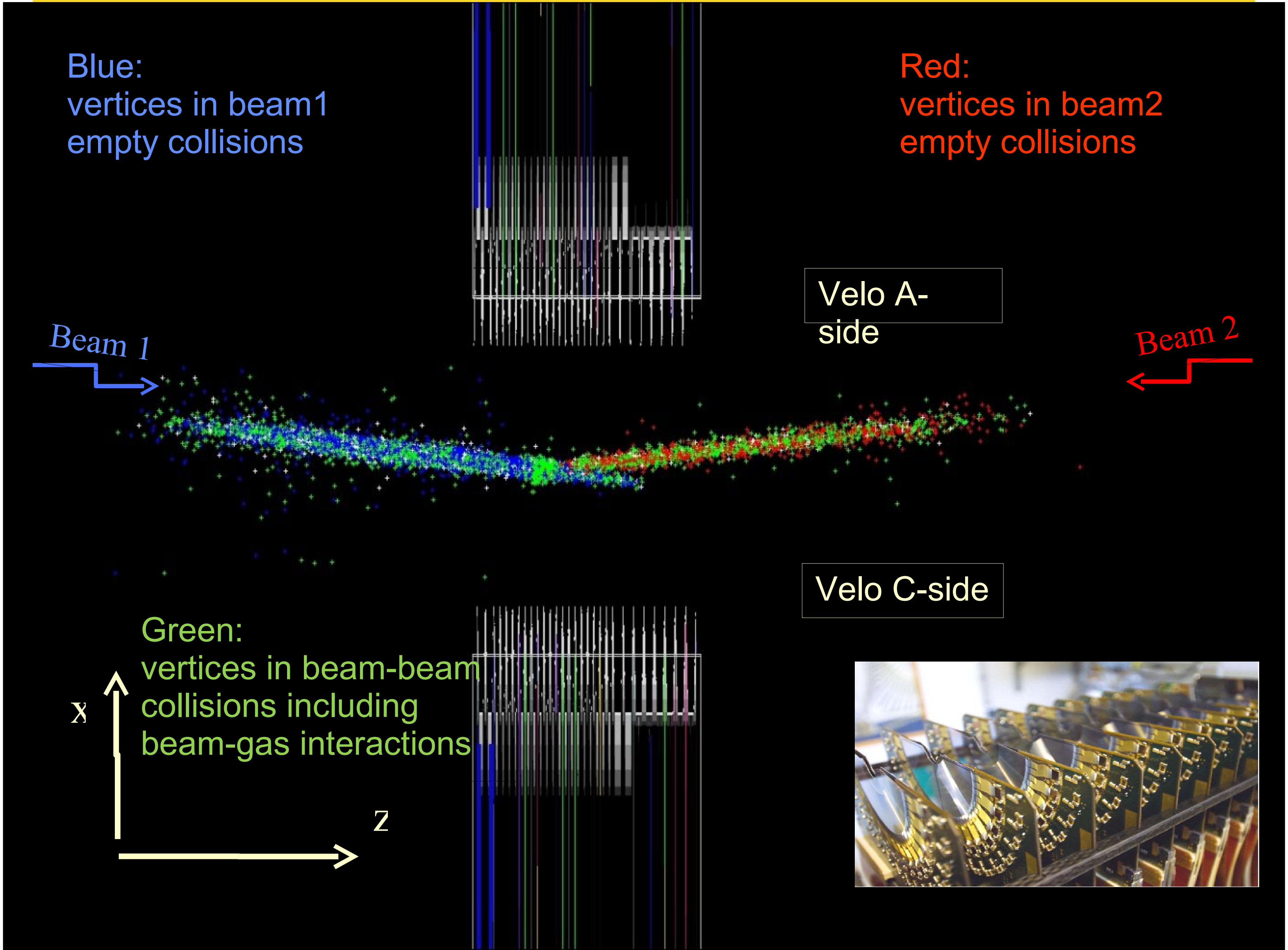
VELO vertex resolution vs. # of tracks



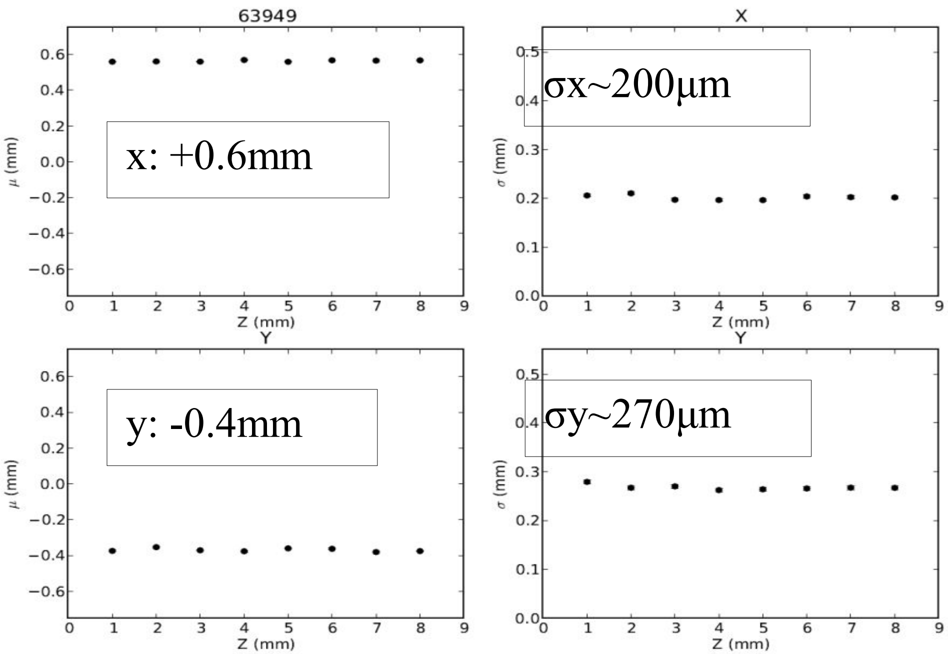
Split track set
In two halves
Fit vertex with both subset of tracks &
compare the position

“random split”

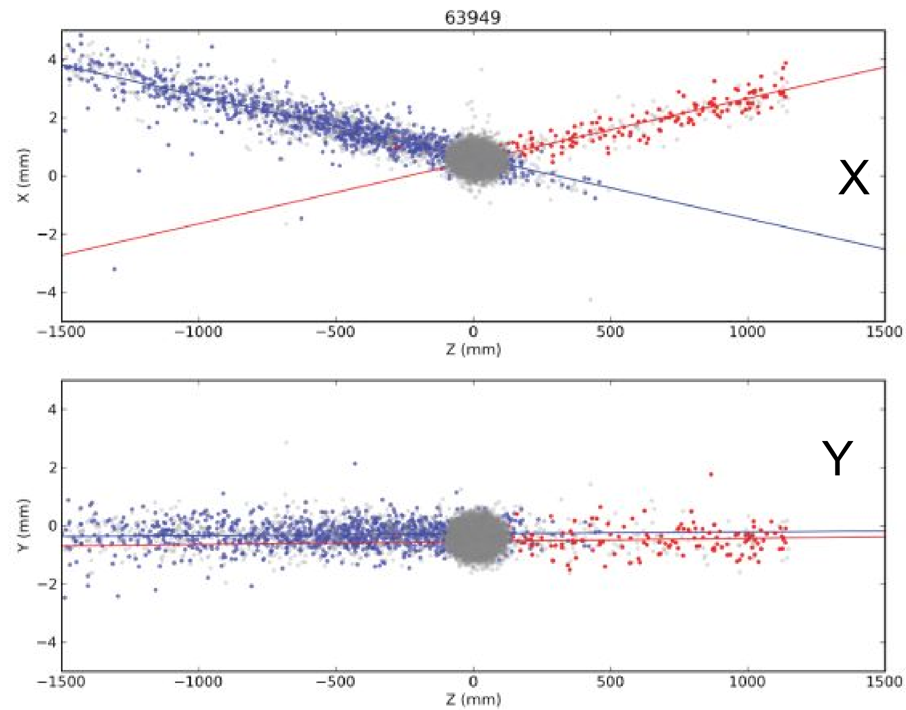
VELO 15mm from nominal closed position



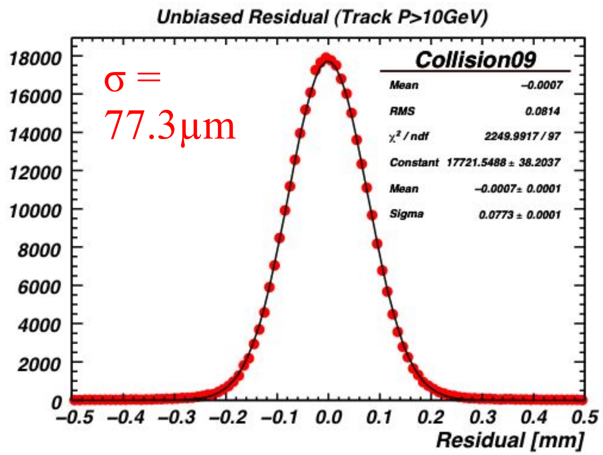
Vertex reconstruction of beam-gas and beam-beam

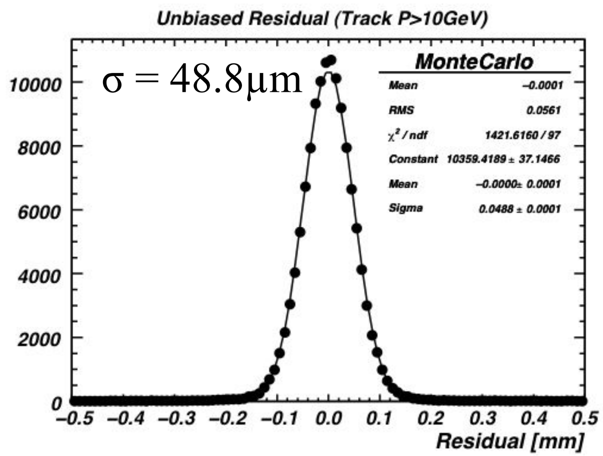


B field in y direction, shifts beam in x direction, no effect in y (annoying side effect, center of mass System and laboratory frame is not identical anymore)



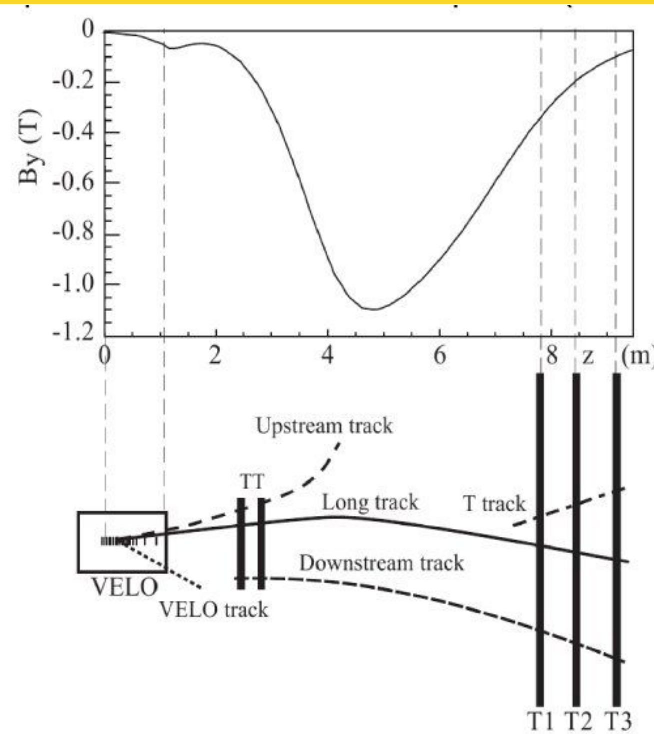
Tracking performance: Trigger Tracker (TT)





Unbiased residuals broader than MC; mainly due to remaining misalignment?

Still a lot of work ahead of us ....



