Cracow groups in LHCb
Software contribution

IFJ PAN and WFiIS AGH

M. Witek

Main contributions of Cracow groups

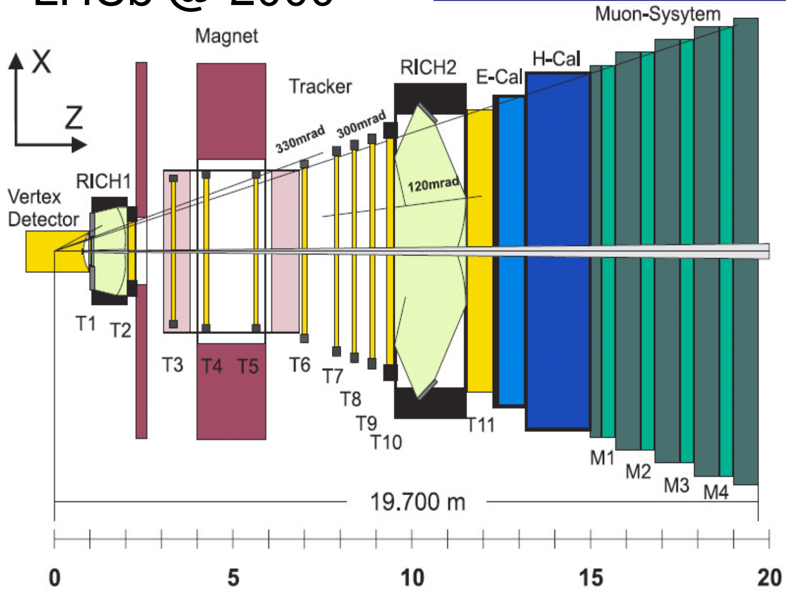
- Simulation of OT
- Fast reconstruction of long tracks Velo-T
- Trigger optimization and development
  - Layout of TT
  - Fast Velo-TT reconstruction
  - Trigger development of ECAL Alley
- Reconstruction of primary vertices (PV)
  - Online 2D,3D, off-beam (speed)
  - Offline PV (precision)
- Measurements of CP violation in:
  - B decays to pair of vector mesons (e.g. $B_s \to J/\psi\varphi$)
  - $B_s \to \eta_c\varphi$, $B_s \to \chi_c\varphi$, $B_s \to J/\psi\eta$, $B_s \to J/\psi f_0$
  - $B \to DK$, $B \to D^*a1$
  - CP violation in baryon decays

Evolution of LHCb detector

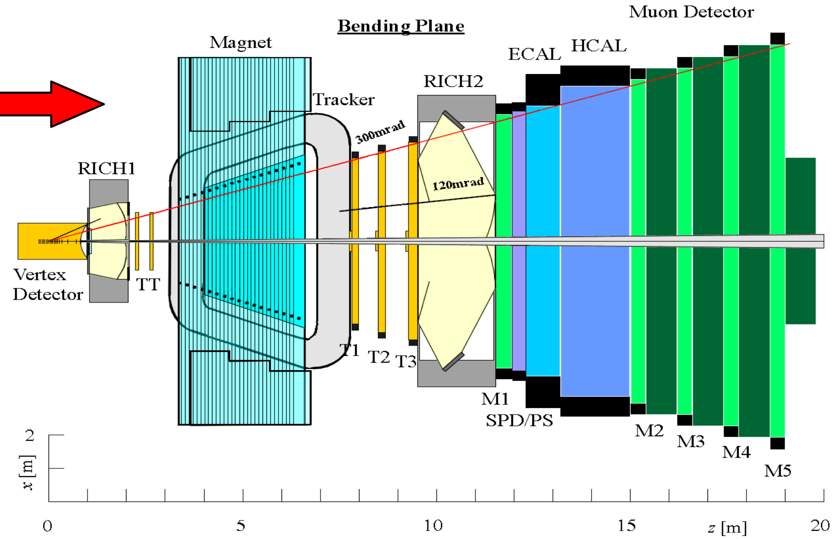
- Trigger (and whole detector) has been designed using simulation with some assumptions on the detector technology.
- The prototyping led to realistic technology.
  - Material budget before calorimeters – X0(λ_i) increased from 40% (10%) to 60% (20%).
  - Increased occupancies
  - Deteriorated capability to detect $e^{\pm}$ and γ. Loss K,π due to secondary interactions
  - Too long execution time for trigger algorithms

