Performance of the Tracking System at the LHCb Experiment

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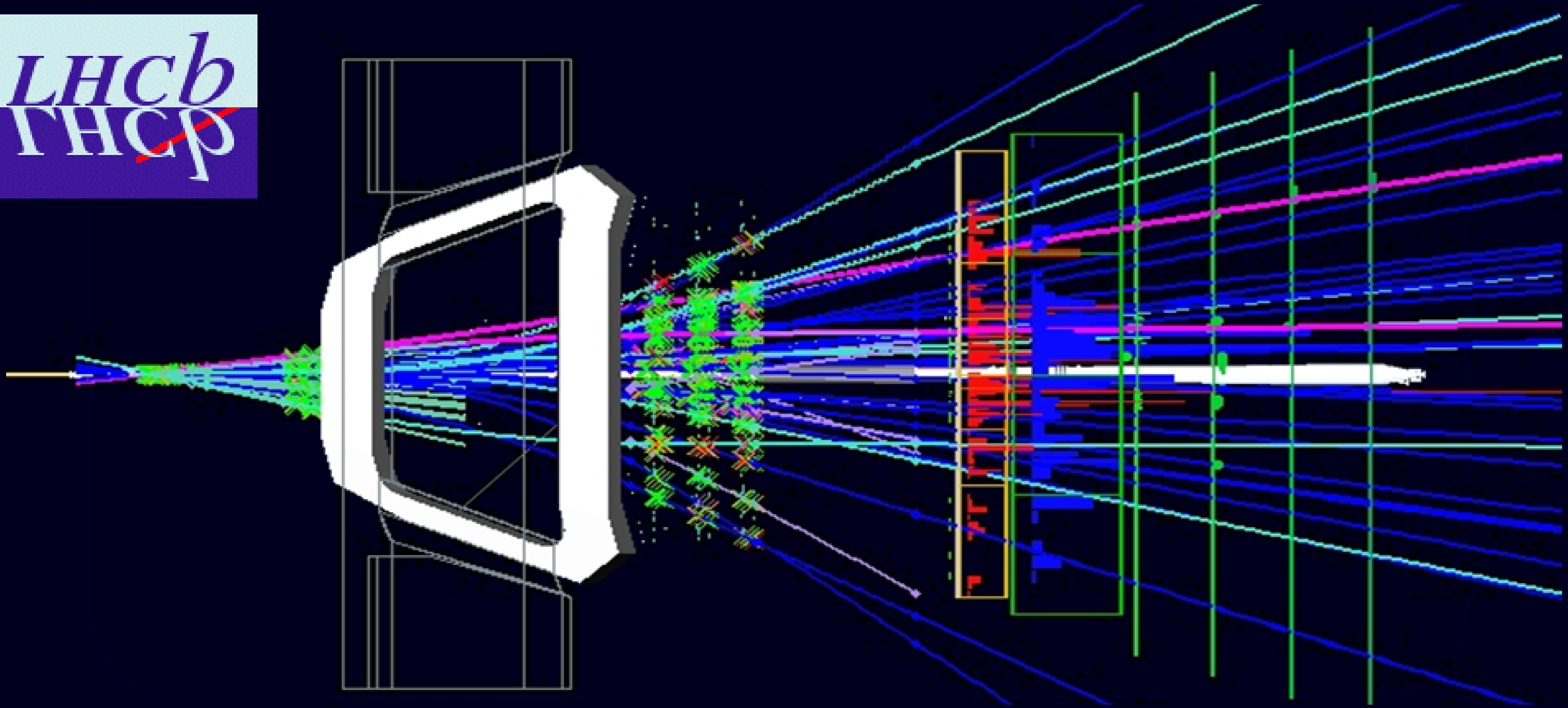
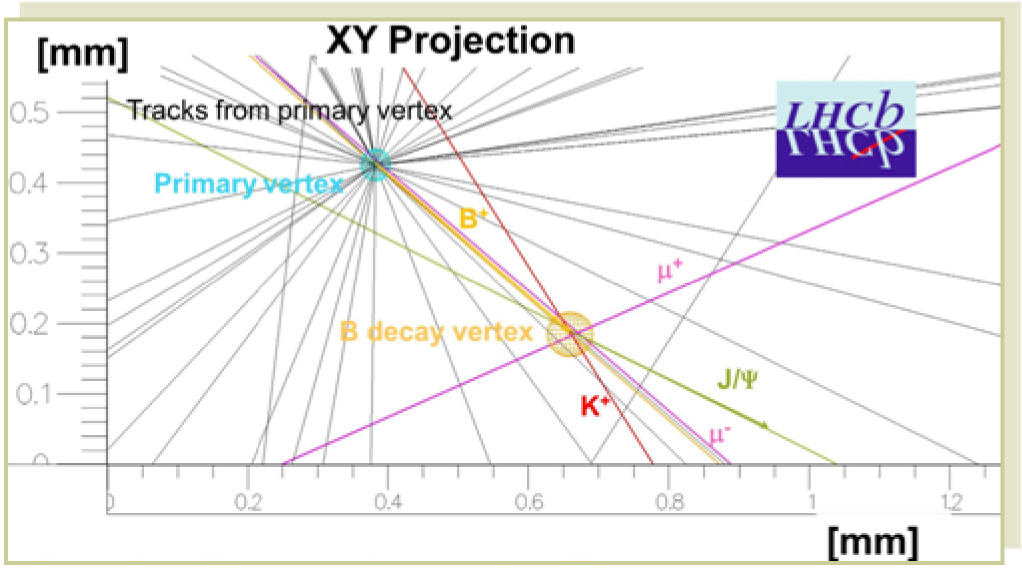
on behalf of the LHCb Collaboration



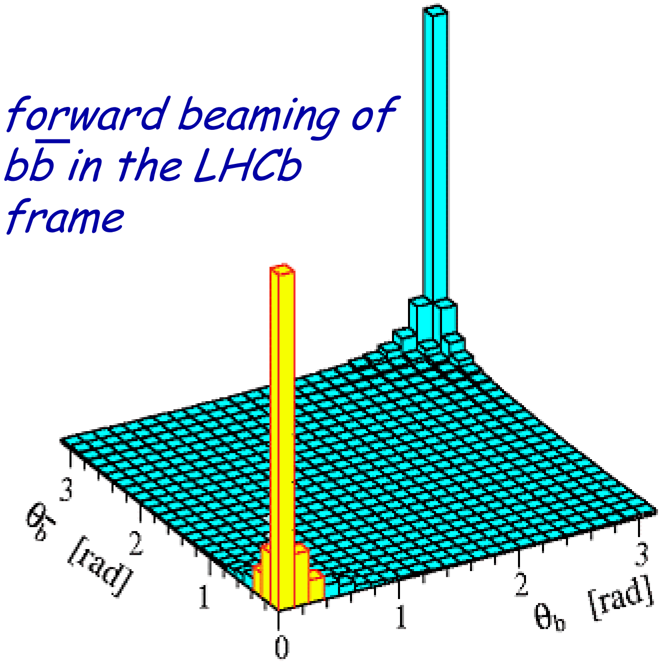
35th International Conference on HEP, Paris, France - July 2010

The LHCb experiment

- LHCb is an experiment dedicated to heavy flavour physics at the LHC.
- Its primary goal to look for indirect evidence of new physics in CP violation and rare decays of beauty and charm hadrons.
- $b\bar{b}$ – pairs produced predominantly close to beam direction
  ⇨Forward spectrometer: $1.9 < \eta < 4.9$
- Nominal luminosity of $2 \cdot 10^{32}$ cm^{-2} s^{-1}
  ⇨ production of 10^{12} $b\bar{b}$-pairs per year



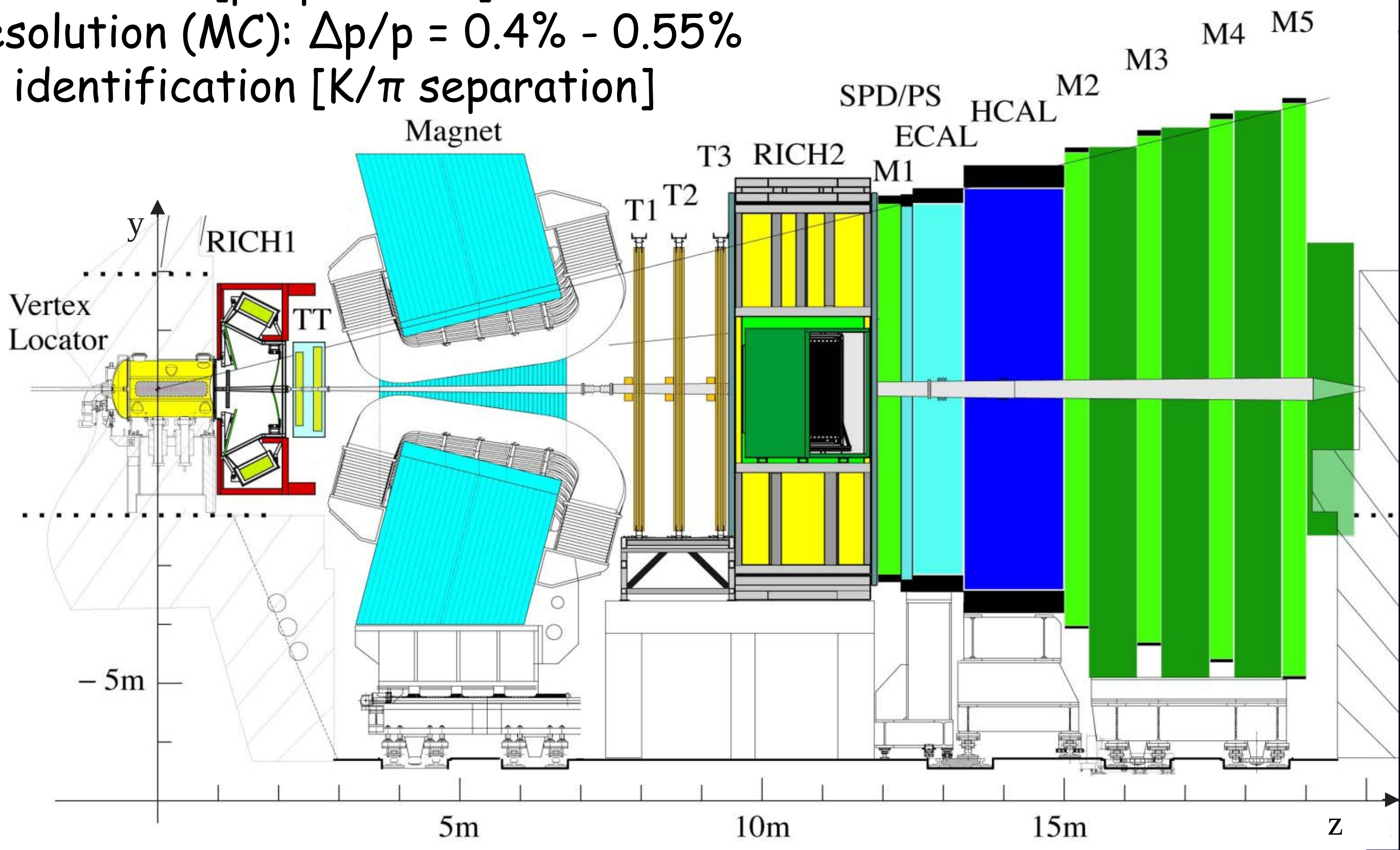
forward beaming of $b\bar{b}$ in the LHCb frame