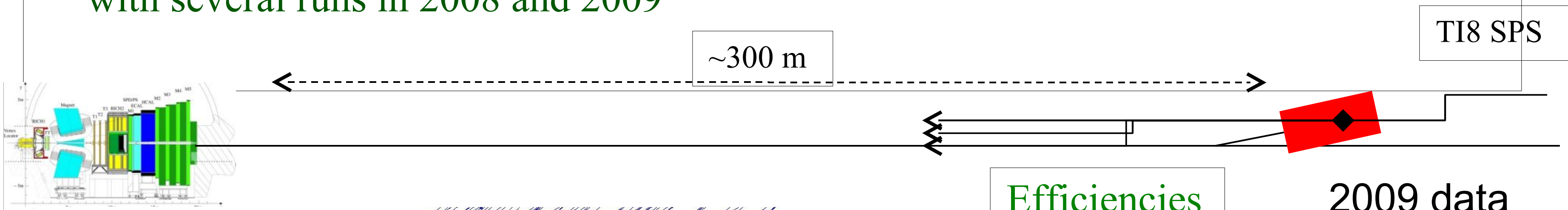
role of TT: improve momentum Resolution via add. Measurement in B field

Use T stations + TT to reconstruct decay products of very longlived Particles “downstream tracks”
Significant lower quality without velo info

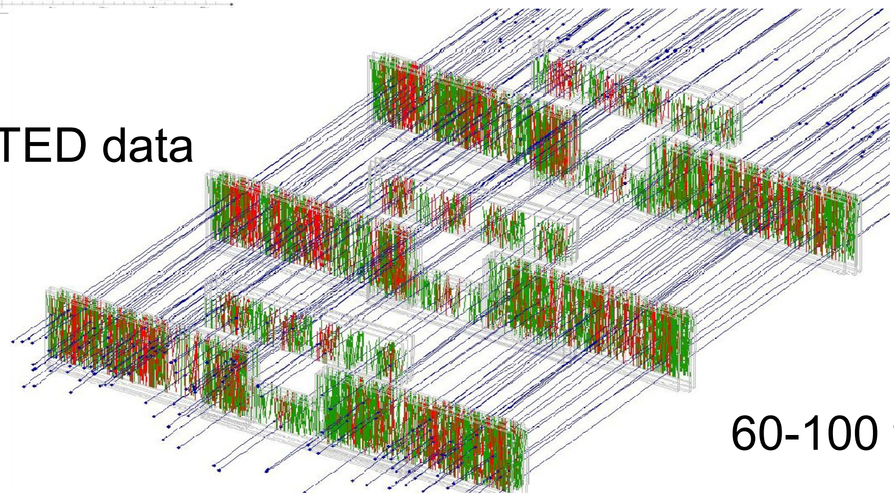
With open velo downstream tracks become very important!

Tracking performance: Inner Tracker (IT)

- 2009 data: VELO open; poor overlap between VELO and IT acceptance
- TED data: VELO closed; large multiplicity, ~2/cm2 useful for small precise detectors with several runs in 2008 and 2009



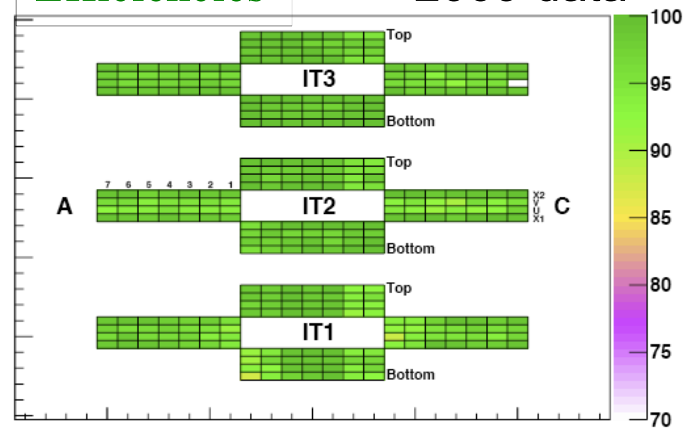
TED data

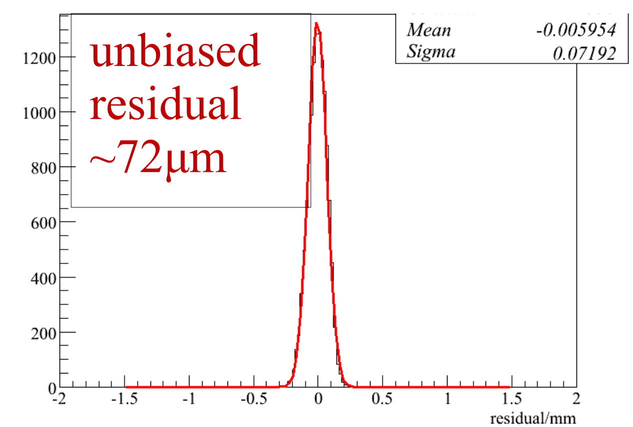


60-100 tracks

Efficiencies

2009 data



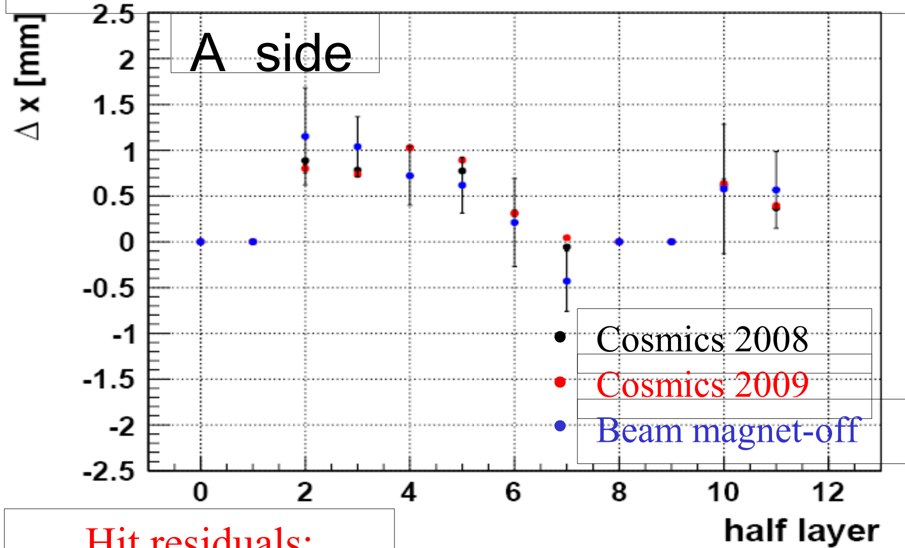


- 99.5 % of detector channels working
- Efficiencies O(98%)
- Alignment to15µm from TED data
- Residuals from 2009 data in agreement with expectations (~60 µm), but room for improvement

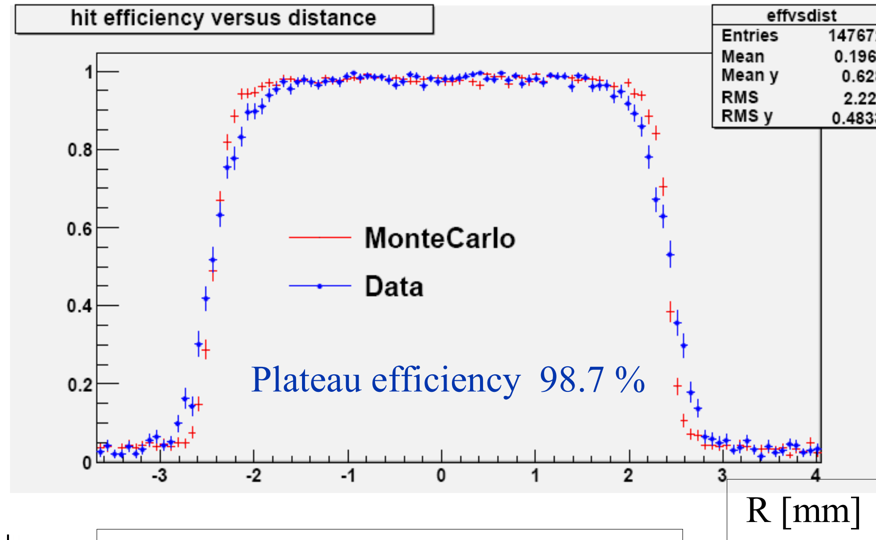
Tracking performance: Outer Tracker (OT)

- 99.3 % of channels operational

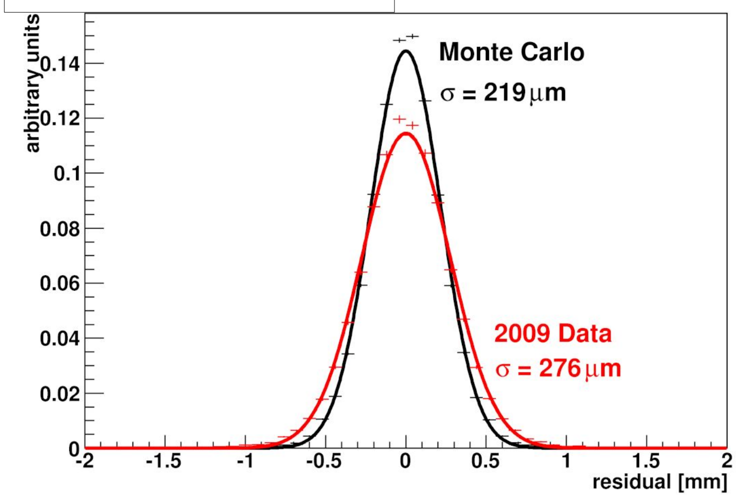
Alignment: Comparison between offsets obtained with cosmics and with magnet-off collision data 2009

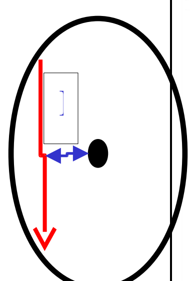


Cell efficiency profile:
Efficiency vs. distance in mono layer plane

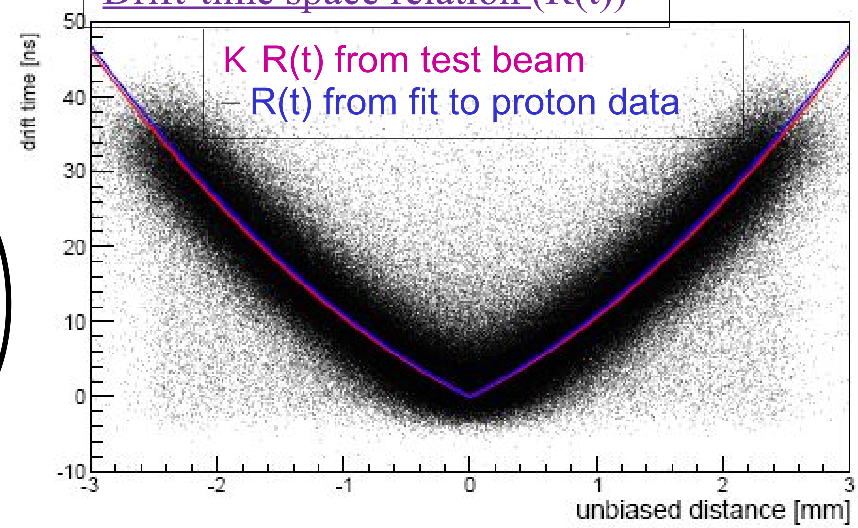


Hit residuals:



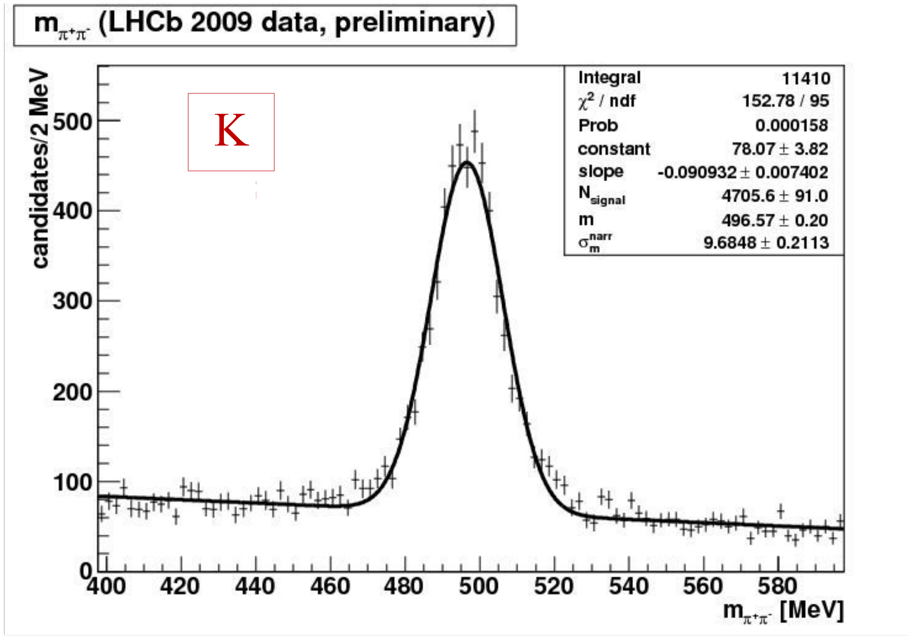


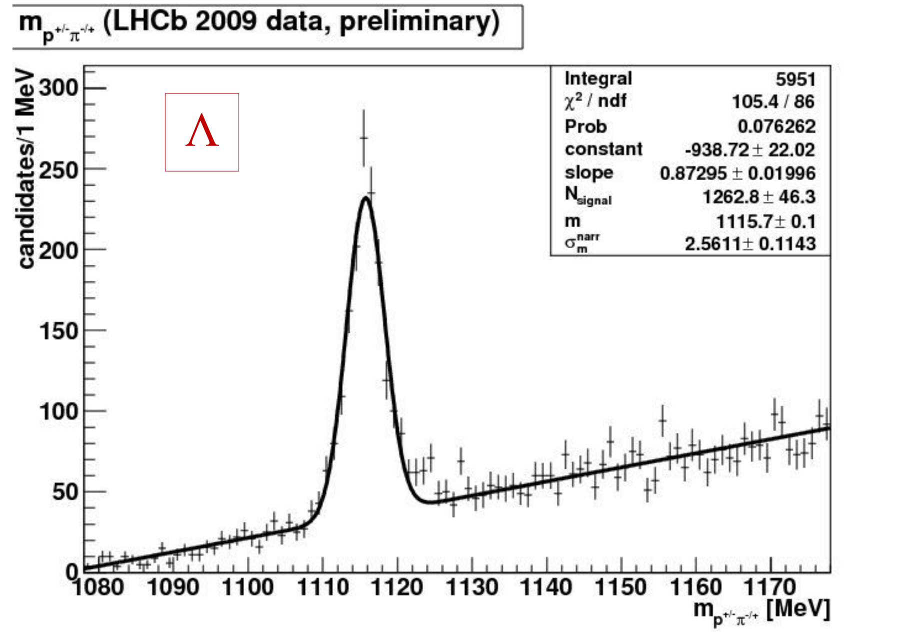
Drift-time space relation (R(t))



Reconstructed Ks and Λ masses

Tracking without VELO





m = (496.6 ± 0.2stat.) MeV/c2

σ = (9.7 ± 0.2stat) MeV/c2
(MC: 6.5 +/- 0.5 MeV/c2)

PDG: 497.61(2) MeV/c2

m = (1115.7 ± 0.1stat.) MeV/c2

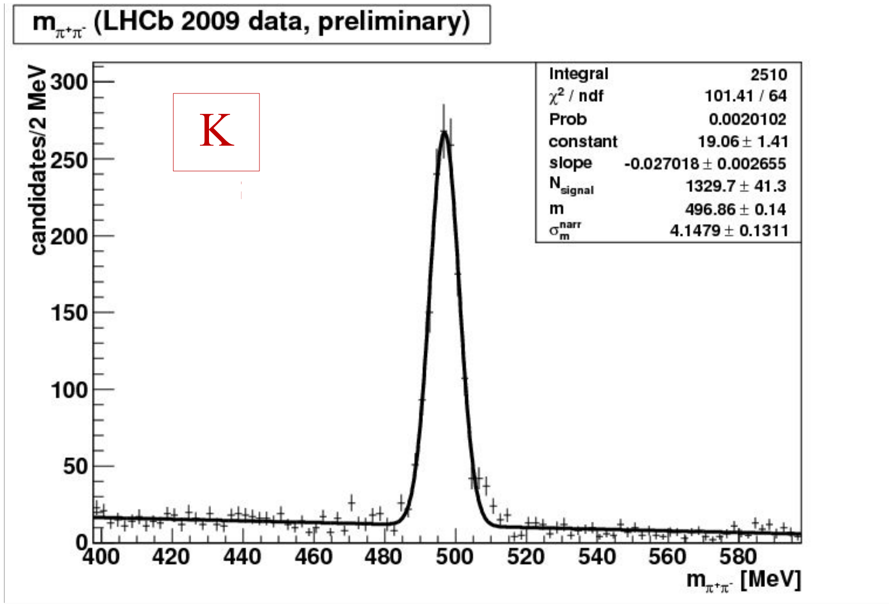
σ = (2.6 ± 0.1stat) MeV/c2

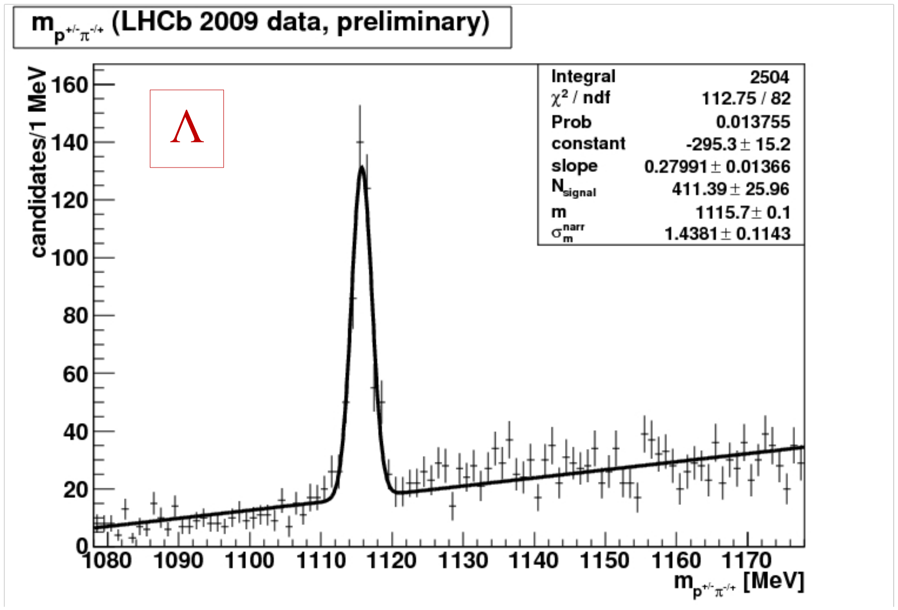
PDG: 1115.683(6) MeV/c2

Masses consistent with PDG, no major problem with the B field

Reconstructed Ks and Λ masses

Using full tracking power, including VELO resolutions improve by ~ factor 2





m = (496.9 ± 0.2stat.) MeV/c2

σ = (4.1 ± 0.1stat) MeV/c2

MC: (3.6 ± 0.2stat) MeV/c2

PDG: 497.61(2) MeV/c2

m = (1115.7 ± 0.1stat.) /MeVc2

σ = (1.4 ± 0.1stat) MeV/c2

MC: (1.2 ± 0.2stat) MeV/c2

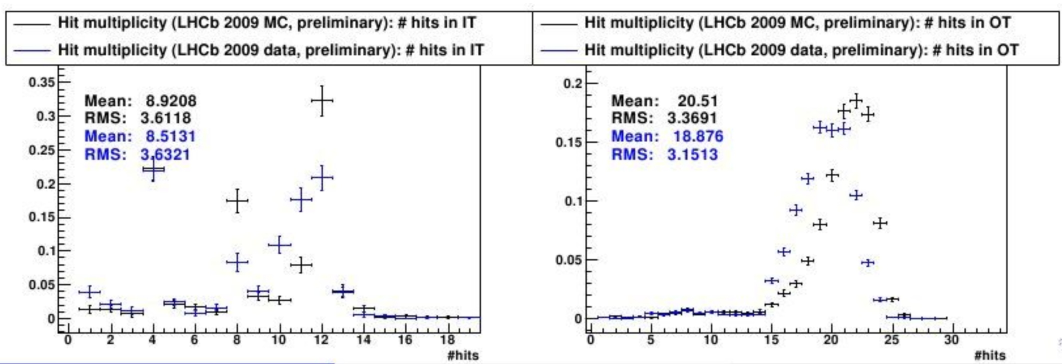
PDG: 1115.683(6) MeV/c2

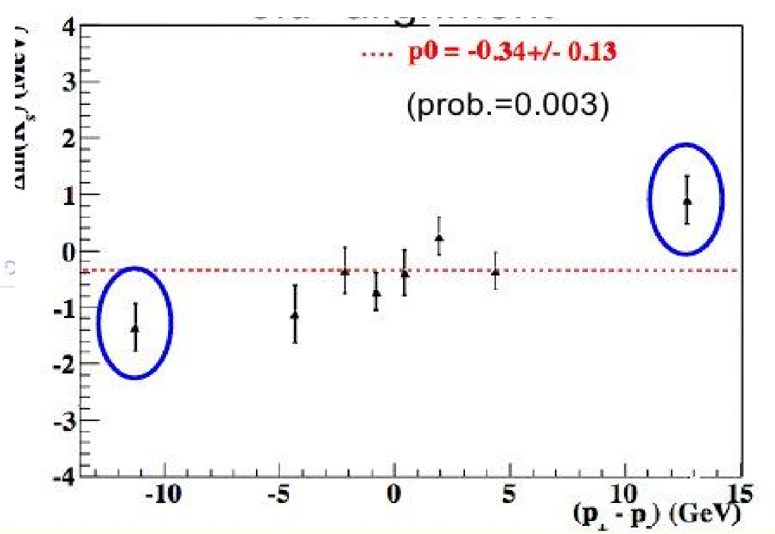
1 MeV shift observed: multiple scattering (dE/dx), b field, ...

Why do we not see similar resolution in data and Monte Carlo?

- fast however “wrong” answer: remaining misalignments
  (hit uncertainties have huge impact on purity of pattern reco and
  vertex resolution and chi2 of the track,
  however not that much on momentum resolution)

- different number of hits on tracks in data and MC; completely given by misalignment
  pure detector efficiencies identical in data and MC