Reoptimization of the detector @ 2003

LHCb @ 2000

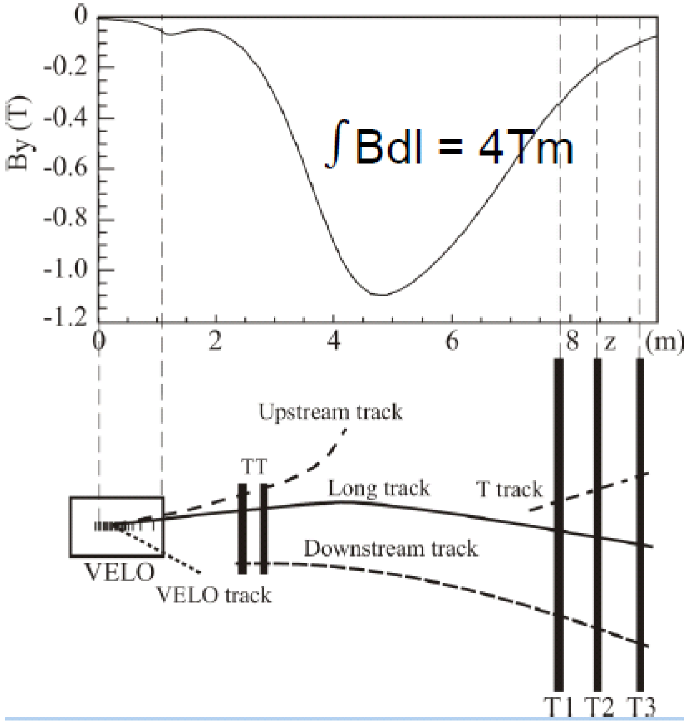


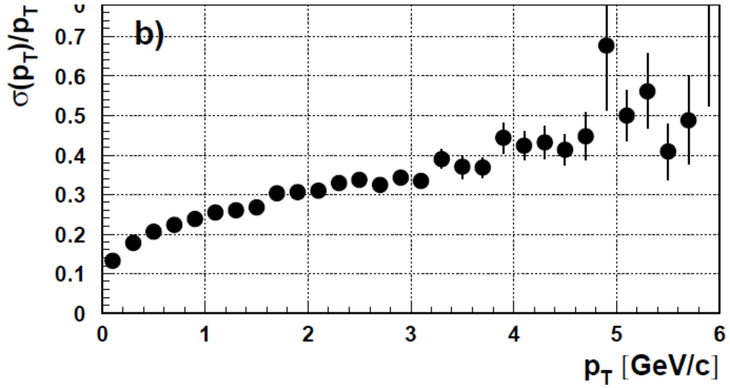
LHCb @ 2009

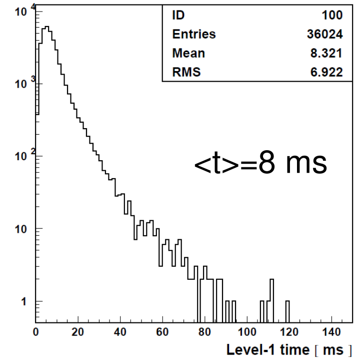


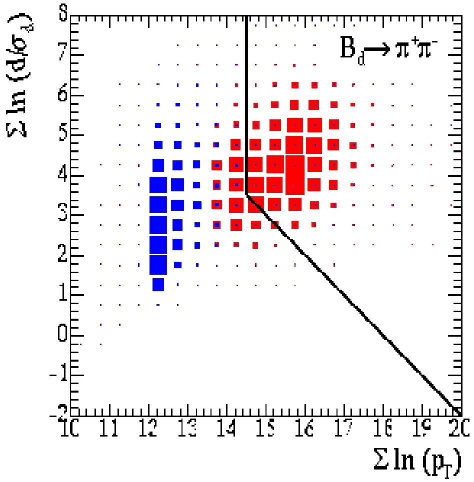
Trigger after reoptimization (L0-L1-HLT) @ 2003