Overview of LHCb detector

Main detector requirements

- Good vertex resolution [proper time]
- Momentum resolution (MC): $\Delta p/p$ = 0.4% - 0.55%
- Good particle identification [K/π separation]



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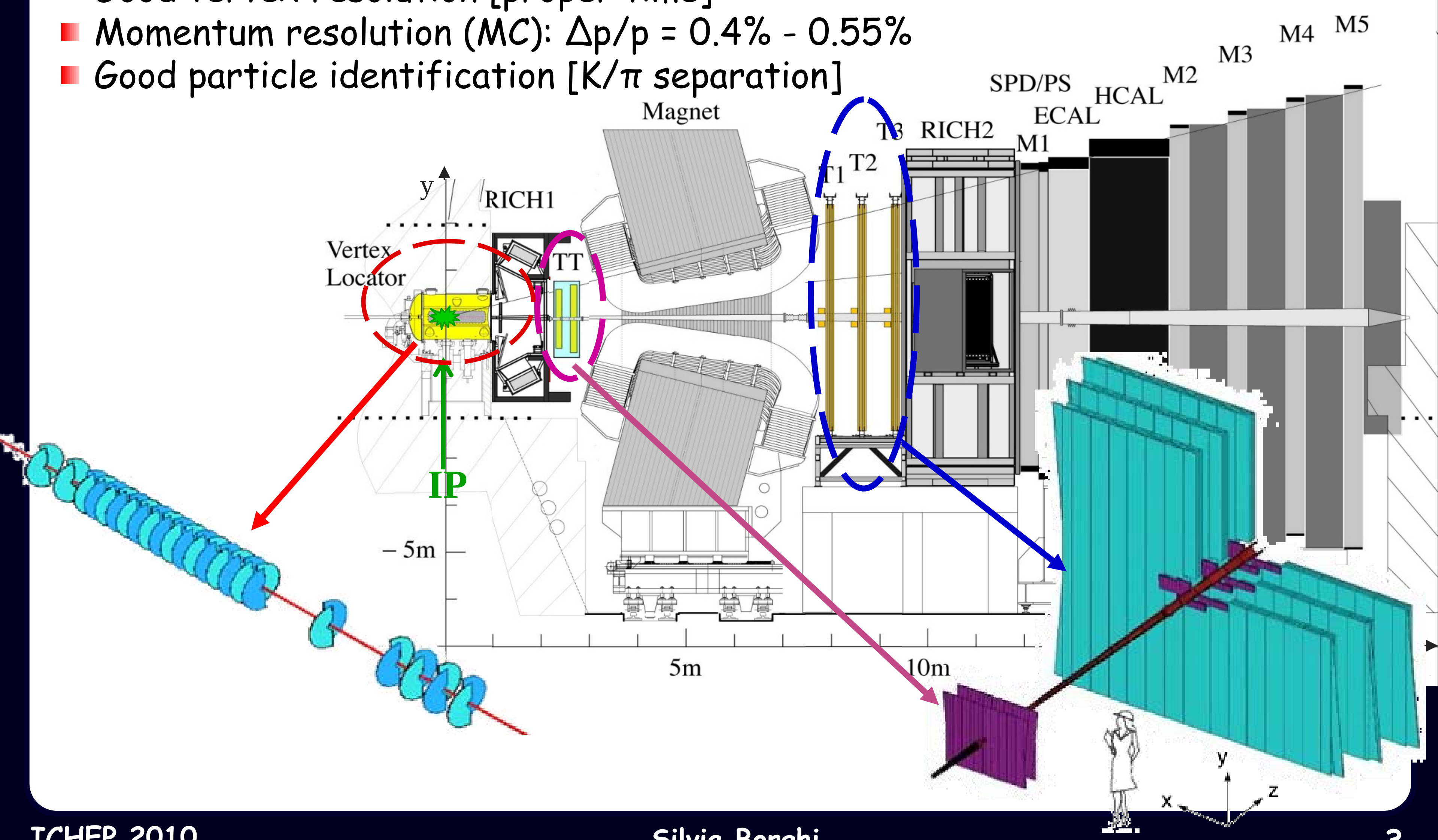

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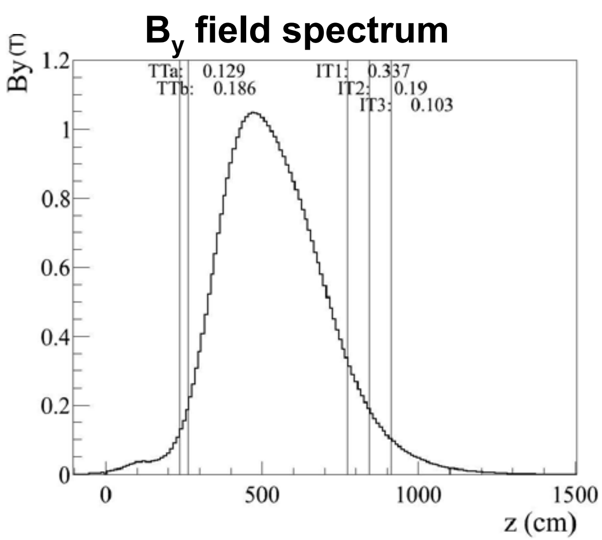

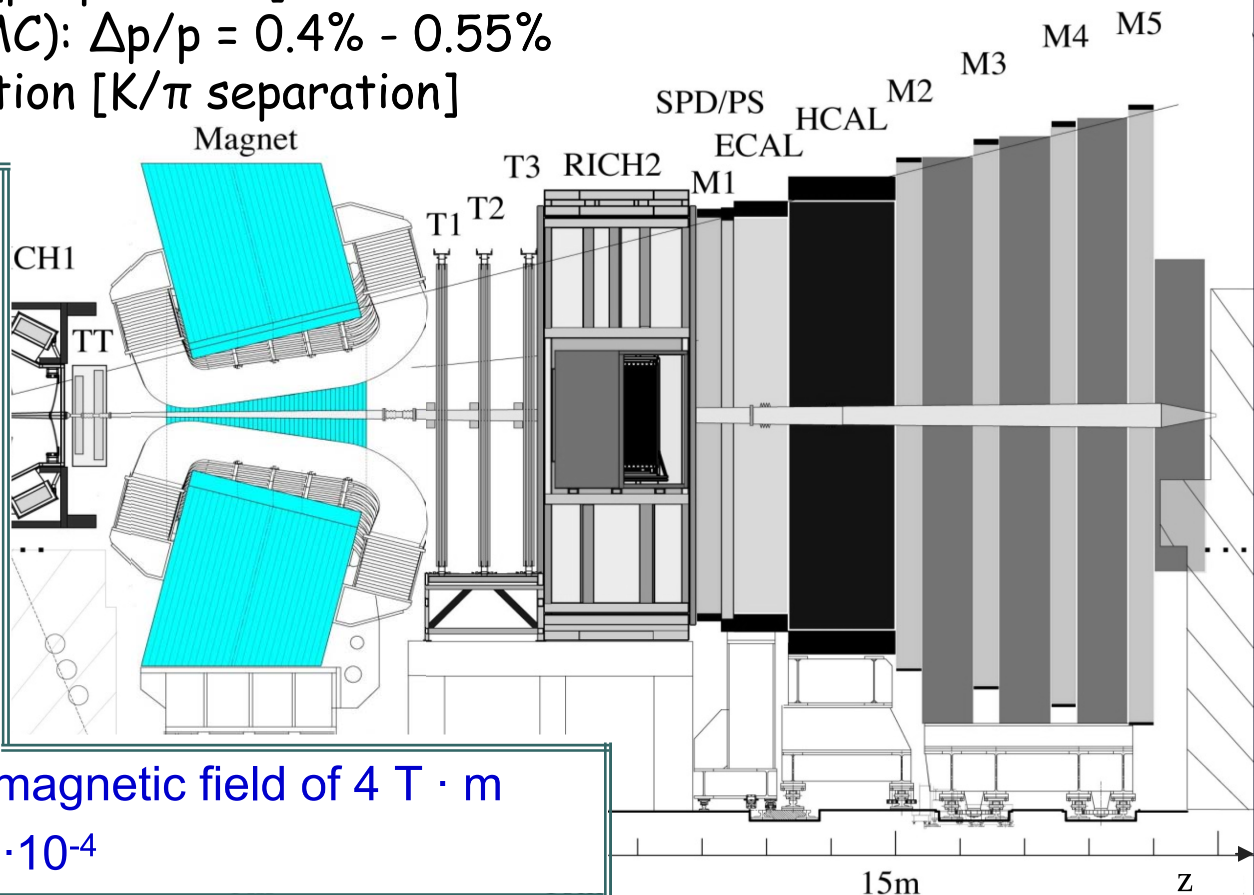

- Warm Magnet integrated magnetic field of 4 T · m
- Measurement precision 4 $\cdot 10^{-4}$