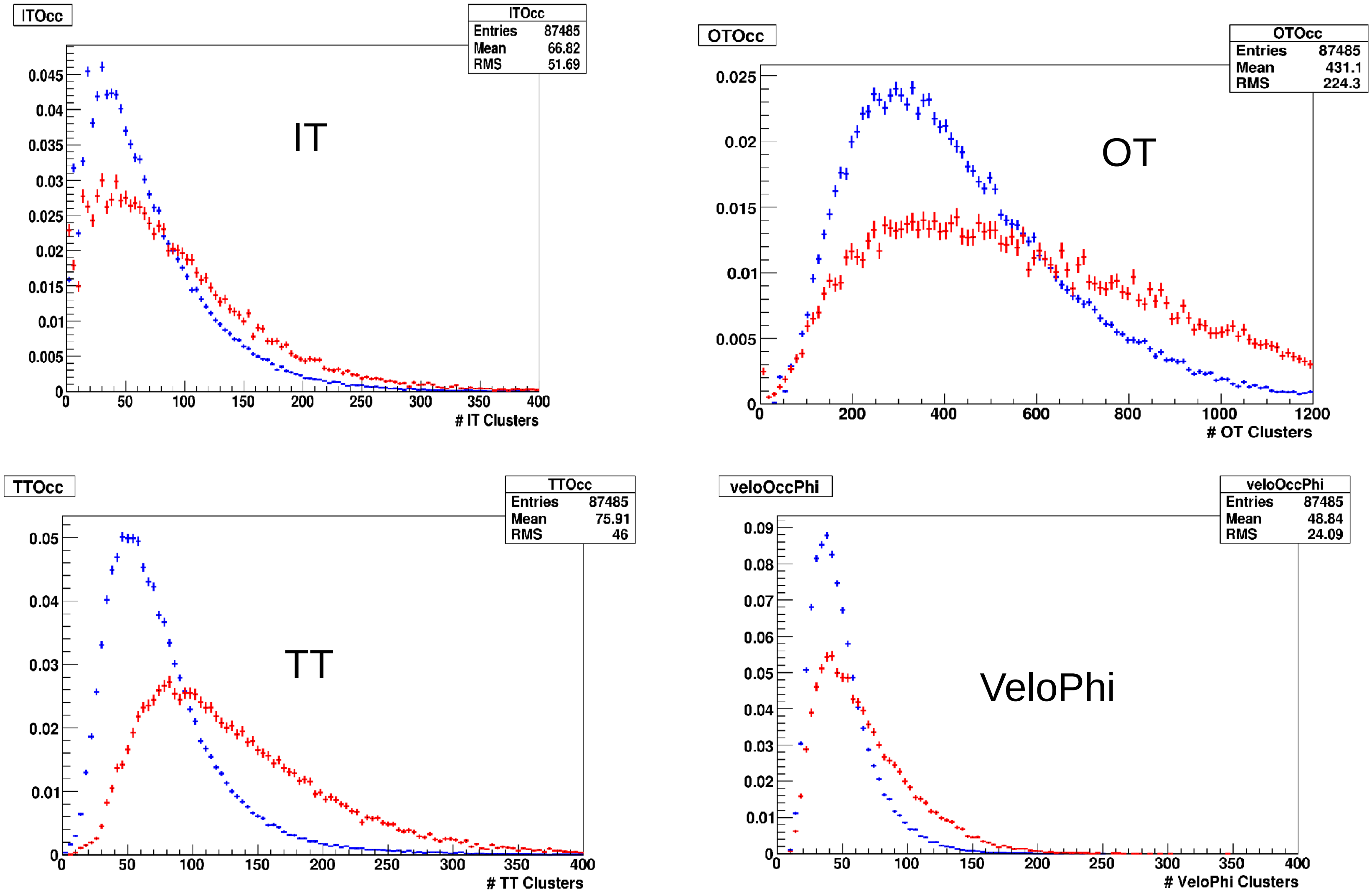
- next candidate B field calibration

- expect many small effects here and there ....

It will take a while before we reach similar good resolution in data and MC

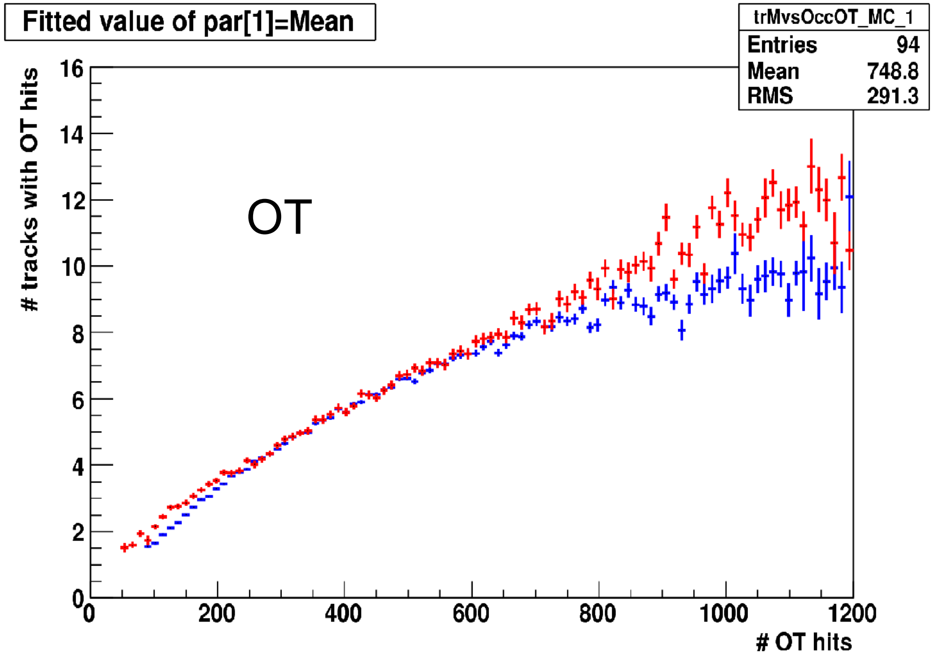
Occupancie - Puzzle

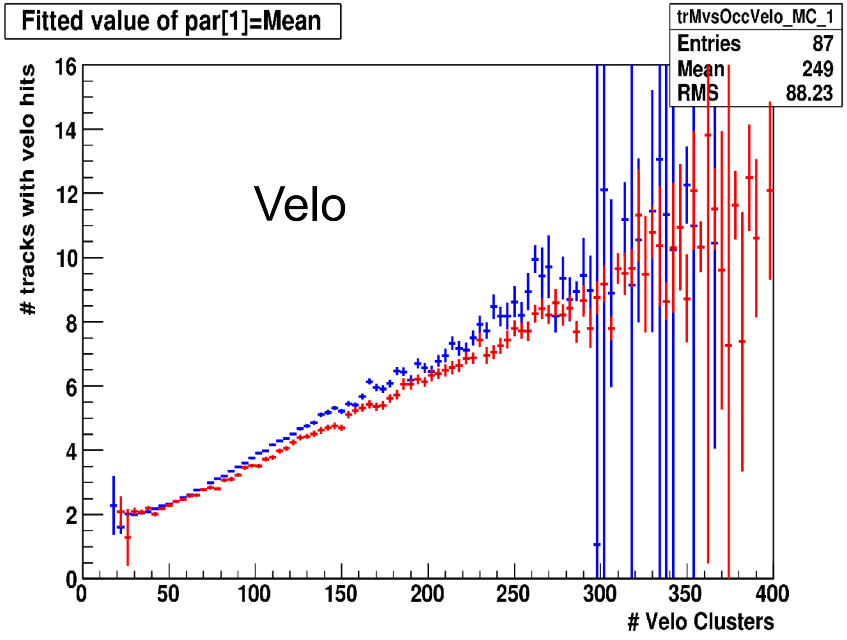
Blue: MC
Rec: data



Track versus Hit Multiplicity

Blue: MC
Rec: data





- additional hits are correlated to higher track rate → no noise
- additional tracks do come from primary vertex and not from secondaries
  (not seen in these plots)

Shapes for forward triggered events

Velo + T

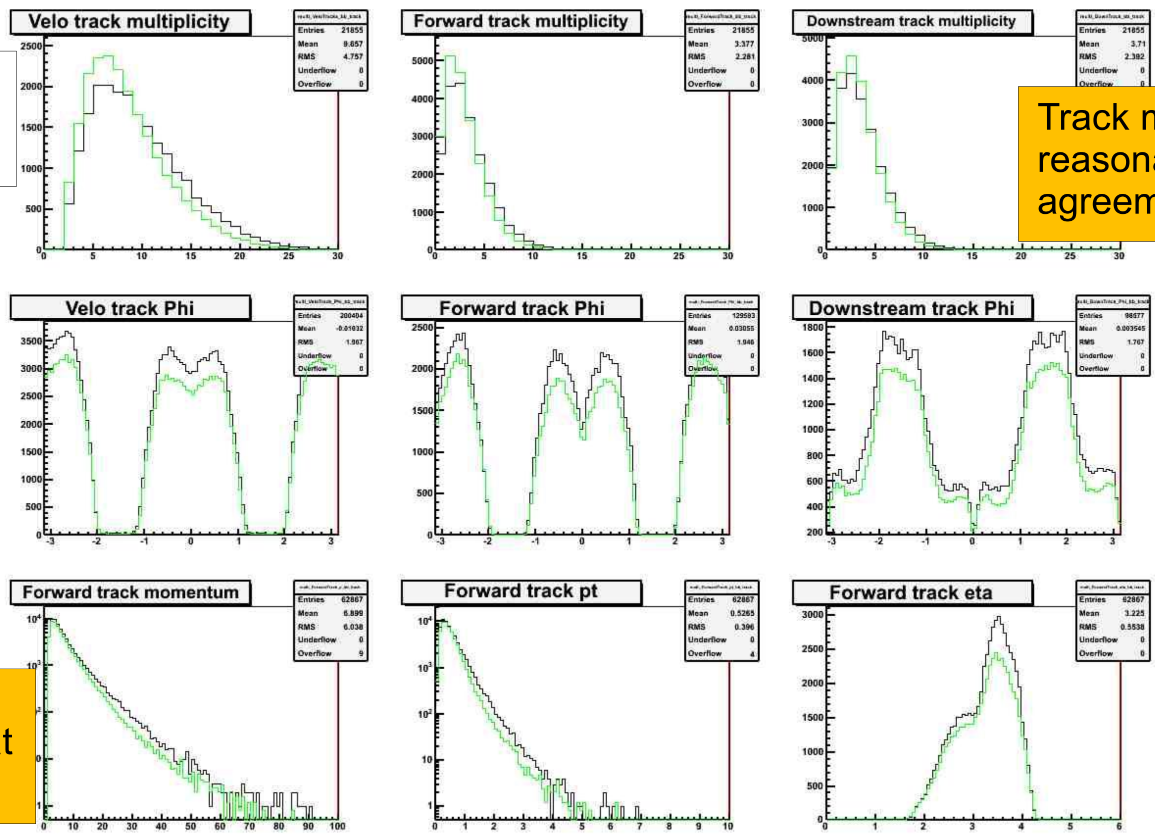
TT + T

Tracks in Velo

Long tracks

Tracks without Velo

Black: 2009 data
Green: MC



Track multiplicites: reasonable agreement with MC

Space distributions: shapes agree well with MC

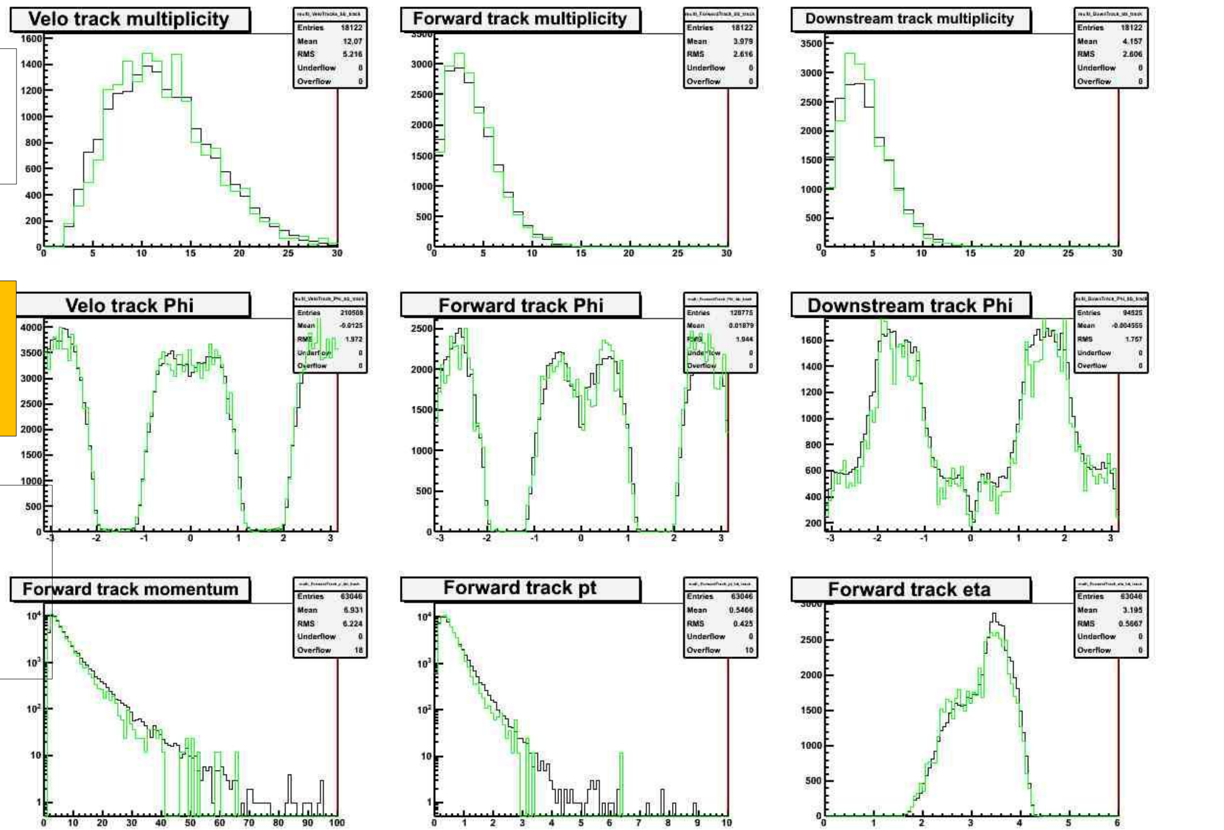
~20% more Tracks in data In all tracking detectors

Momentum distributions: Some excess at in data at larger pt

Shapes for backward triggered events

Tracks in Velo | Long tracks | Tracks without Velo

Black: 2009 data
Green: MC

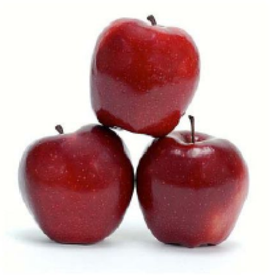


For backward triggered events, very good agreement with MC.