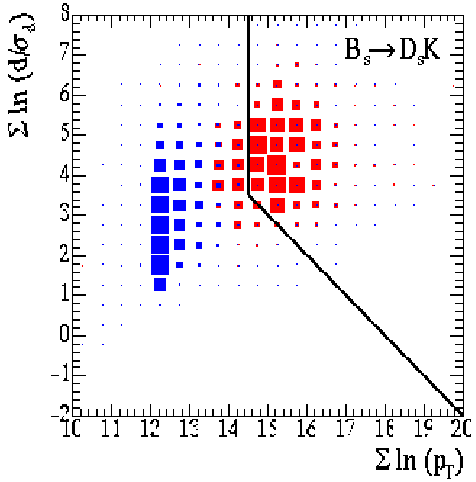
- L1 - New approach @ 2003
  - Add a bit of momentum information to combine IP & PT already at L1
  - Removal of shielding plates to bring a bit of B field into the Trigger Tracker (TT) area.
  - Execution time within time budget ~1 ms (8 ms @ 2003 → 1 ms @ 2008)





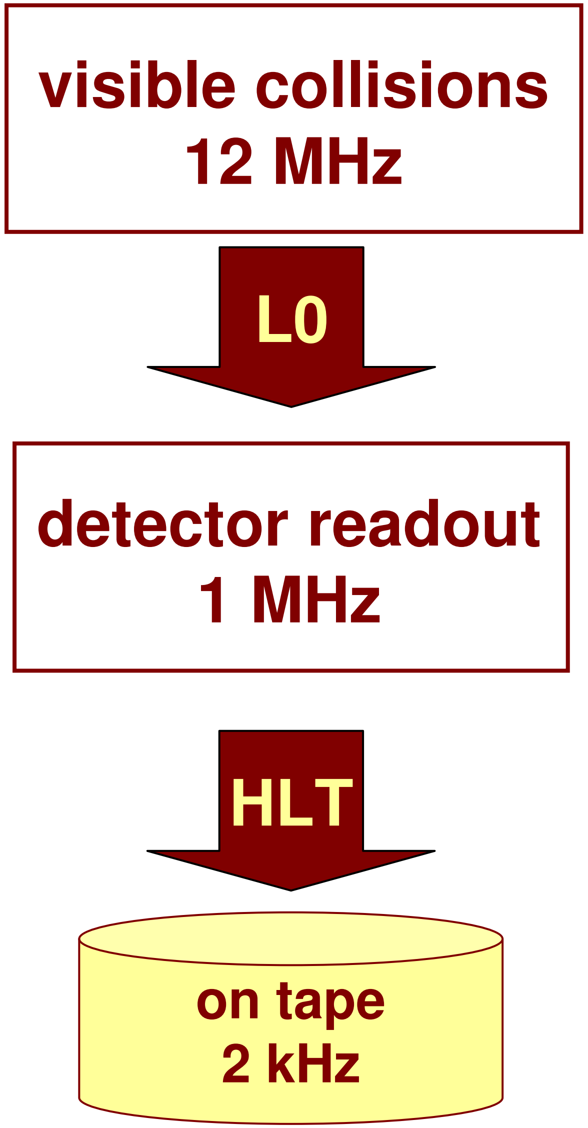






Trigger Overview @ 2009

- Hardware Trigger (Level-0 or L0)
  - "high pt" calorimeter & muon objects
  - rejects busy events
- Software Trigger (**H**igh **L**evel **T**rigger)
  - HLT first level:
    - trigger on B decay products
  - HLT second level:
    - trigger fully reconstructed B decays