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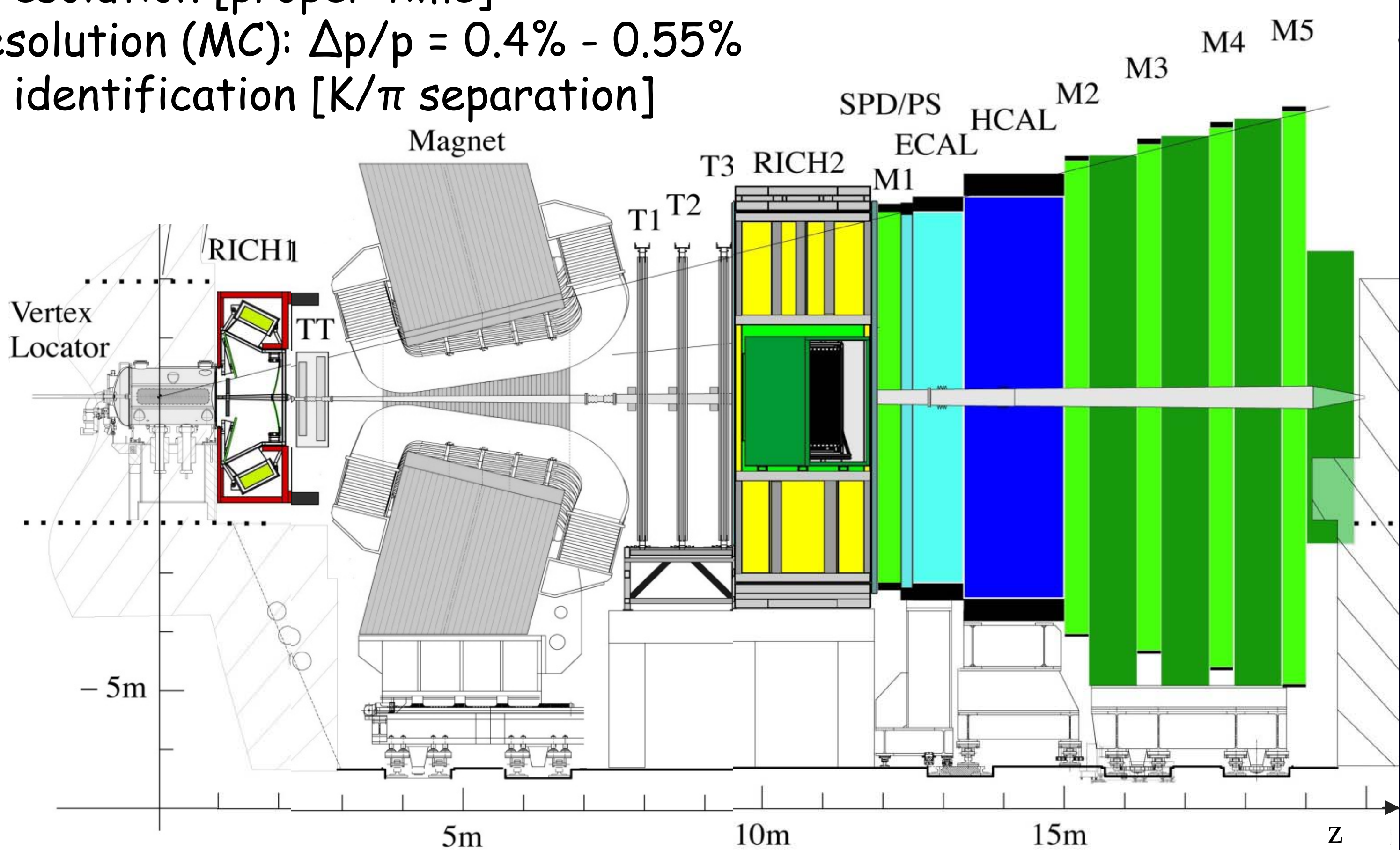
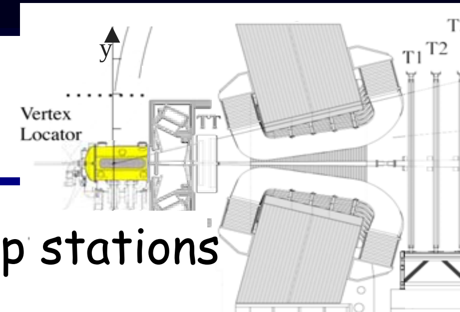
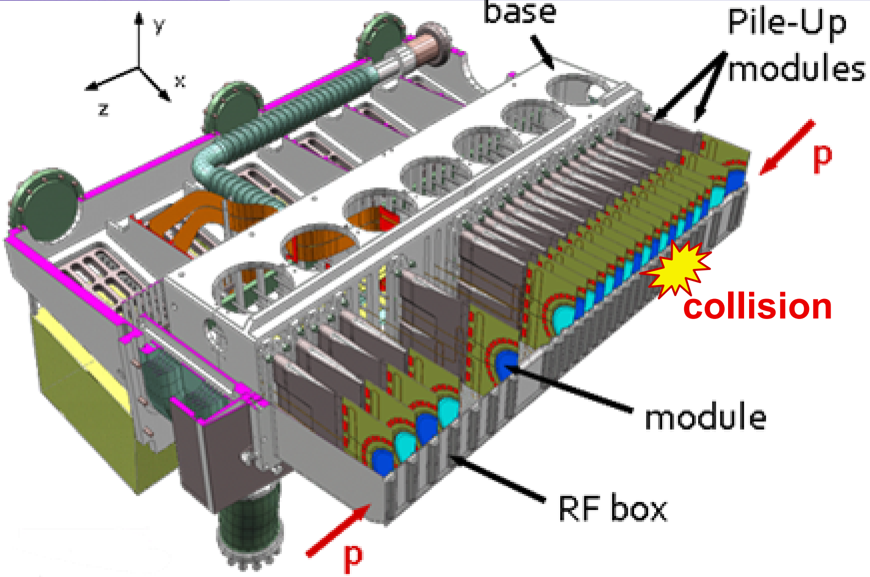


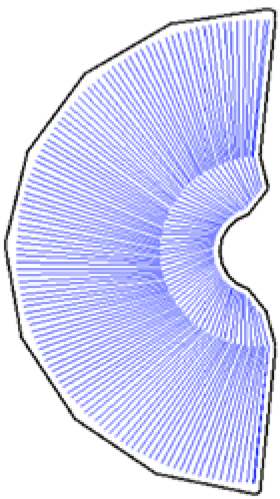
More details by Andrew Powell during the afternoon session

Vertex Detector (VELO)

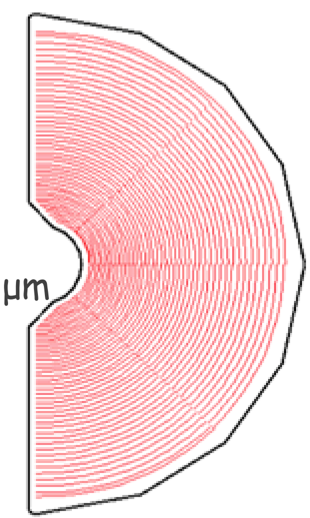


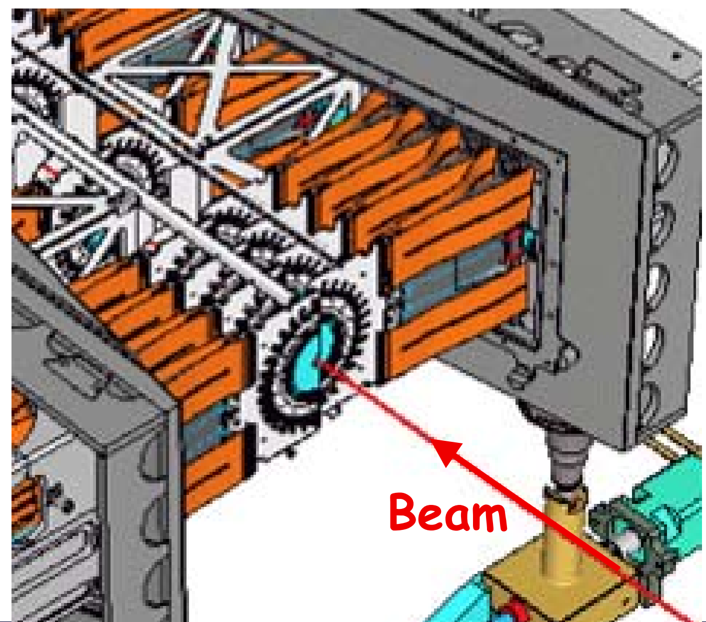


- 21 silicon micro-strip stations with r- ϕ geometry
- 2 Pile-Up stations used in the trigger
- 2 retractable detector halves:
  - 8.2 mm from beam with stable beam condition,
  - 30mm from beam during injection and MD
- 300μm foil separates detector vacuum from beam vacuum and constitutes beam-pipe in VELO region

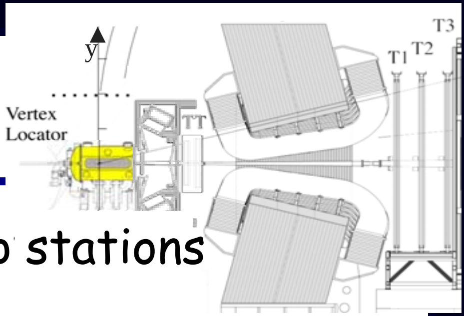


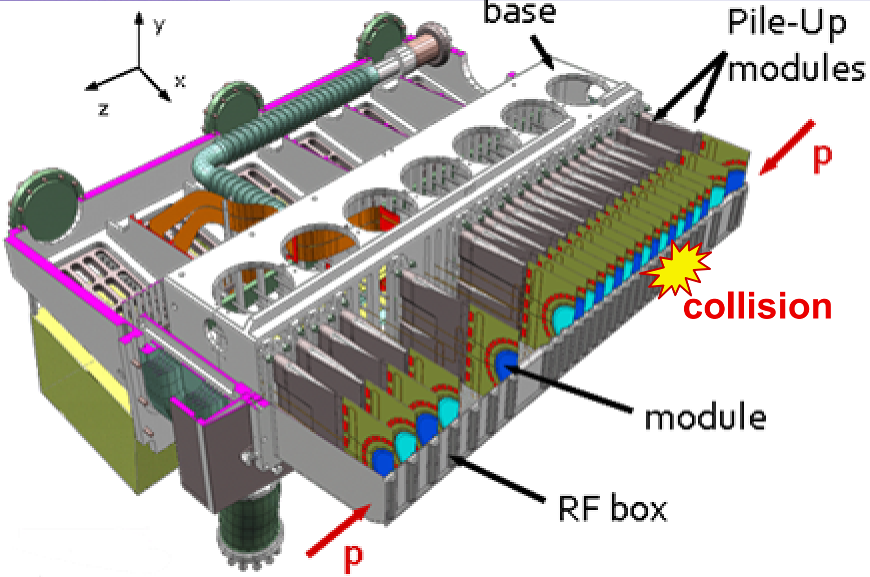
R-φ design
- 2048 strips
- 42 r-φ pairs
- 172k channels
- pitch= 40-100 μm
- 40MHz clock
- DAQ: ~1MHz