Need to understand possible trigger biases.

Better agreement for backward triggered events

- Do we really compare apples



and apples

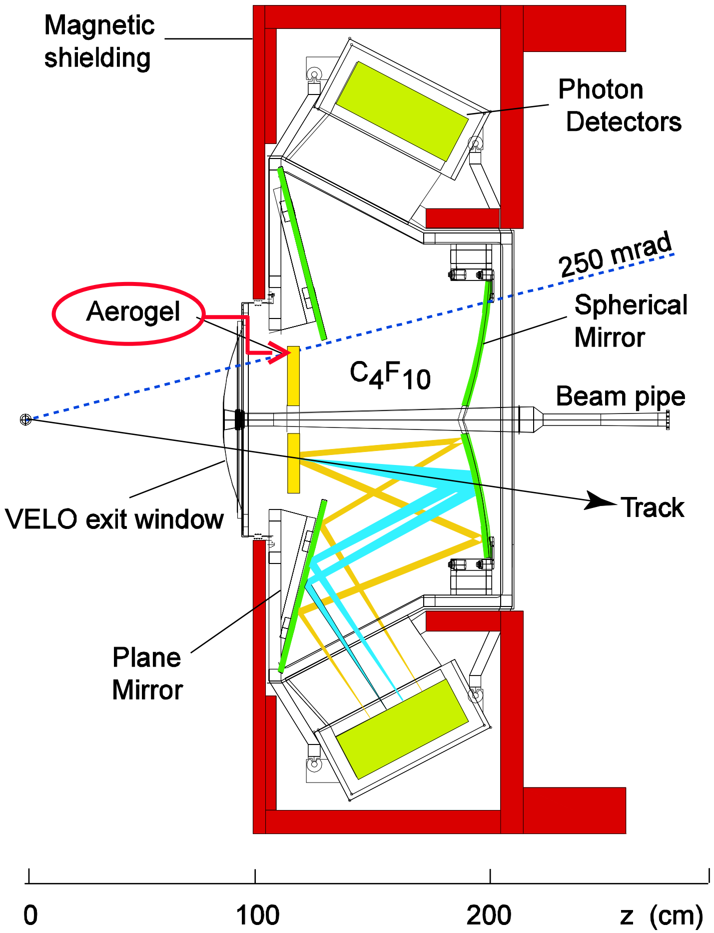
?

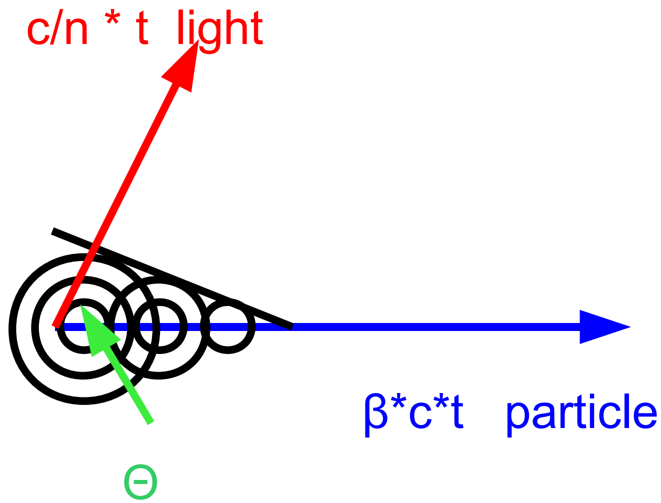
- Is there any trigger bias (not properly simulated trigger?)

- Do we believe our Monte Carlo (Pythia) tuning, many switches, one might easily be wrong (one fix already reduced the problem to now 25%)

- DO NOT BLINDLY TAKE ANY CORRECTION FROM MONTE CARLO, First physics analysis need to adress all of this!

RICH I performance





$$\cos(\theta) = \frac{1}{n\beta}$$

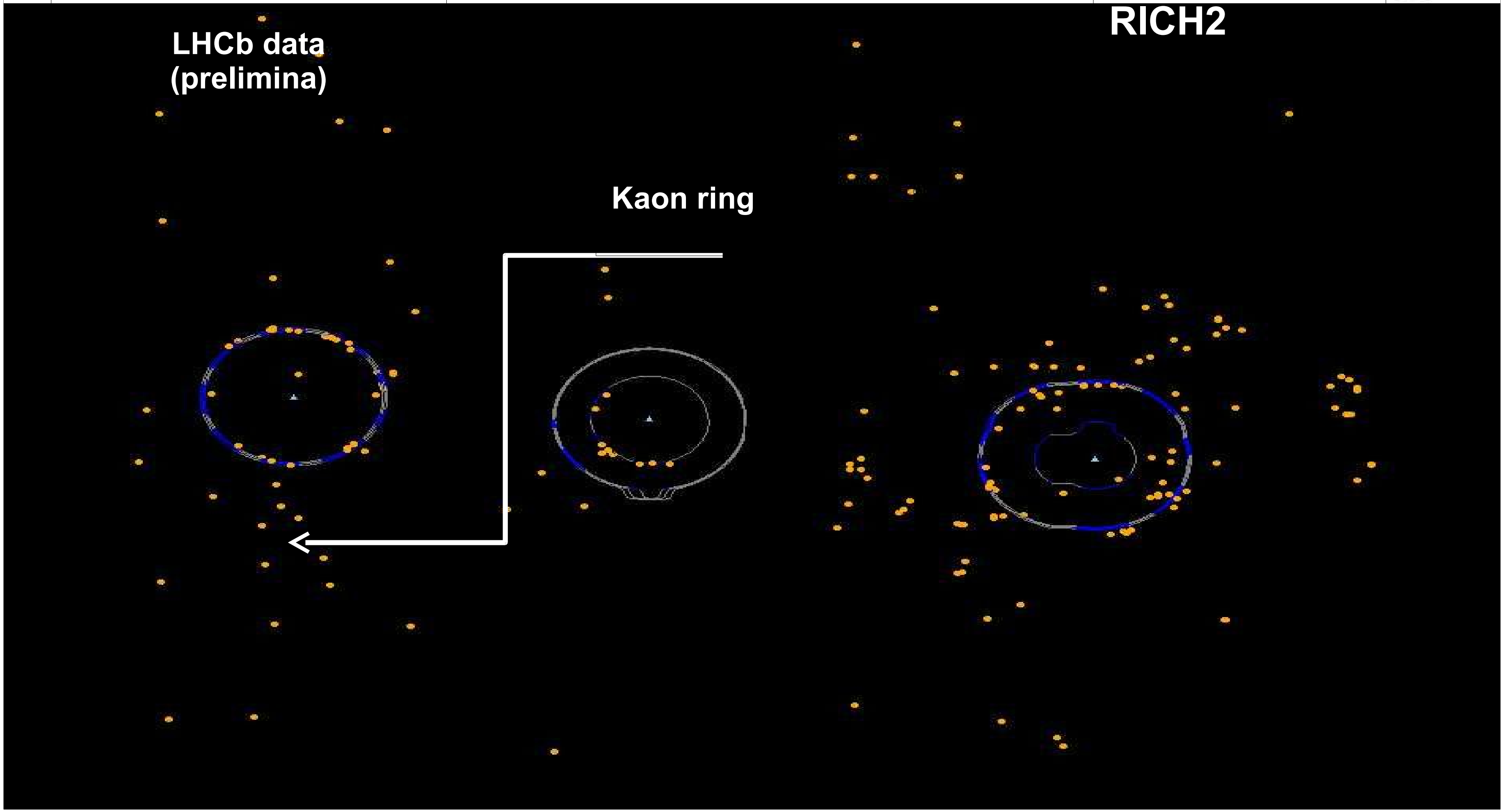
Heavier particle have smaller beta, thus larger Cos(Θ), thus smaller opening angle, smaller Cherenkov rings

Slower particles have smaller rings as well.

Limit of max Cherenkov angle for beta =1

Tracks cross aerogel and gas, we measure two cones (different n values) per track.

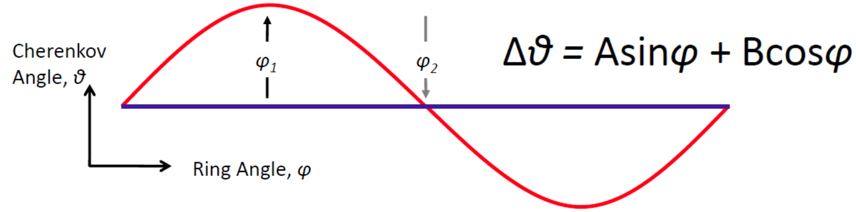
RICH2 HPD Panels with Pixels and CK Rings

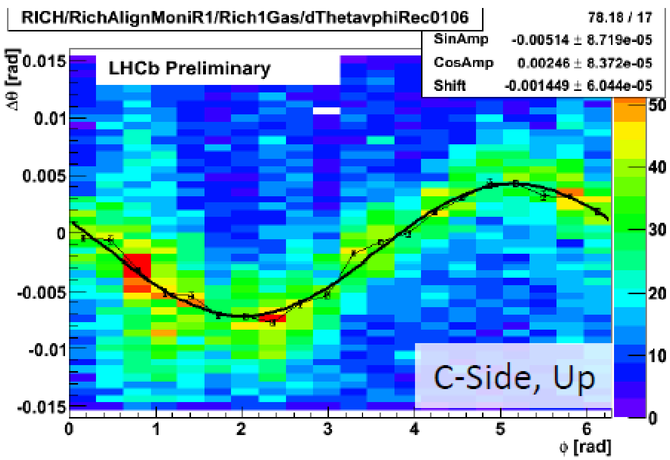


Test tracks with each mass hypothesis, smaller ring: kaon, larger pion

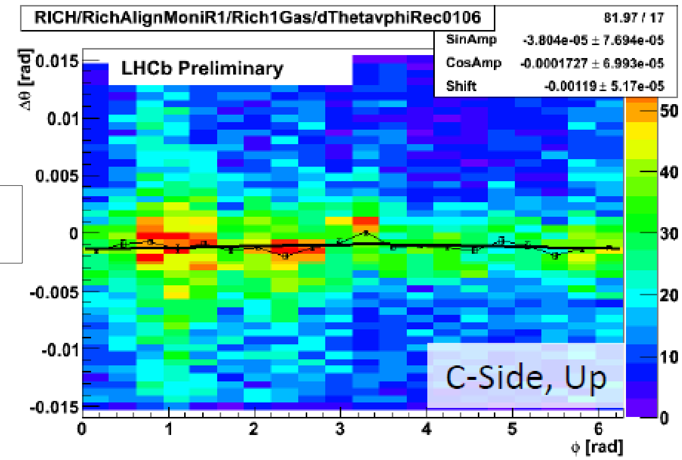
RICH performance

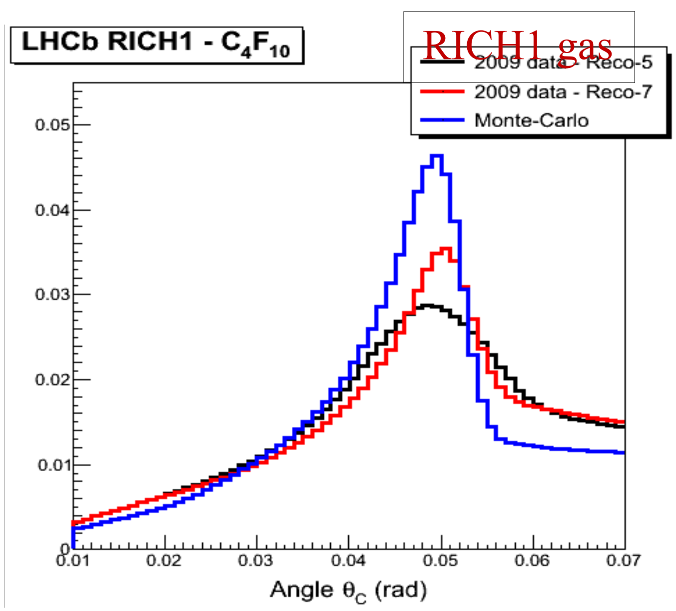
- improvement after first alignment relative to tracking





RICH 1 gas





Rich1 aerogel still more work to do,
Same detector system however light sees
Different part of mirrors.