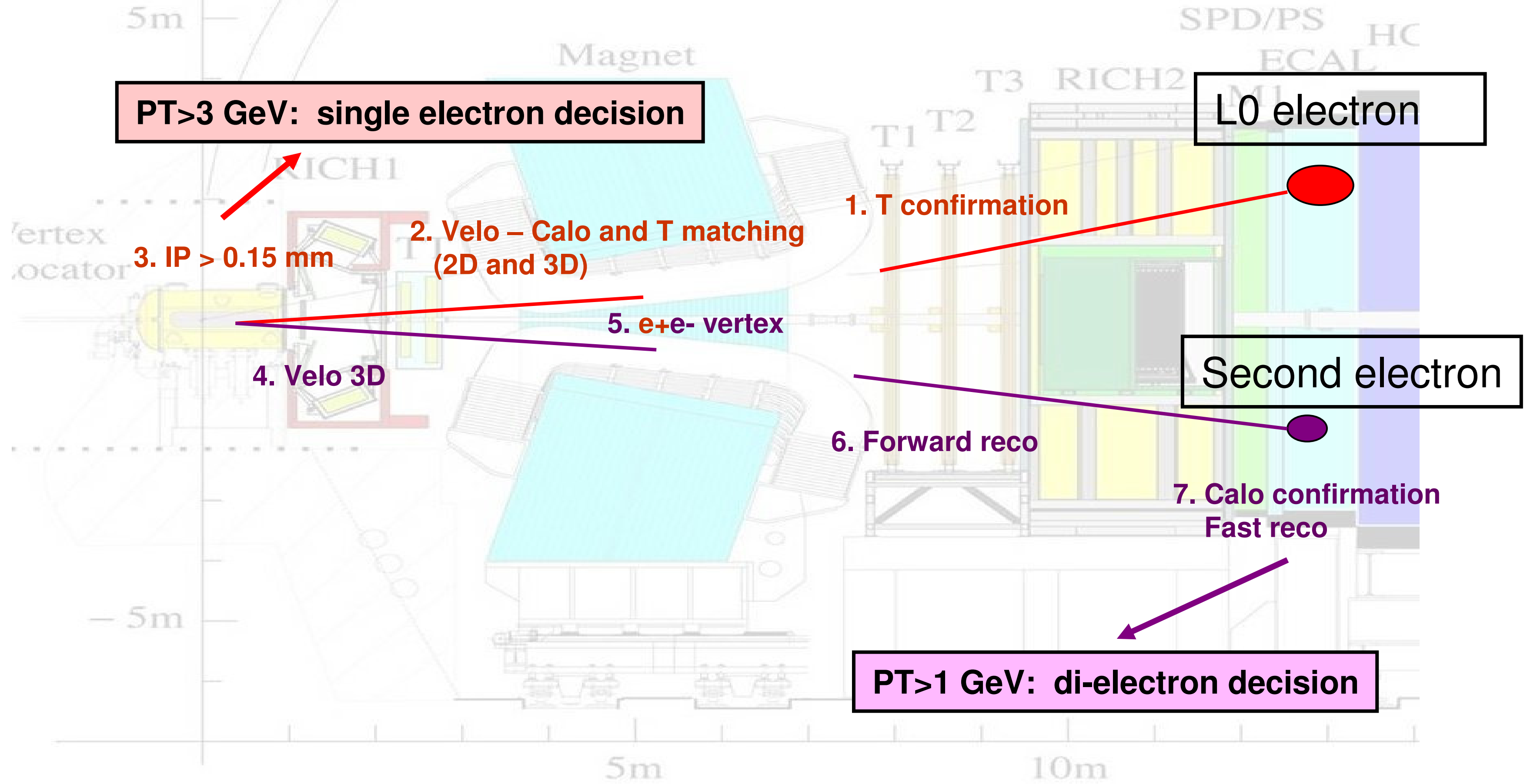


10 years of development

HLT1 - electron line

$B^+ \to K^+ e^+ e^-$, $B_s \to J/\psi(ee)\varphi$

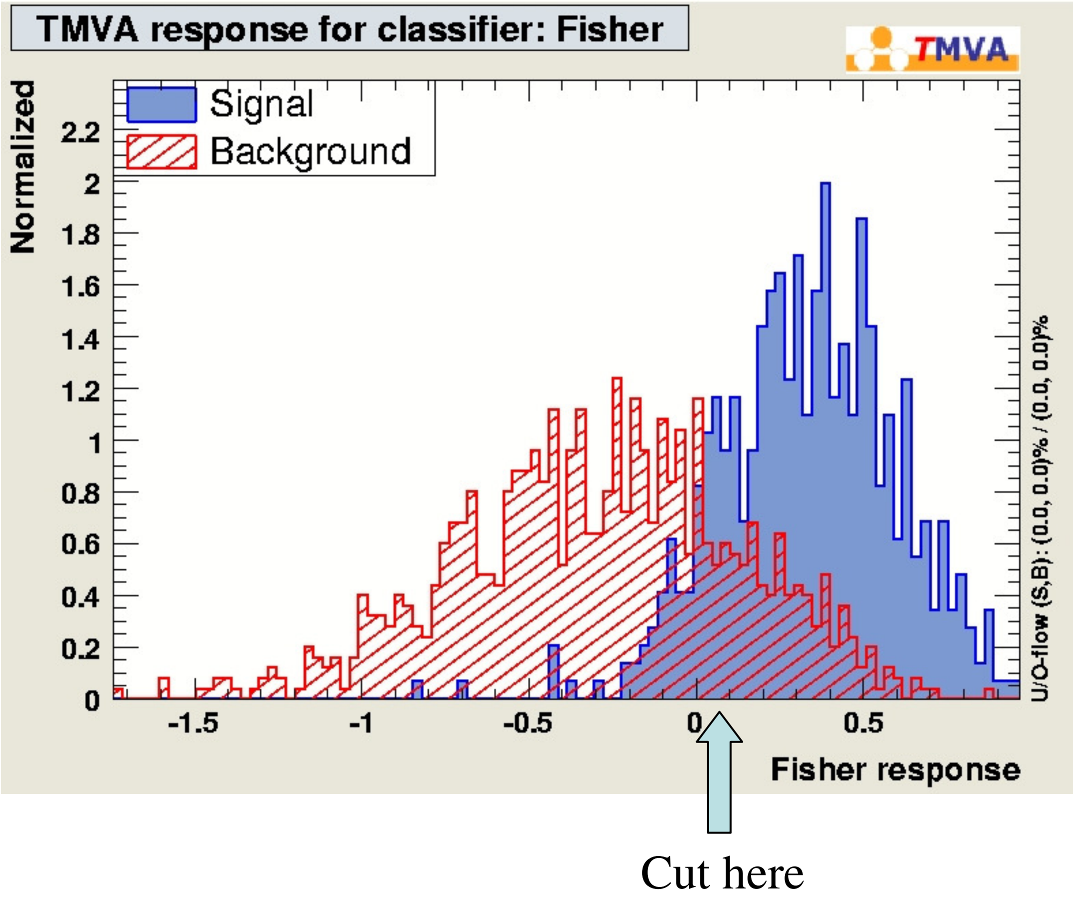
Latest strategy of trigger is to confirm L0 by HLT1.
Good control of trigger biases (corectable using control channels).



HLT1 – photon line

L0 photon – π^0 merged removal

$B_s \to \varphi\gamma$, $B \to K^*\gamma$



Broader cluster in ECAL for $\pi^0 \to \gamma\gamma$

Input variables:

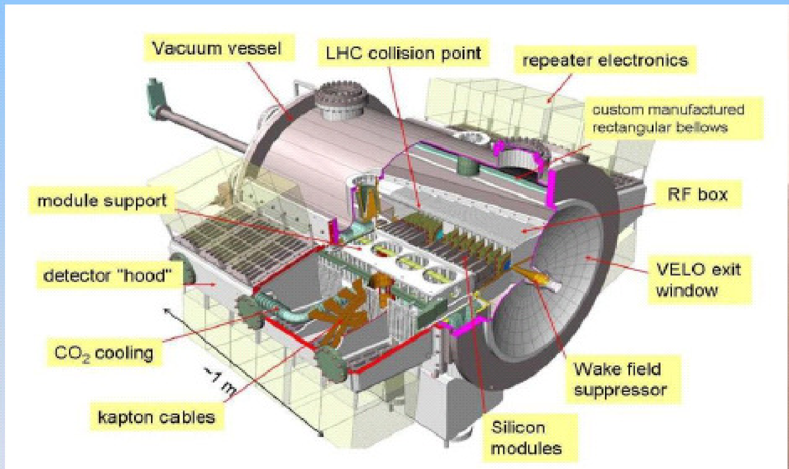
1. Eγ
2. Shape
3. Tails/Core
4. Asymmetry
5. Kappa

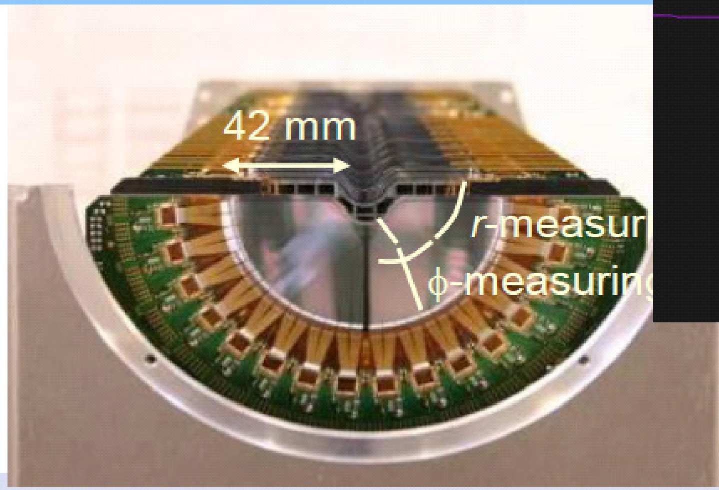
Signal eff = 90 % and 50 % reduction of mbias events

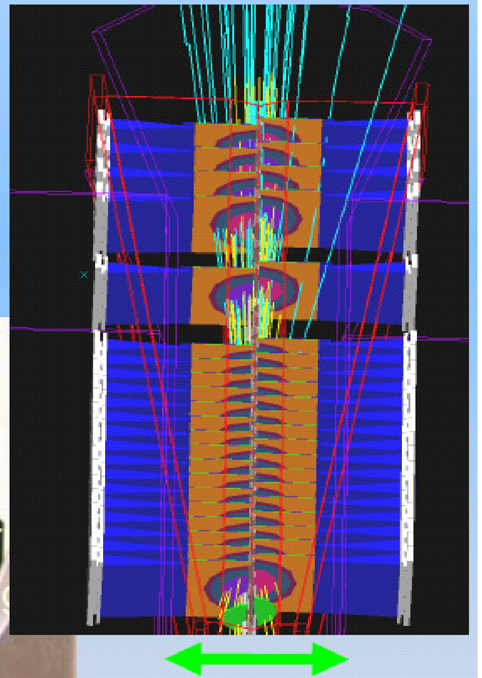
Vertex Locator - VELO

Vertex reconstruction in vacuum

- Silicon strip detectors with r-phi geometry for fast online track reconstruction
- 2 halves, 21 stations, 7mm from beam, with 250μm Al foil between detector and beam vacuum
- Impact parameter resolution: $\sigma_{IP} = 14\mu m + 35\mu m / p_t\,[GeV/c]$







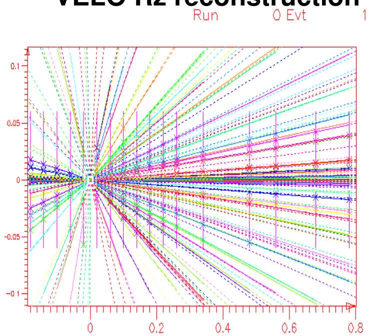
Halves move out during LHC injection

- Dedicated geometry for fast online reconstruction
  - Rz and Rφ projections. Fast Rz reconstruction (tracks are straight lines: R = az+b)
  - But no B field - no momentum