Vertex Detector (VELO)





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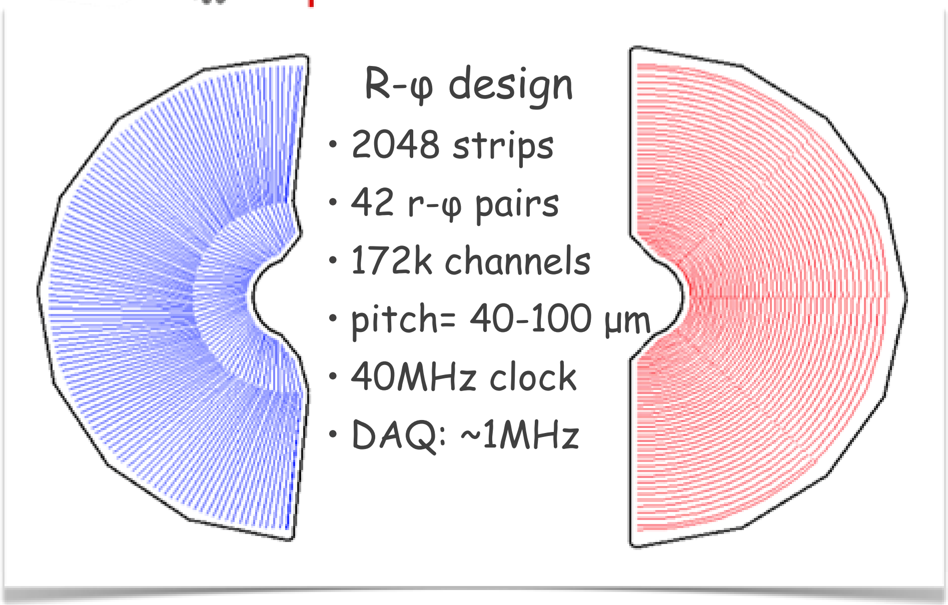
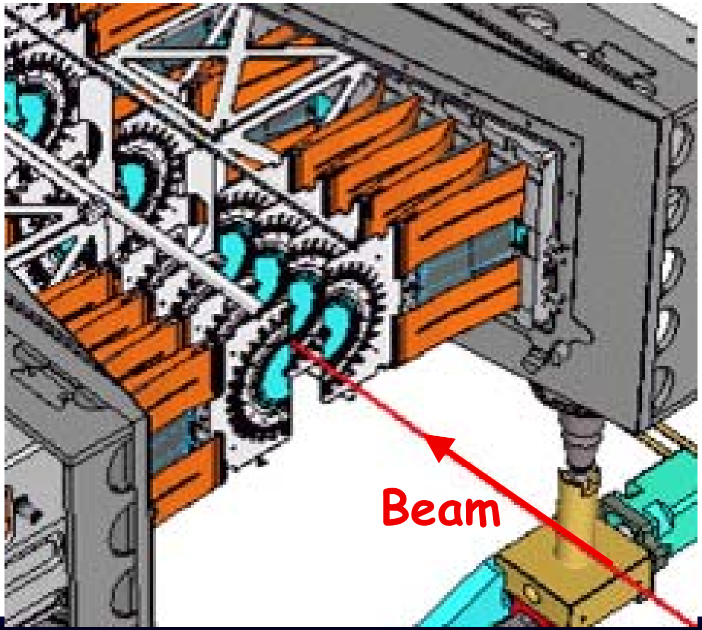
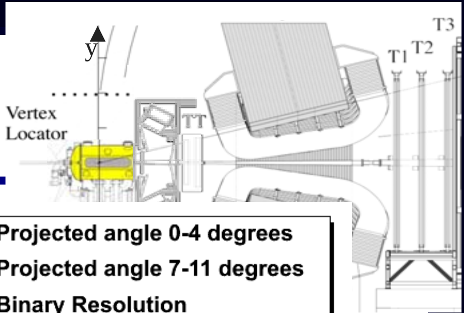




VELO performance

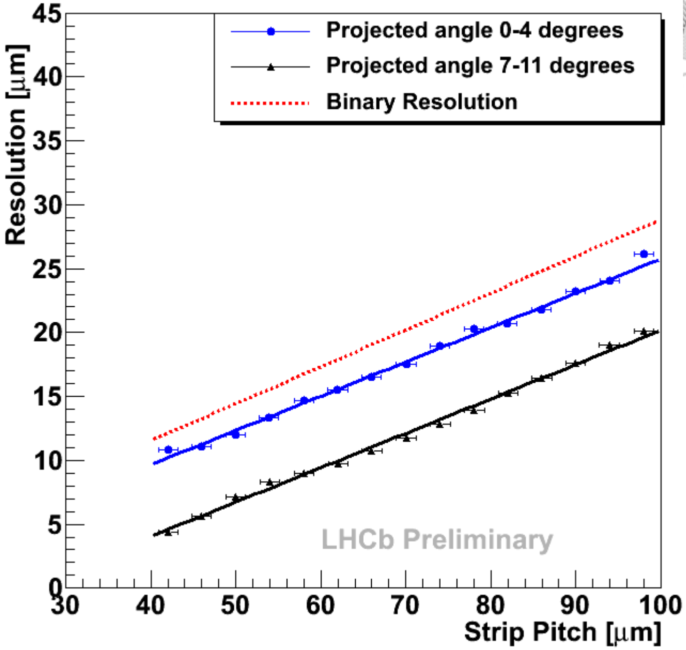


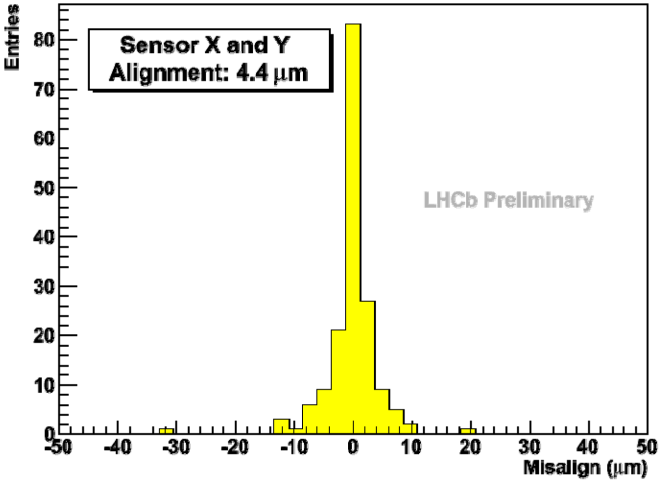
- Cluster finding efficiency 99.7 %
- Hit resolution as fraction of strip pitch and function of projected angle
  - *Measured with hit-track residuals corrected for track uncertainty*
  - *Good agreement with MC given current alignment*

  Best resolution ~4 μm

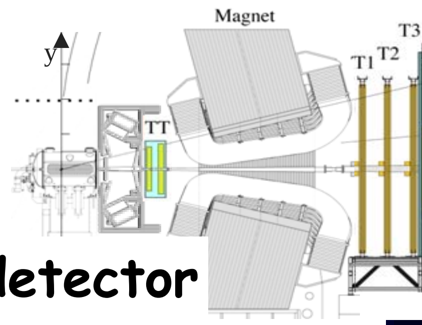
- Module and sensor alignment known better than 5 μm
- Fill-to-fill variation along (x,y) of relative alignment of two halves within (± 5 μm, ± 3 μm)

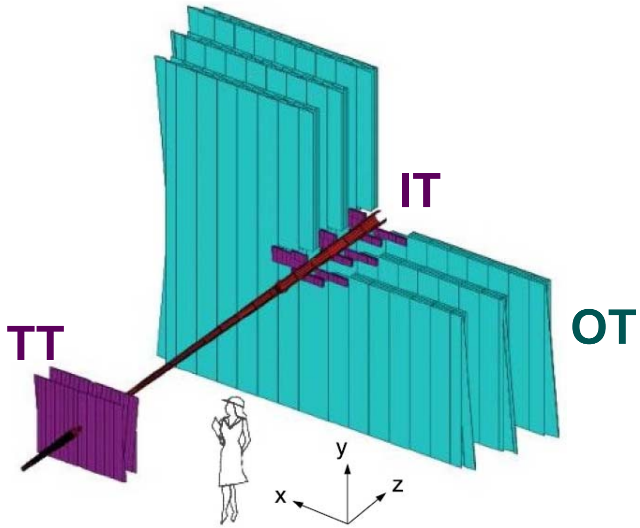
More details in the Poster session



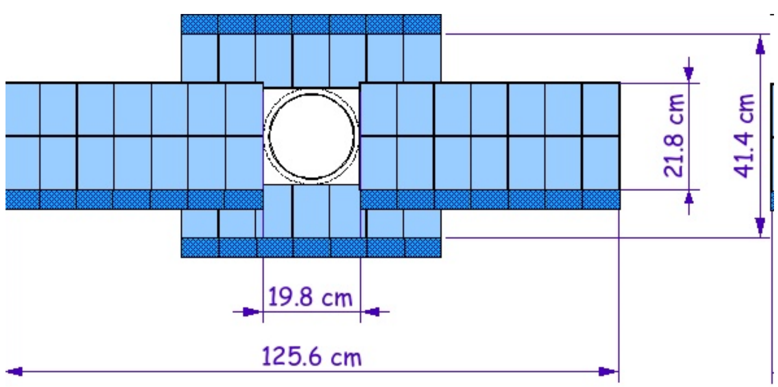


Silicon Tracker system



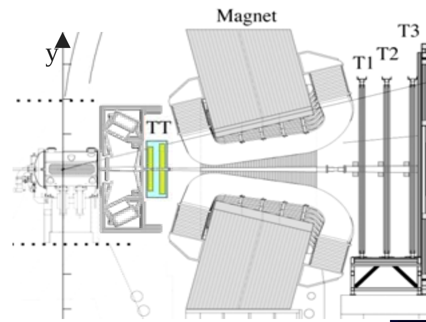


- Track Turicensis (TT) detector
  - Upstream of the magnet
  - Four planes of Silicon microstrip sensors (0°, +5°, -5°, 0°)
  - Readout pitch 183 μm pitch
  - 500 μm thickness
  - Area of 8.2 m^2 covered by Silicon, 143 k strips