RICH1 gas

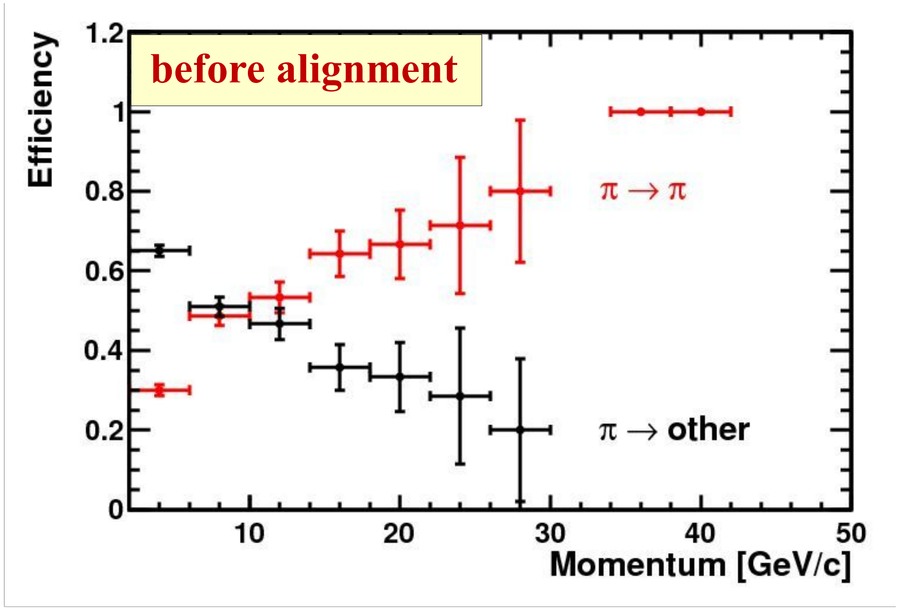
- Monte Carlo σ~1.6mrad
- After alignment σ~2.3mard
- Before alignment σ~8.4mrad

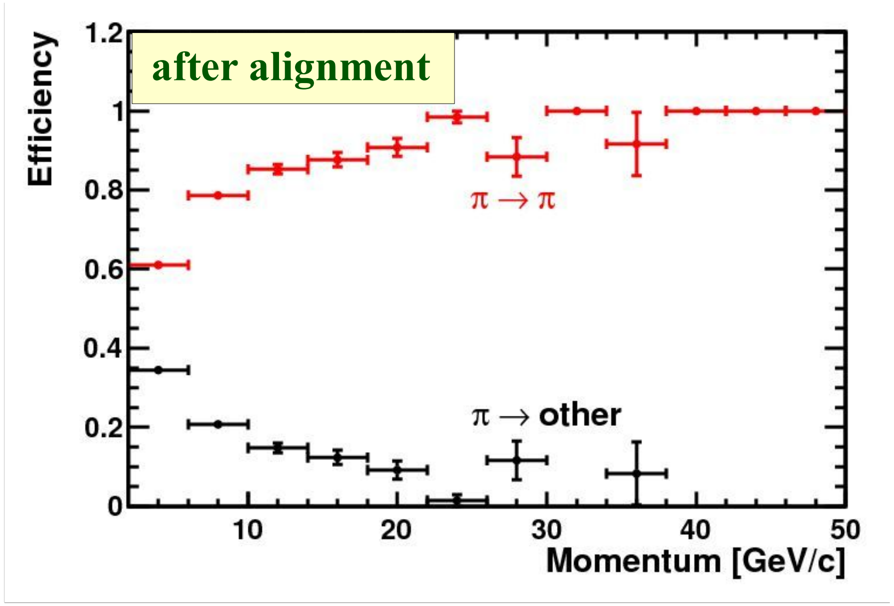
RICH2

Monte Carlo σ~0.7mrad
After alignment σ~0.8mrad
Before alignment σ~1.1mrad

RICH performance

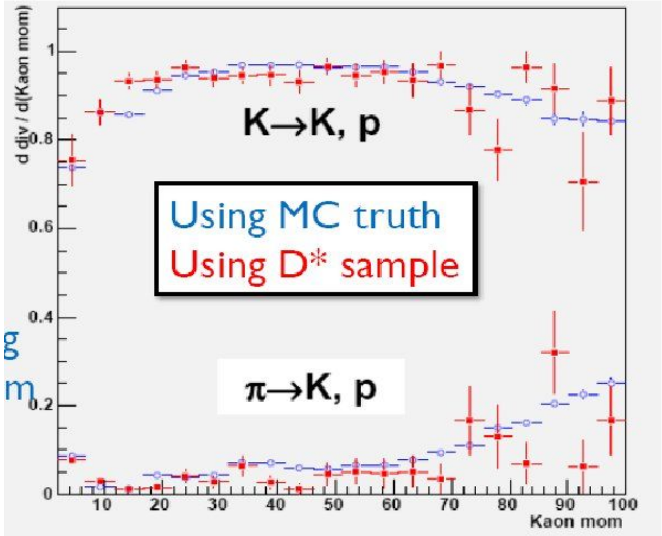
Use K_s daughters as clean pion sample



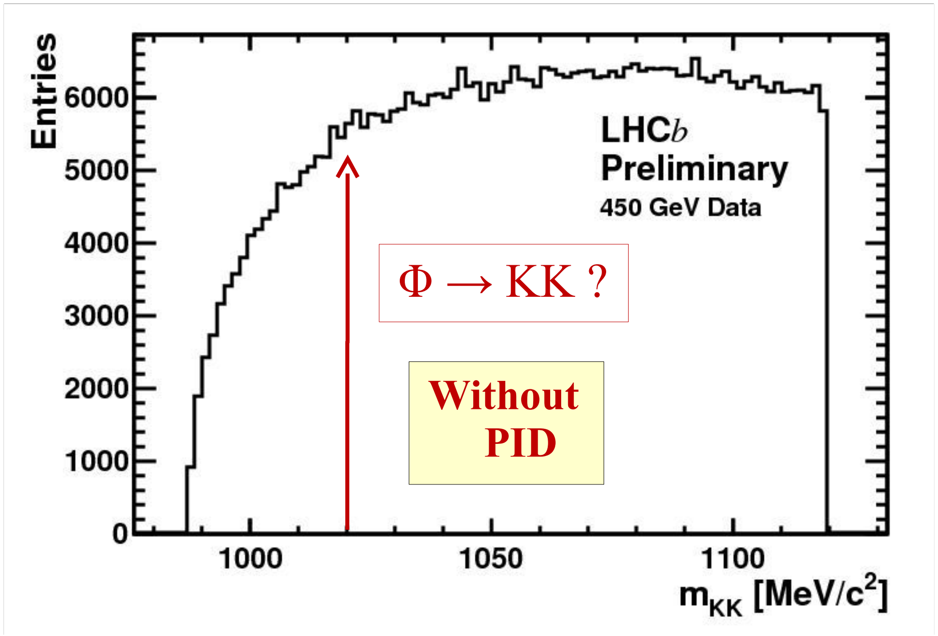


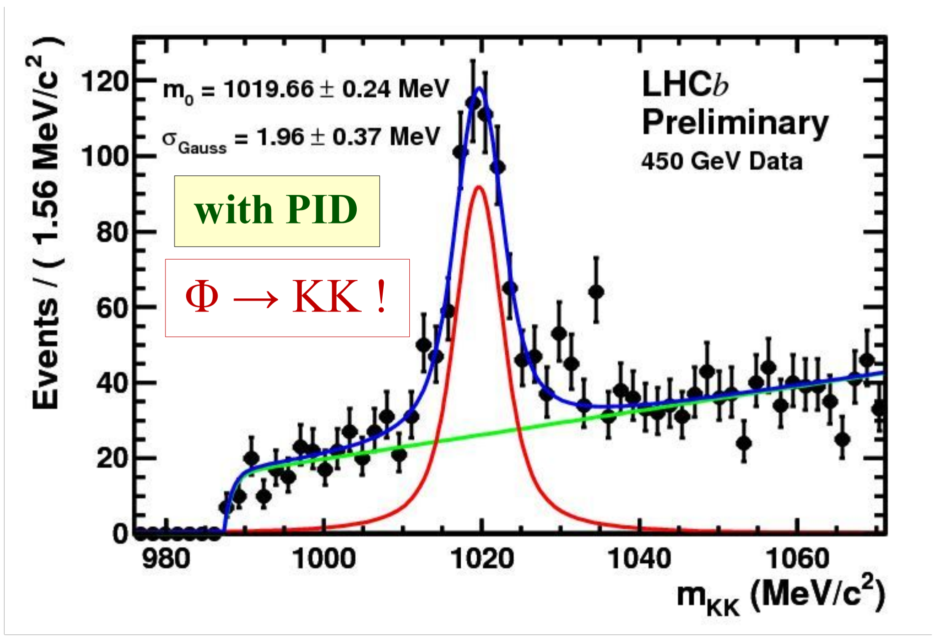
Low momenta, RICH rings are very small, hard to distinguish kaon and pion rings

Mis-ID rate about a factor of two larger at similar efficiency, still room for improvements