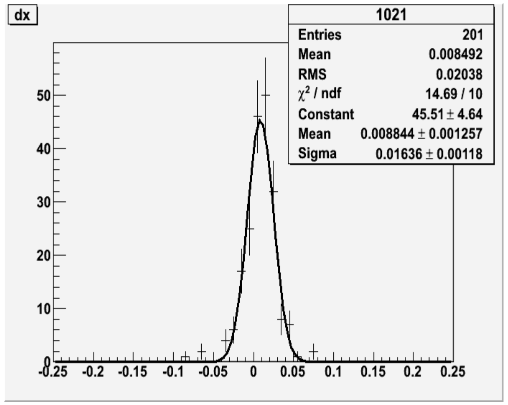
A foretaste of data - VELO misalignment and trigger

- The quality of PV reconstruction is essential for trigger. In first phase of HLT1 a 2D PV is reconstructed and used to reject events with all tracks compatible with PV.
- 2D PV (x,y,z) is reconstructed with RZ VELO tracks. Only half of information is available wrt full 3D tracks.
- The exact φ is not known (only sector π/4), hence the 3D - 2D track transformation is approximate.
- In case of VELO misalignment the shift of 2D PV position is hard to correct.

VELO Rz reconstruction

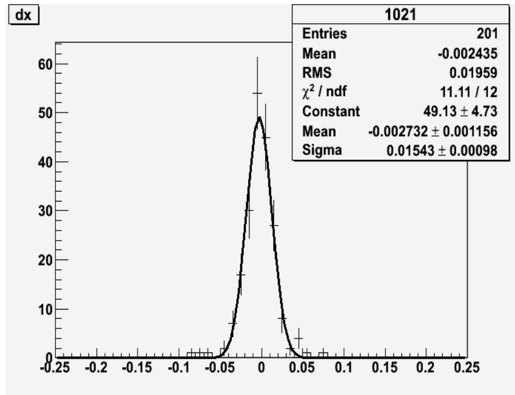


„Standard" reconstruction



PV x - 9 μm bias

Corrected 2D tracks



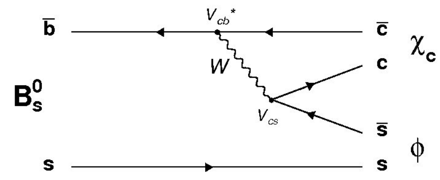
PV x - no bias

Preparing for physics analysis

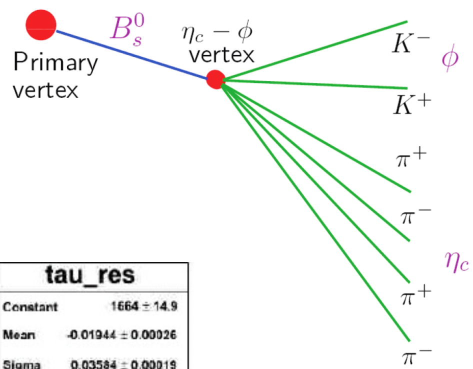
- $B_s \rightarrow J/\psi\varphi$
  - Vector-Vector decay – angular analysis needed to estimate φ_s phase.
- $B_s \rightarrow \eta_c\varphi$, $B_s \rightarrow \chi_c\varphi$, $B_s \rightarrow J/\psi\eta$, $B_s \rightarrow J/\psi f_0$
  - Vector-Scalar decays
  - Final state is CP eigenstate
  - Valuable supplementary measurement of φ_s
- $B \rightarrow D^*a1$
  - Relatively large BF ~ 10^{-4}
  - Supplementary to $B \rightarrow D^*\pi$
- CP violation for beauty baryons $\Lambda_b \rightarrow \Lambda D^0$
- $B \rightarrow DK$ to be resumed.
- …