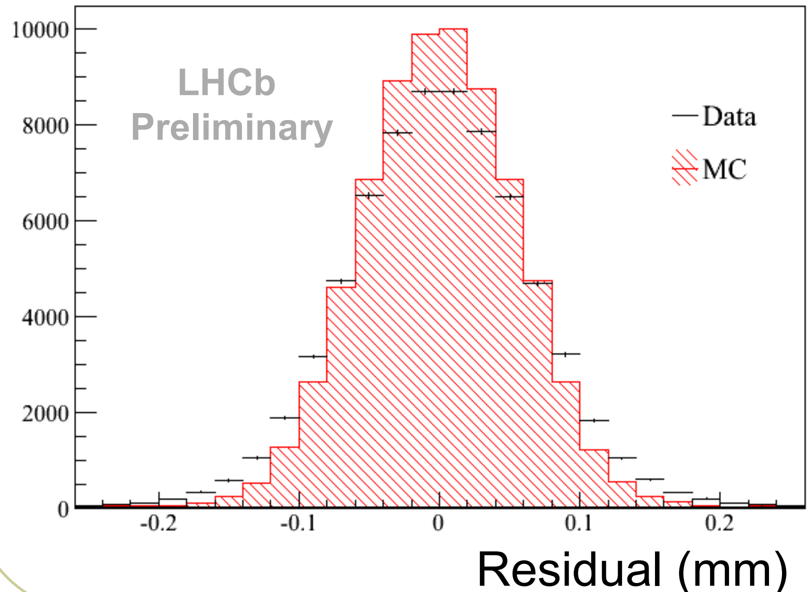


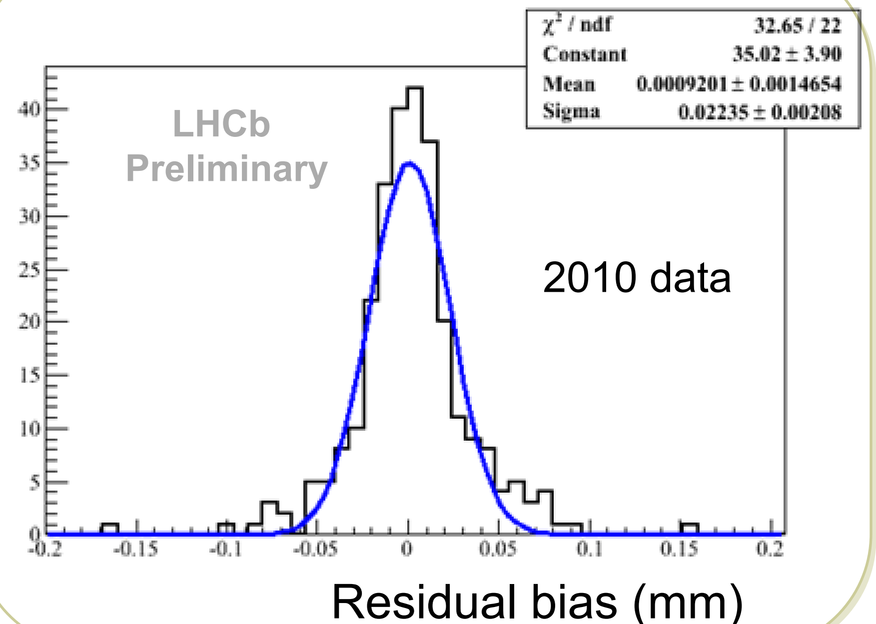
- Inner Tracker (IT) detector
  - Downstream of the magnet
  - 3 stations with 4 layers (0°, 5°, -5°, 0°)
  - Readout pitch 198 μm
  - 320/410 μm thickness for 1/2 sensor ladders
  - Area of 4 m^2 covered 130 k readout strips

TT performance

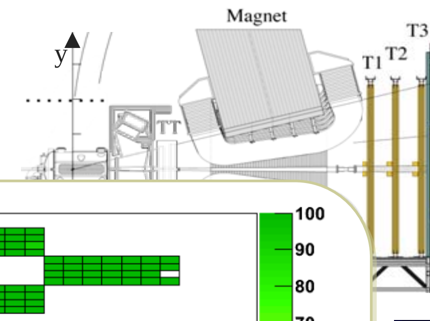


- 99.6 % of detector channels working
- **Hit resolution 55 μm**
- Misalignment 35 μm

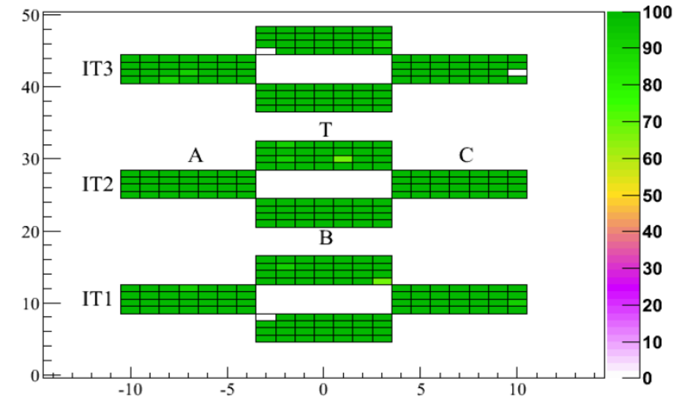


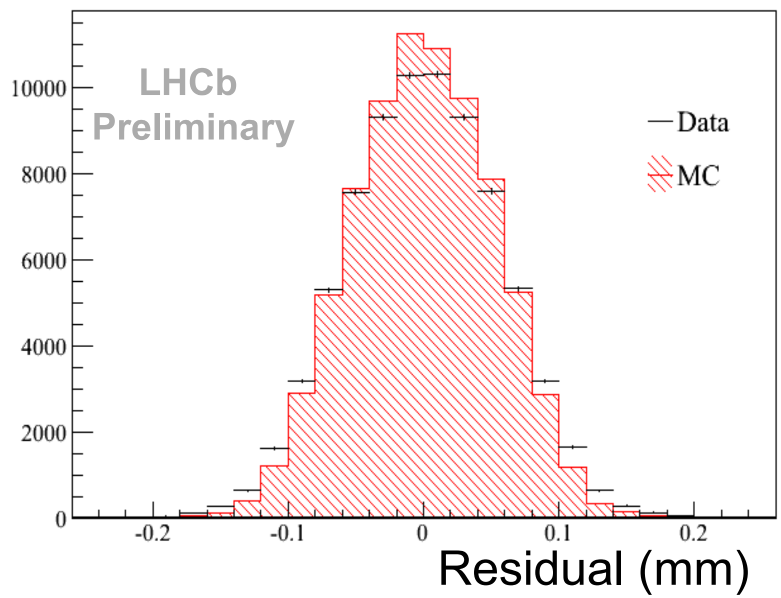


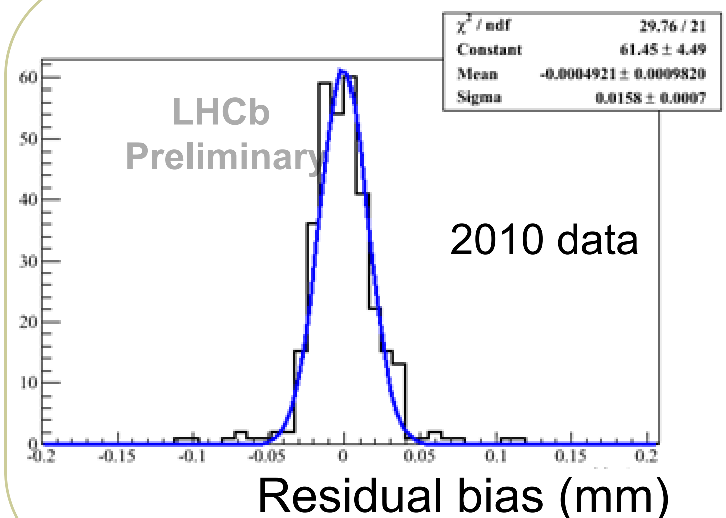
IT performance



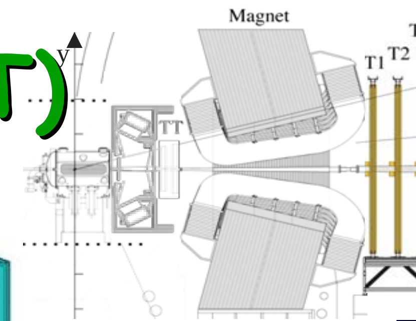
- 98.6 % of detector channels working
- **Hit resolution 54 μm**
- Misalignment 16 μm