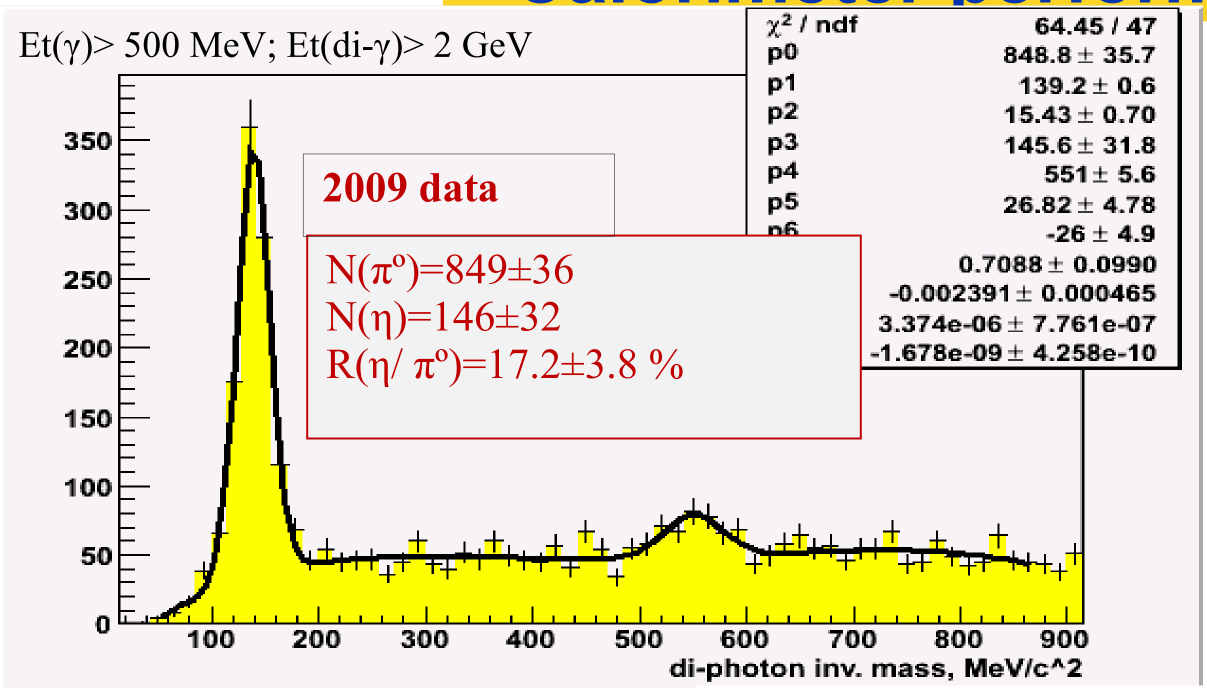
RICH performance

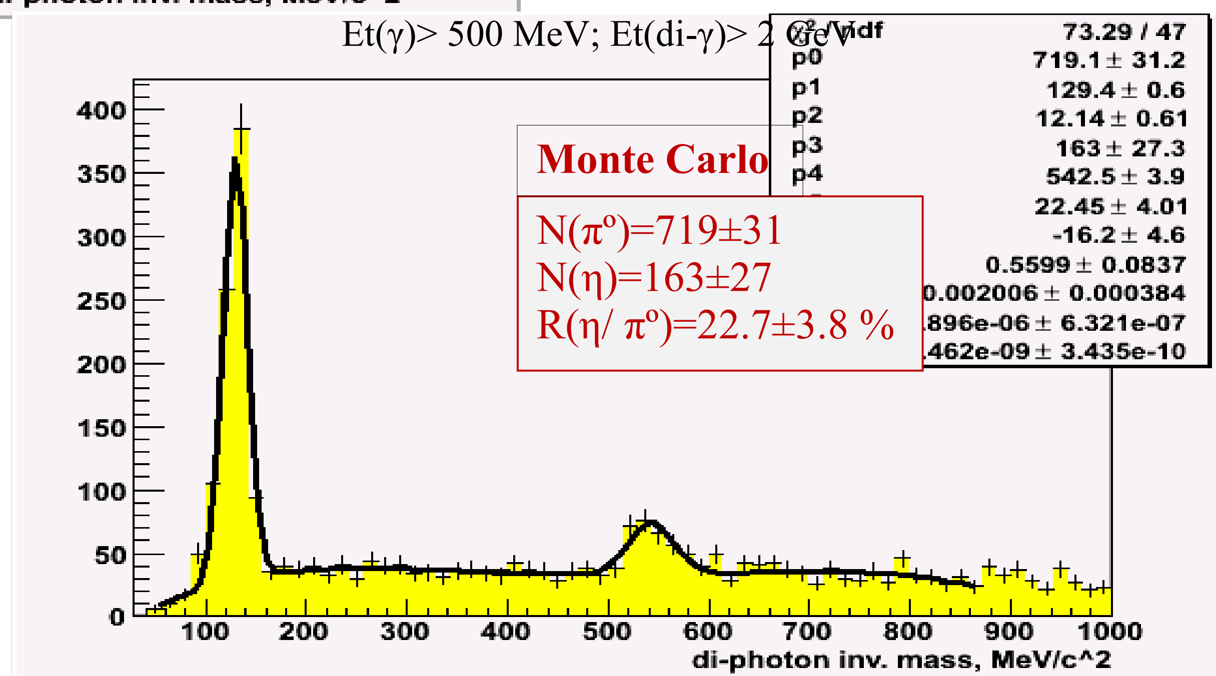




Apply pion calibration to kaon ID (no clean kaons sample available up to now)

Calorimeter performance



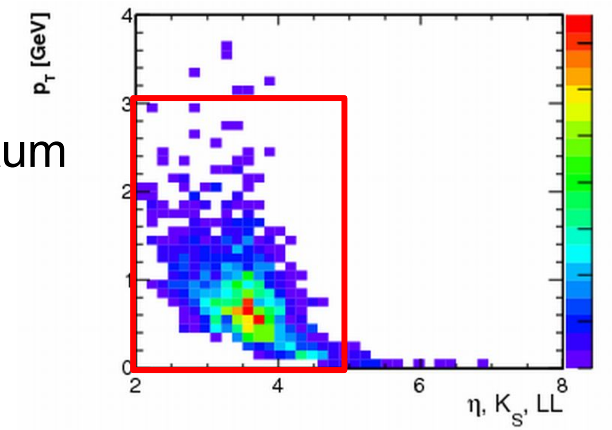


Potential Physics with 2009 data

Explore unique η range [2,5]

Measure:

- Ks production rate in bins of eta and transverse momentum
- Lambda/Ks rated particles
- Lambda/Anti-Lambda rates
- track multiplicity
- jet structure



TEST OUR UNDERSTANDING OF THE DETECTOR, ESTABLISH ANALYSIS PROCEDURE

Take from MC ?
- what is the effect of misalignment & resolution on Reconstruction efficiency
- what about different occupancies in data & MC
- can we rely on fraction of prompt V0 in MC
- can we rely on fraction of diffractive events in MC

Example:

$$dN/d\eta dp_T = N * \epsilon_{PV\ \ reco} * \epsilon_{V0\ \ reco|PV} * \epsilon_{trigger|reco}$$

Get relatively easily from data
(can we trust beam gas subsraction?)

can be measure on data
rely on independet triggers

Cross section analysis

Need luminosity as additional input

Idea for direct luminosity determination:

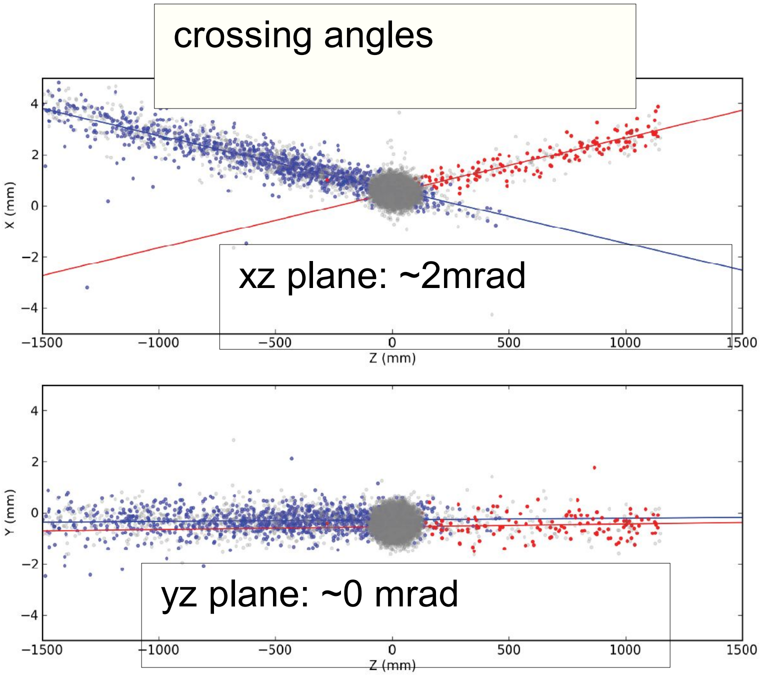
- n = protons/bunch
  (bunch currents needed as input,
  critical point right now, see strong bunch by
  bunch variations)

- f = collision rate, given by ratio
  of empty/filled bunches

- A = effective area, can be calculated
  with known size and position of beam
  this we can measure with the VELO detector

- For 2009 data, expect ~20-30% uncertainty due to beam shape

- In 2010 aim for < 5%



Physics in 2010 & 2011

- The bbar cross-section goes down by factor 2-3 from 14 TeV to 7 TeV

- “With L larger 200 pb^{-1} expect to make significant contribution in all channels of our physics program, with particular exciting potential in:

  - $Bs \rightarrow \mu\mu$

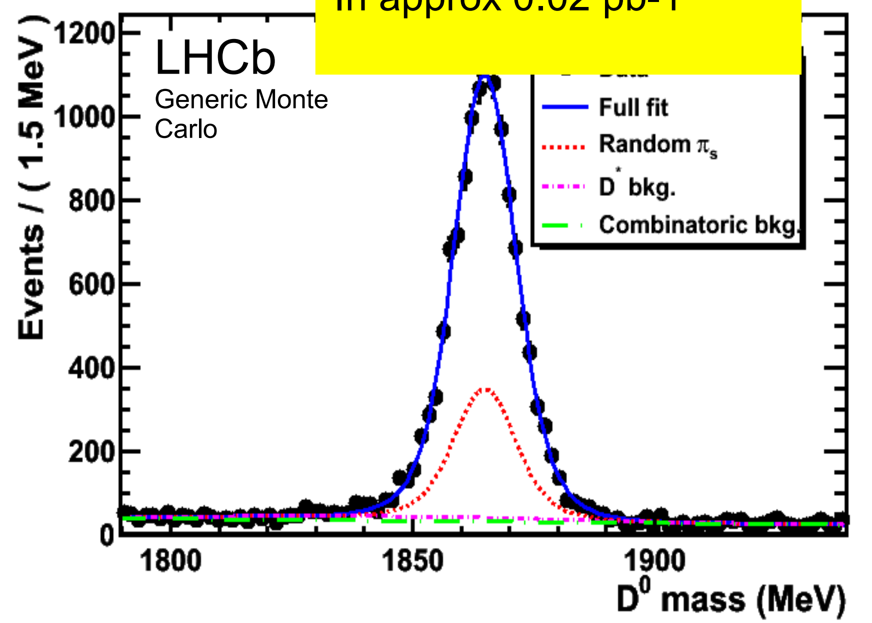
  - $Bs \rightarrow J/\psi\ \Phi$ 2011

  - $Bd \rightarrow K^*\ \mu\mu$

  - charm physics 2010

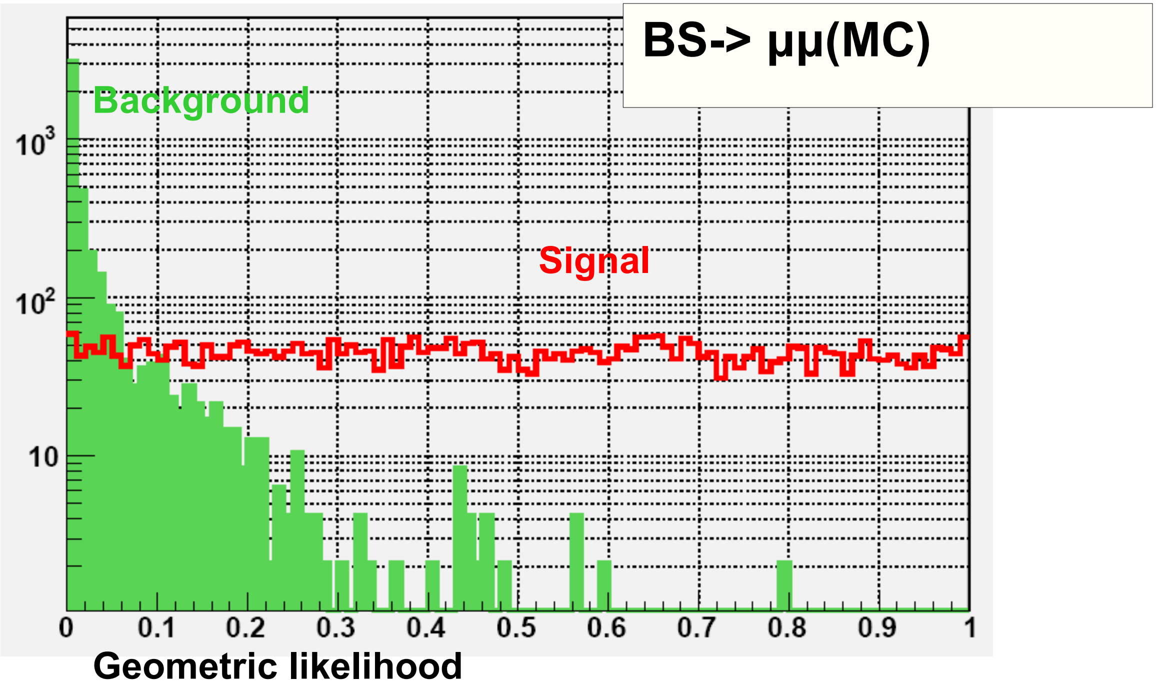
    - excellent probe for B physics analysis
    - triggers are optimized for charm at low lumi
    - about 4 Million $D^* \rightarrow D\ (KK)\pi$ in 100 pb^{-1}
    - potential analysis topics:
      - D mixing
      - CP violation
      - $D \rightarrow \mu\mu$ (rare decay)

D*+ → D0(K- π+)π+
In approx 0.02 pb-1



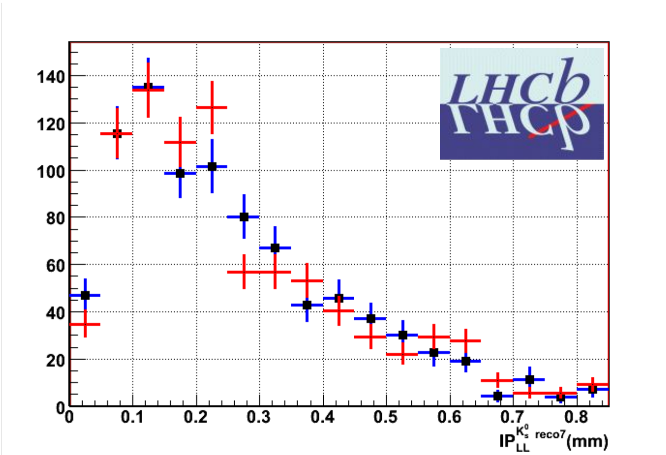
Use 2009 data for preparation of B physics

- search for rare decay Bs → μμ
- largest background from b → μ + b → μ and b → μ + b → c → μ
- use mass resolution, vertex and pointing constraints to reject background (combine all of them in a likelihood)
- We have no Bs right now, use K_s decay to check data-MC agreement for input quantities (crucial as signal description will be taken from MC ...)

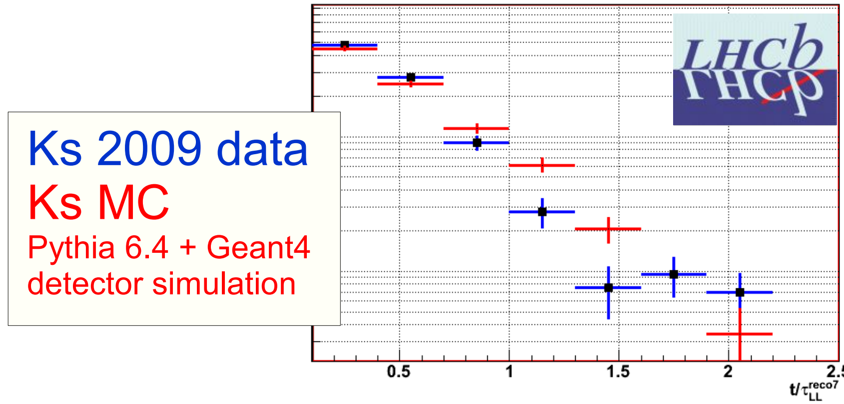


Differences seen here are mainly due to velo misalignment, already reasonable agreement

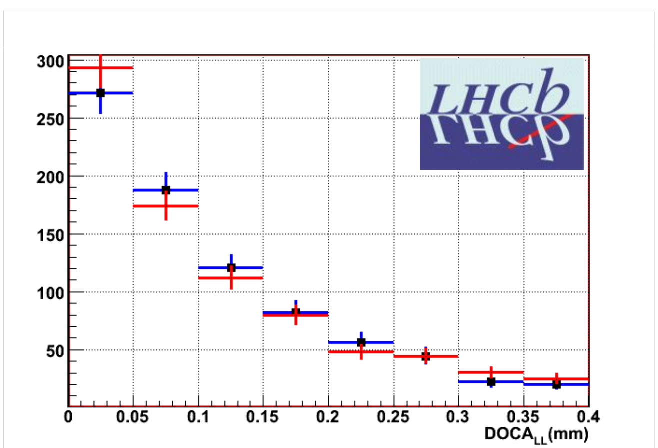
- Impact Parameter of Ks with respect to pp collision point



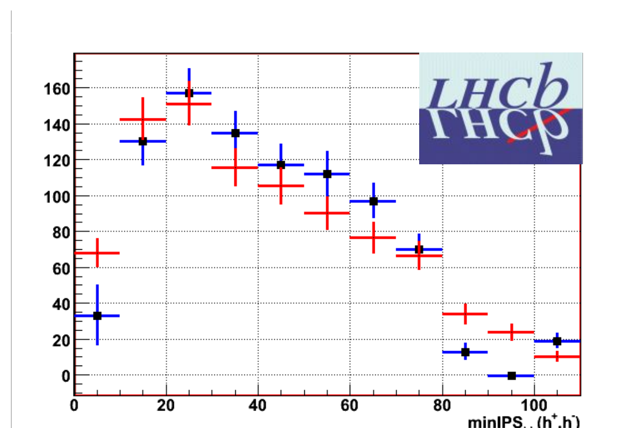
- Lifetime



- Distance of closest approach of daughter tracks

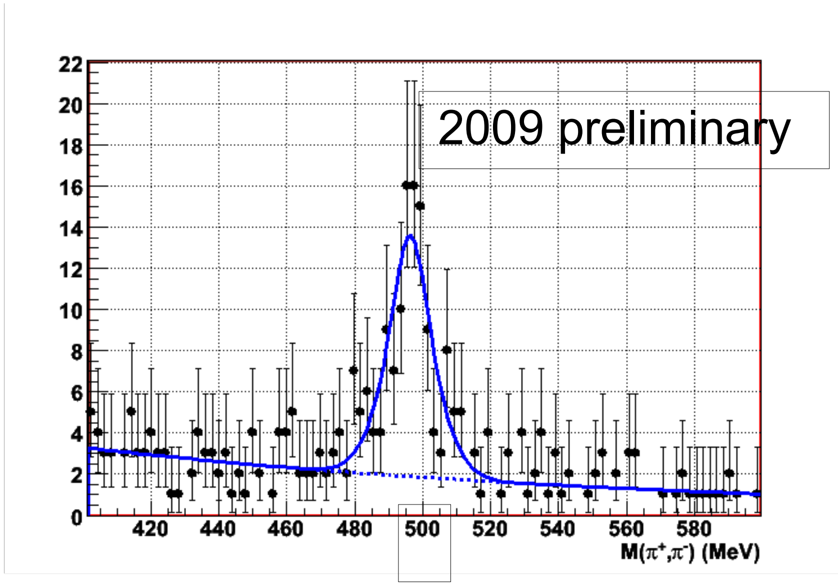


- Minimum Impact parameter significance of pi±



Muon mis-identification

▶ Estimate misidentification probability for pions from Ks decay



Result:
The probability of a pion from Ks to be identified as muon μ is computed to be:

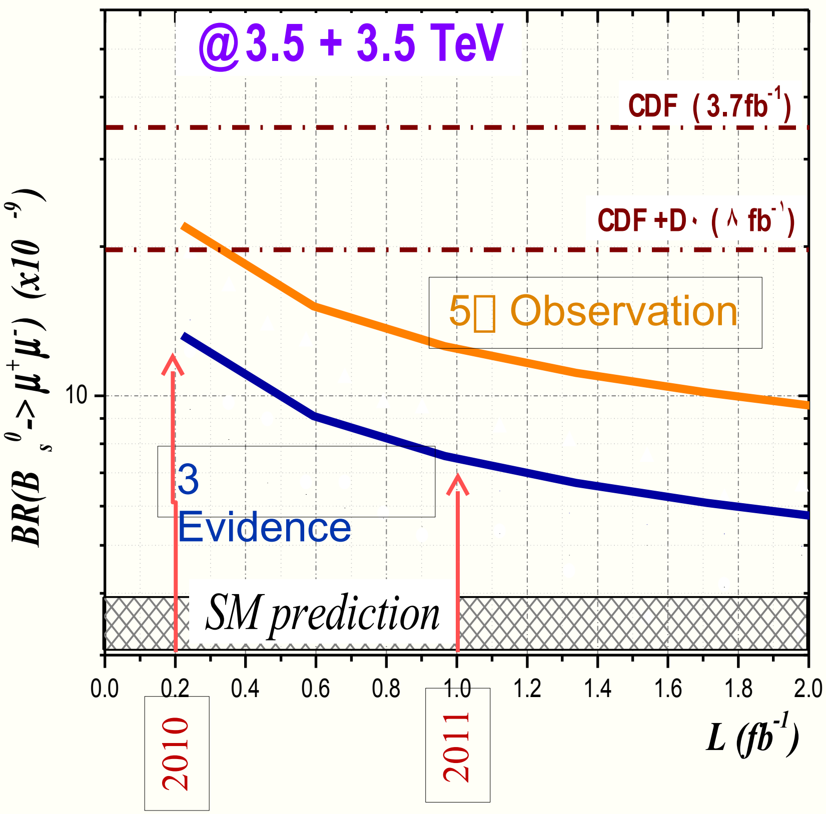
1.6 +/- 0.2 % **(MC: 1.4 +/-0.2 %)**

(mainly decay in flight)

▶ Performances achieved with 2009 data agree with expectations
▶ We are on the right track to come close expected performance for B decays

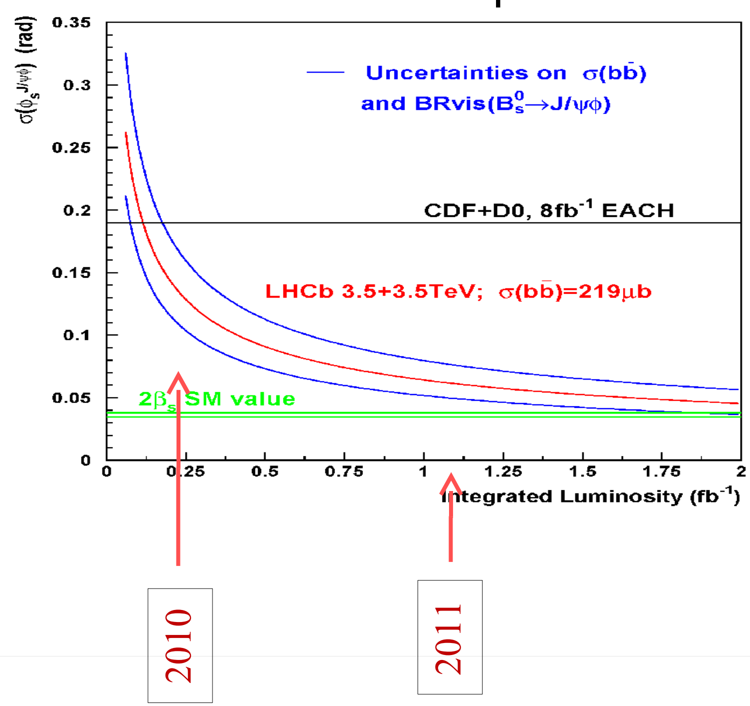
Expected Physics Reach in 2010 and 2011

- Assume ~200 pb-1 in 2010 and ~1 fb-1 in 2011



Sensitive probe for SUSY:
Br ($B^s \to \mu^+\mu^-$) ~ $\tan\beta^6$

bb Cross section lower by a Factor 2-3 compared to 14 TeV



Large phase favoured by D0 and CDF:
Φs [−1.47 ; −0.29] ∪ [−2.85 ; −1.65]
(90% CL range)

Summary

- LHCb had a very good start, no major problem in any detector component
- 2009 data extremely important for calibration and alignment
- First analysis of V0 yields, track multiplicity etc are an excellent training ground
- We will get interesting physics results for many LHCb key analysis with the 2010 & 2011 data.
- It's fun to get hands on “real data”!