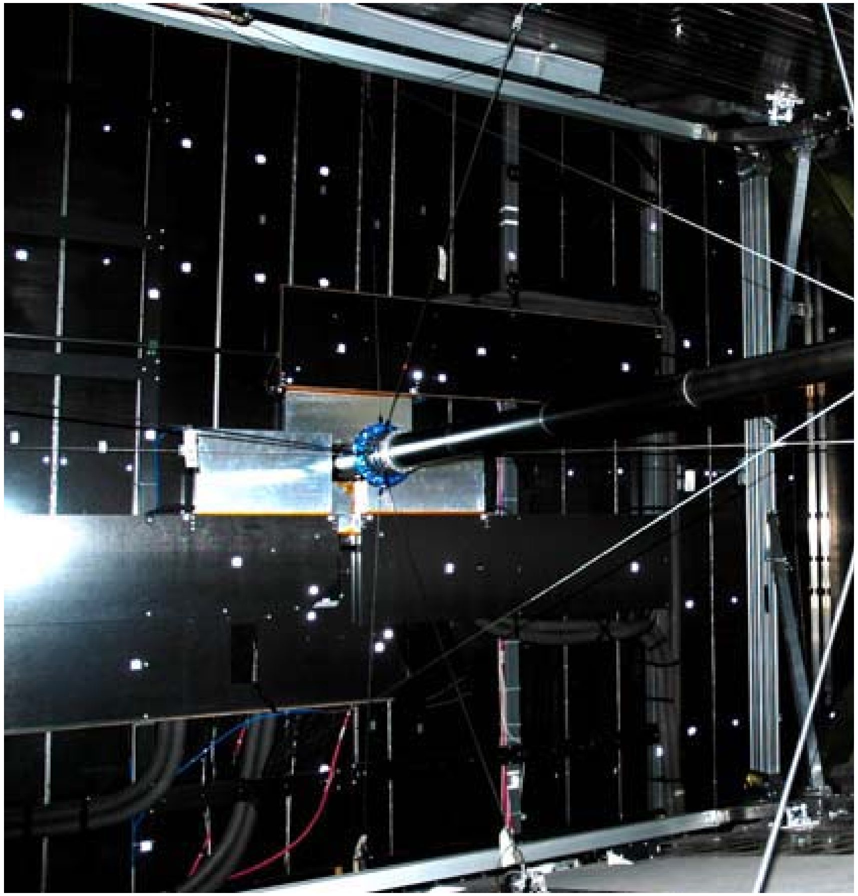


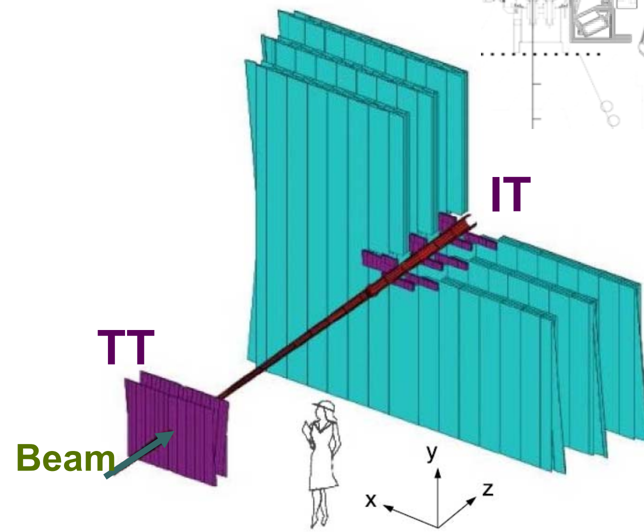




Outer Tracker Detector (OT)

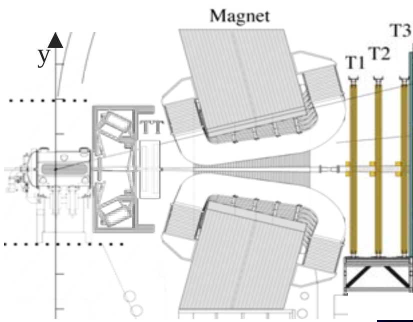




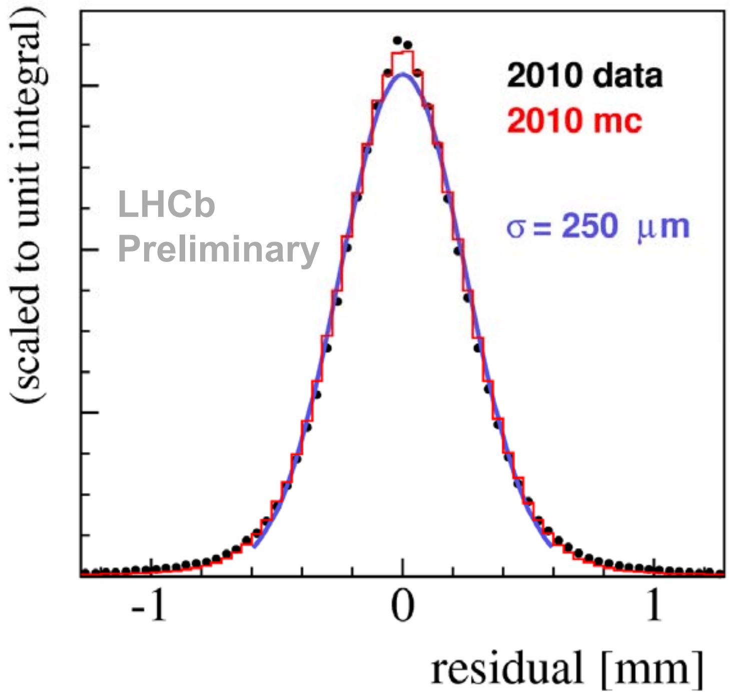


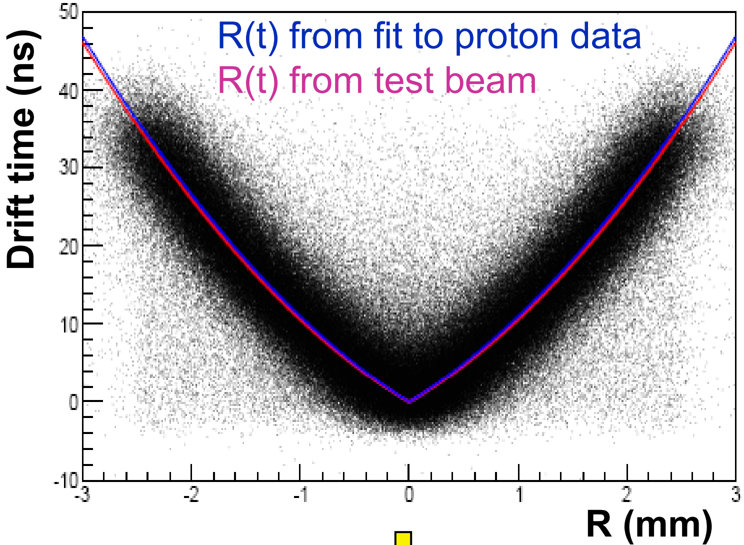
- Straw Tubes
- 3 stations with 4 double layers (0°, +5°, -5°, 0°)
- straw tube diameter 5 mm
- Gas: $Ar/CO_2/O_2$ =70/28.5/1.5
- 56 k readout channels

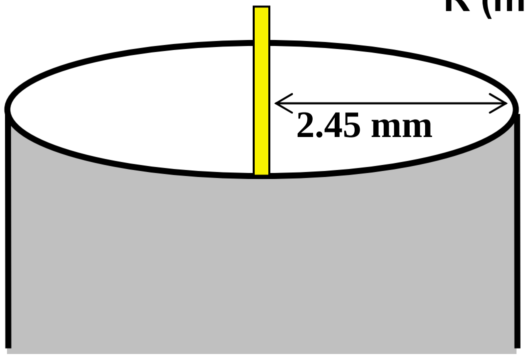
OT Performance



- 99.3 % channel working
- Space drift-time relation corresponds to expectation from test beam data
- **Resolution 250 μm**, close to nominal

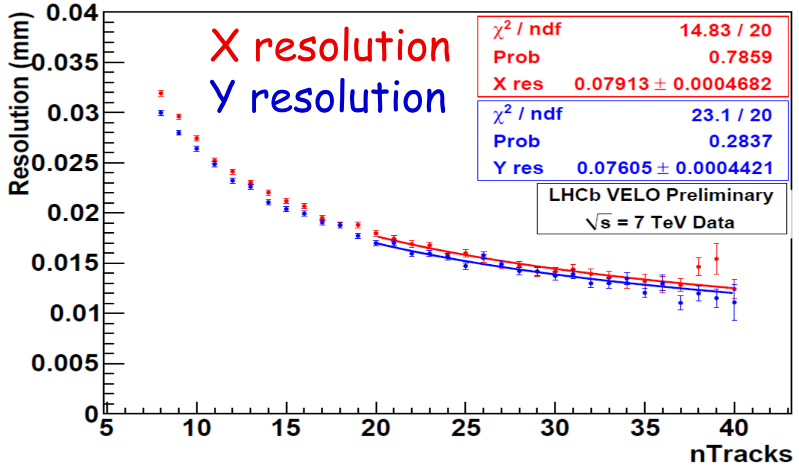


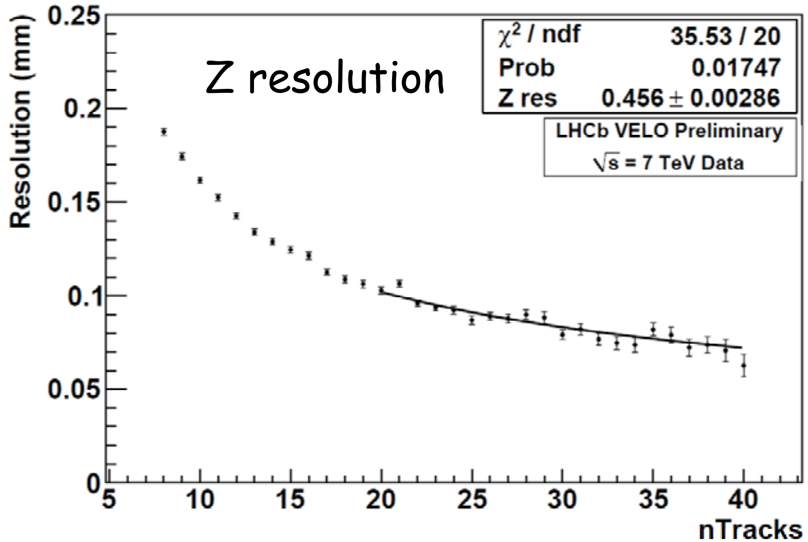




PV resolution

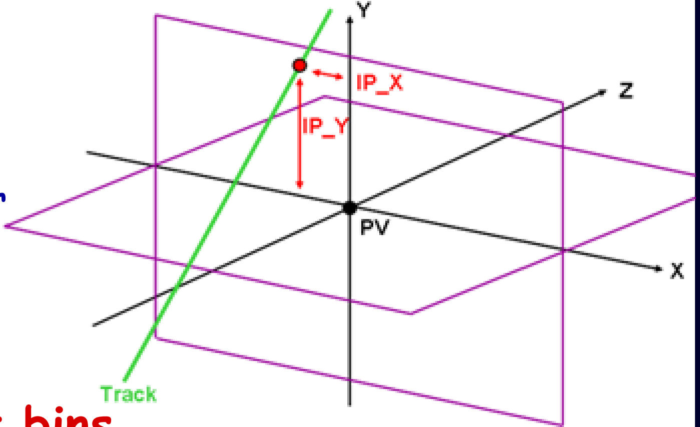
- Vertex resolution
  - Measure resolutions by randomly splitting track sample in two
  - Compare split vertices of equal multiplicity
  - Method validated with MC
- PV resolution (x,y,z) with 25 tracks:
  - **Data (15.8, 15.2, 91) μm**
  - MC (11.5, 11.3, 57) μm
- Room for improvement: alignment, material description

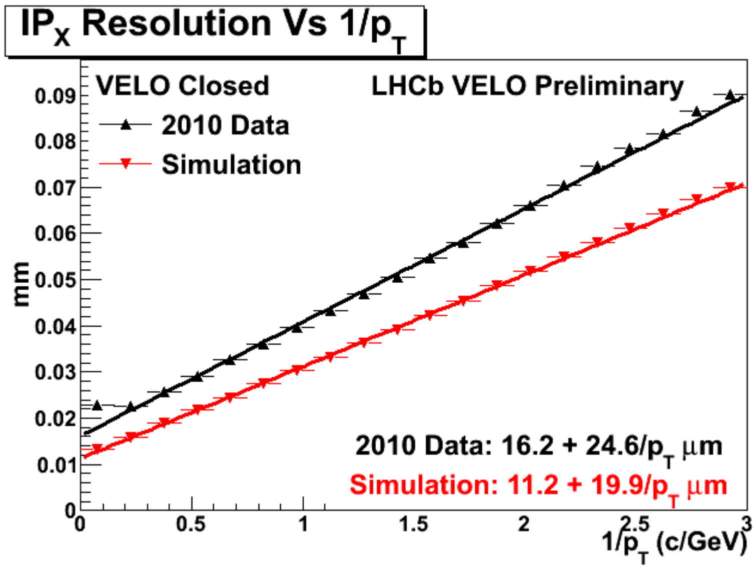


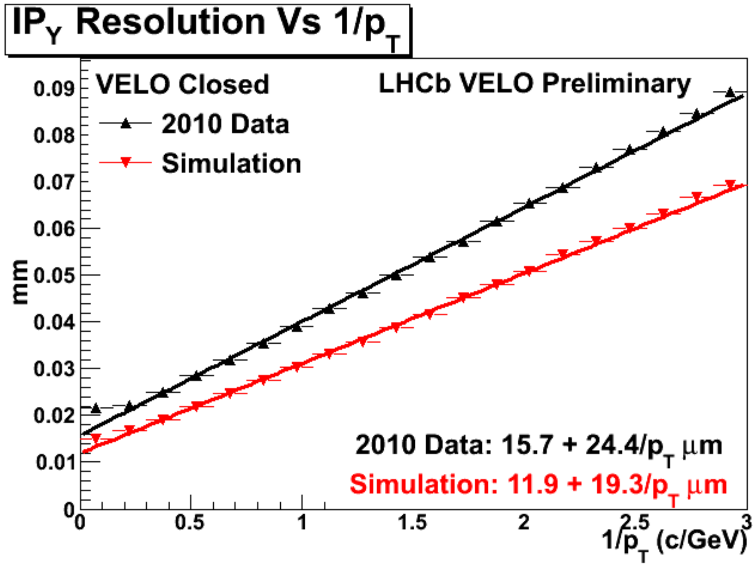


Impact Parameter resolution

- IP resolution:
  - Impact Parameter (IP) is defined as the closest distance of each track to the primary vertex:
  - Measure x and y component of impact parameter
  - Assume all tracks originate from primary interaction point
  - Measure resolution as spread of IP distribution
- **IP resolution up to 20 μm for the highest pt bins**
- Room for improvement: alignment, material description

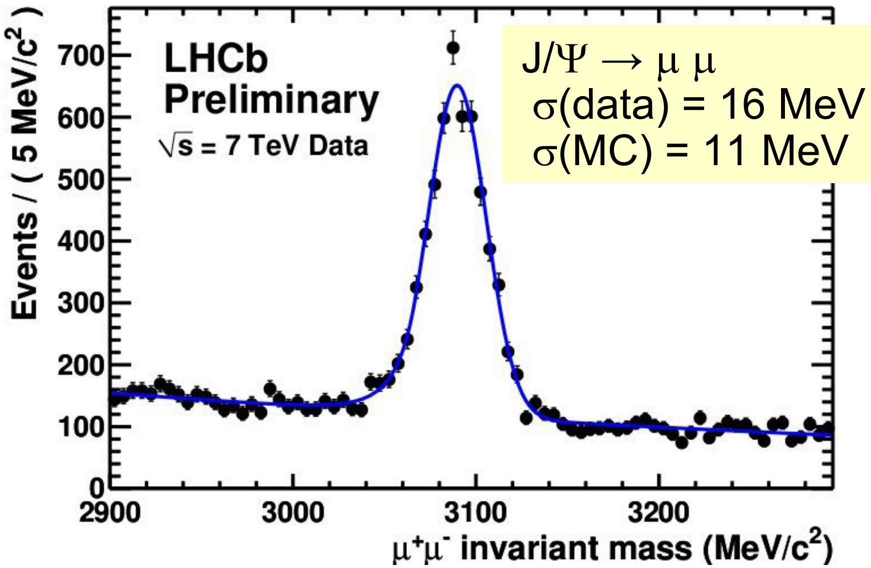


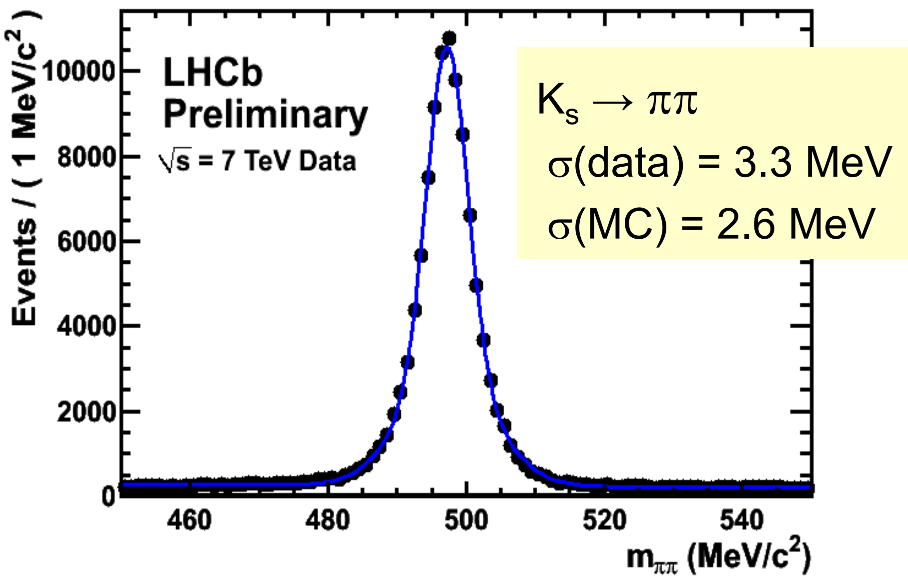


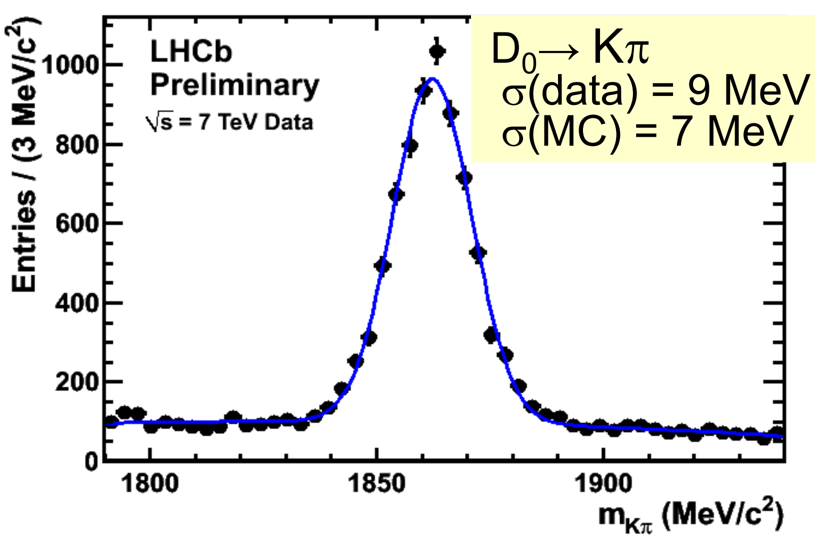


Invariant mass resolution

- **Very precise momentum and mass resolution**
- Not yet B field calibration
- Still some room for improvement

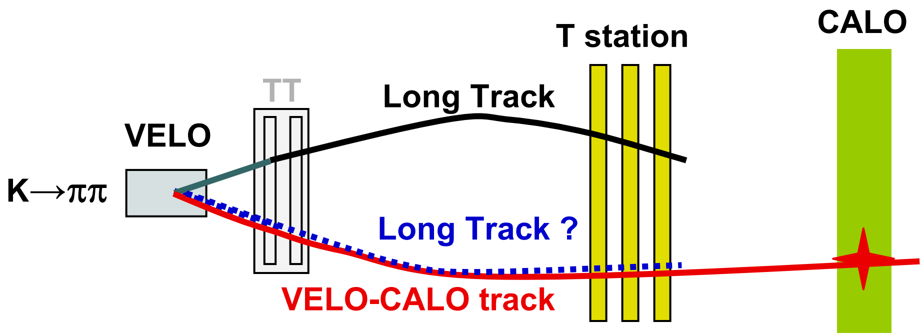


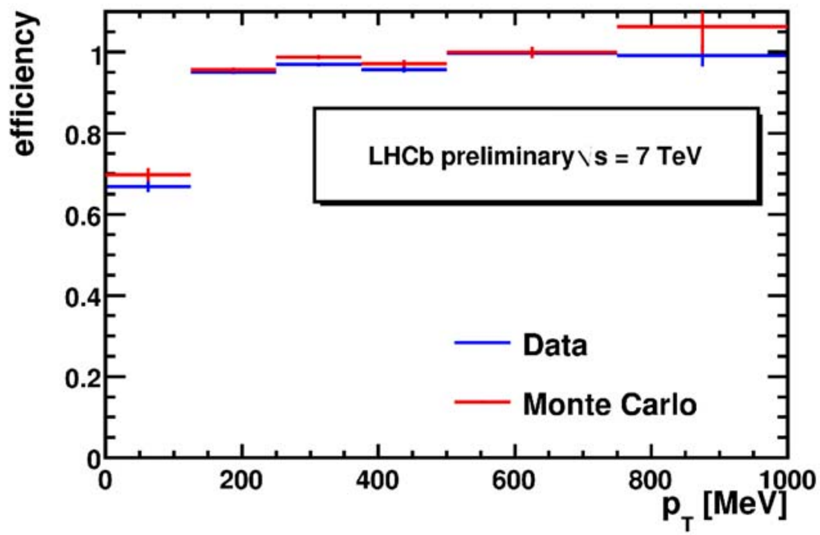




Track efficiency

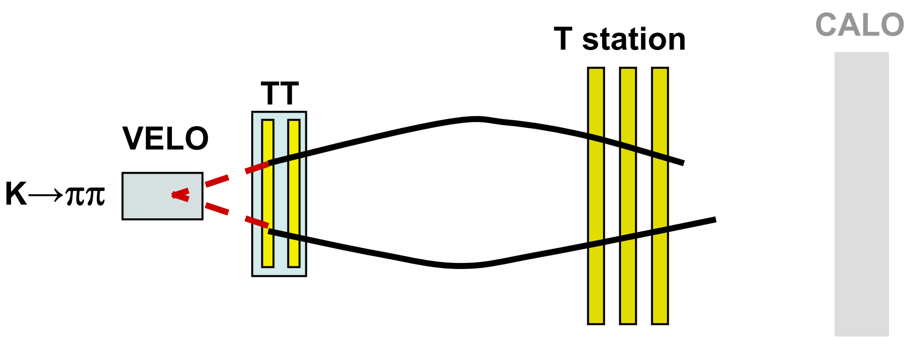
- Efficiency of the tracking system:
  - Using Tag and Probe method with VELO and Calorimeter





Good agreement between data and MC

- Similar method can be used to evaluate the efficiency of the VELO

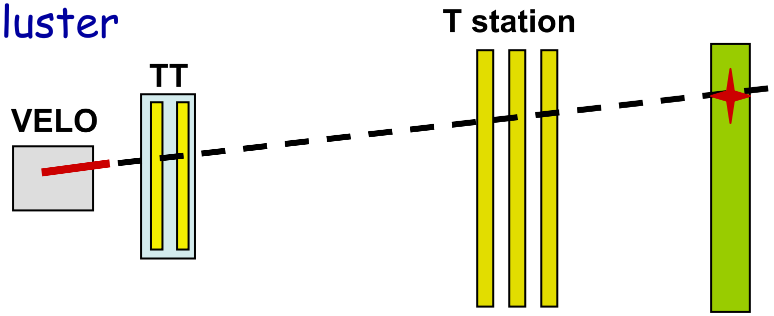


- This method can be applied also to J/Ψ reconstruction

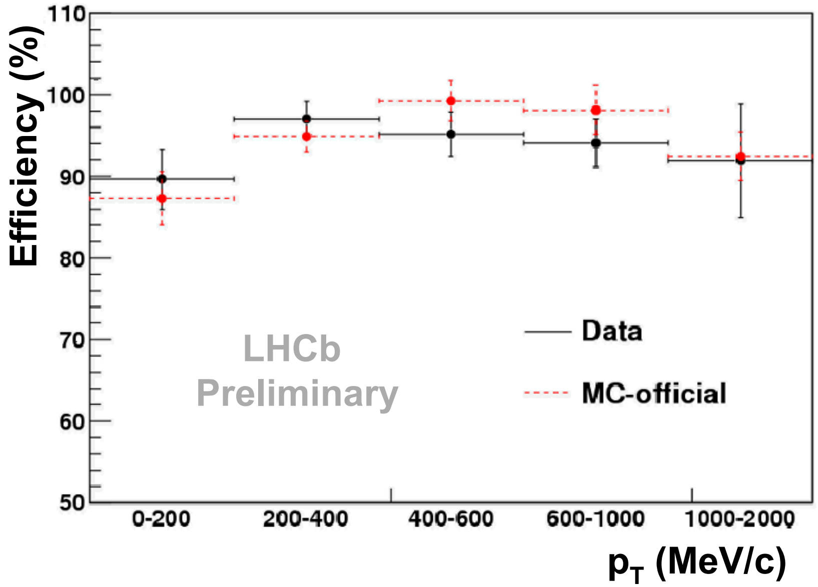
Track efficiency

Measure tracking efficiencies from data

- Matching the VELO segment with a CALO cluster



- Matching the Velo-Calo trajectory to the parameters of tracks found by each tracking algorithm



Good agreement between Data and MC

Both methods evaluate:

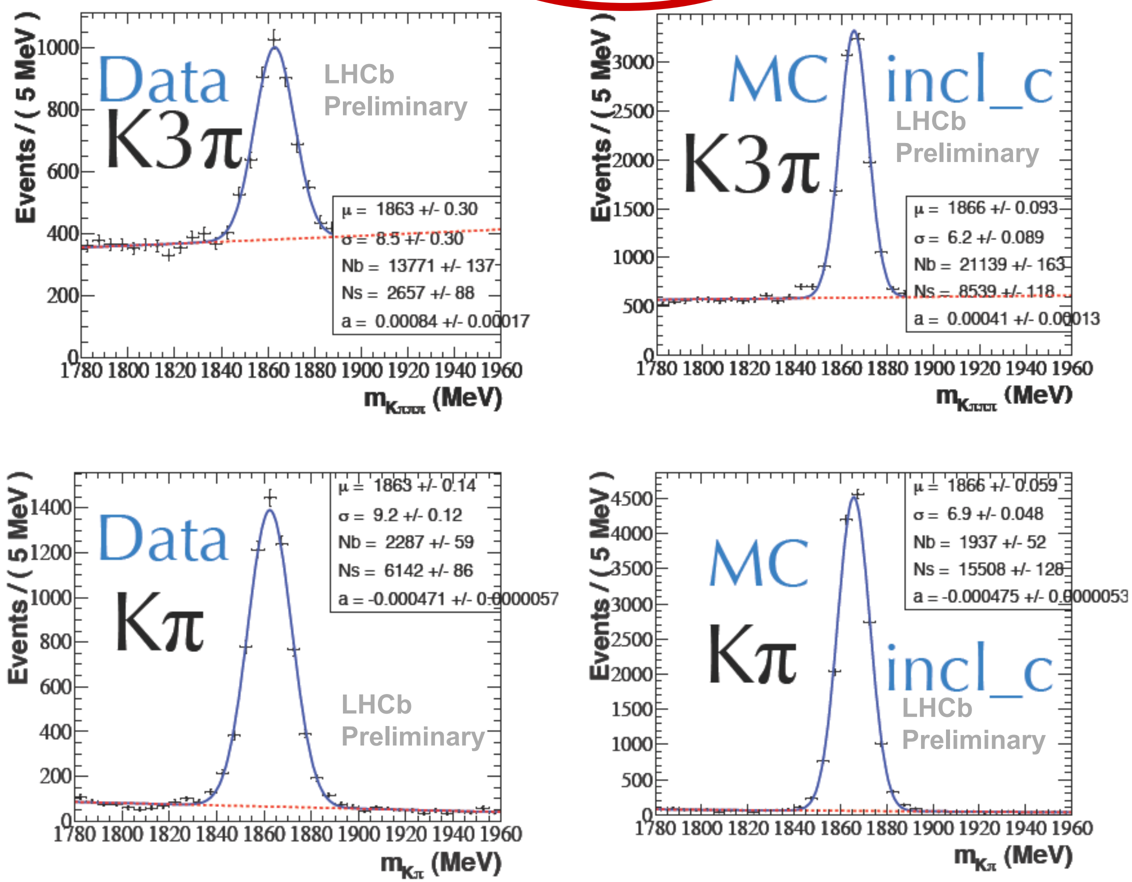
$$Ratio\left(\frac{\varepsilon_{data}}{\varepsilon_{MC}}\right) = 0.99 \pm 0.02$$

Integrated over the full phase space

Track efficiency

$$\varepsilon(track)^2 \sim \frac{N(K\pi\pi\pi)}{N(K\pi)} * \frac{BR(K\pi)}{BR(K\pi\pi\pi)}$$

Precisely know ± 2%



ε(data)/ε(Monte Carlo) = 1.03 ± 0.03

Conclusion

- LHCb was designed with very ambitious tracking performances
- Very close to reach these performances with the first data
- The first physics results are presented in several talks at this conference:
  - First Physics results from LHCb *by Sheldon Stone*
  - PDF Sensitivity Studies using electroweak processes at LHCb *by Ronan McNulty*
  - Particle Production Studies at LHCb *by Chris Blanks*
  - Search for New Physics with Rare Heavy Flavour Decays at LHCb *by Giovanni Passaleva*
  - Results and prospects for Charm Physics *by Vanya Belyaev*
  - Studies of charmed hadronic B decays with early LHCb data and prospects for gamma measurements *by Susan Haines*
  - Prospects for CP measurements with charmless hadronic B decays at LHCb gamma measurement *by Ignacio Bediaga*
  - Prospects for CP violation in $B0_s \rightarrow$ J/psi phi from first LHCb data *by Gerhard Raven*
  - Search for New Physics with Rare Heavy Flavour Decays at LHCb *by Giampiero Mancinelli*