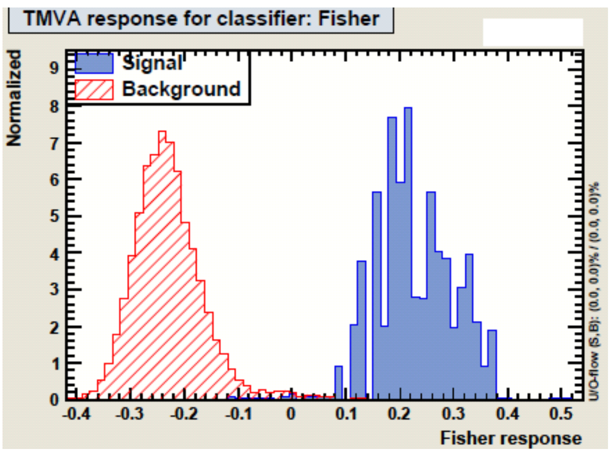
$B_s \rightarrow \chi_c \varphi$ decay - not observed yet

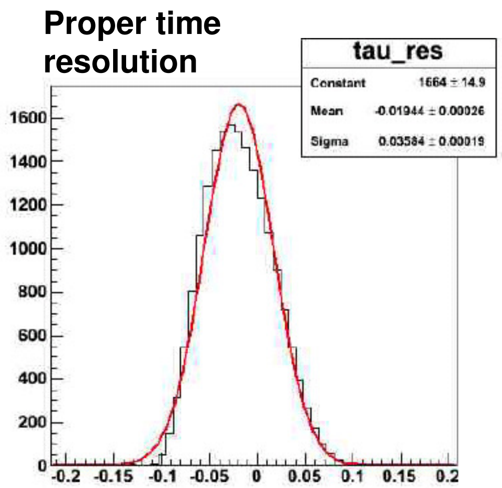
$$\mathcal{A}_{CP}(t) = \frac{-\eta_{\chi_{c0}\phi}\sin(\phi_s)\sin(\Delta M_s t)}{\cosh(\frac{\Delta\Gamma_s t}{2}) - \eta_{\chi_{c0}\phi}\cos(\phi_{CKM})\sinh(\frac{\Delta\Gamma_s t}{2})}$$



- Event selection in two steps
  - Preselection
    - PID, p_T, impact parameter, $\chi 2$ of secondary vertex, flight distance …
  - Mutivariate analysys
    - TMVA on selected parameters





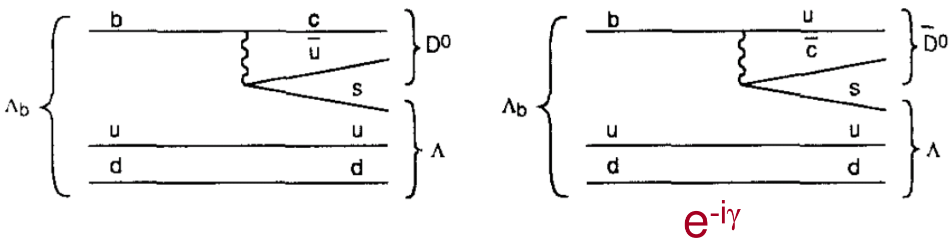


Preliminary results:

- Yearly yield ~2000 of $B_s \rightarrow \chi_c \varphi$ decays @ S/B > 4

CP breaking for beauty baryons

- $\Lambda_b \to \Lambda D^0$ is interesting
  - First observation of CP breaking for baryons
  - No need for b-tagging nor time dependent analysis.
- Study of S/B showed that extraction of this decay is very difficult in LHCb environment
  - Low BF ~10^{-7}, b fragmentation to baryons factor
  - Long lifetime of Λ (most decays outside VELO)
  - Weak discrimination of Λ coming from PV
- Yearly yield ~100 events (Λ decay inside VELO) at small S/B ratio.
- **Conclusion:** very challenging channel, no good prospects.



$\Lambda_b \to \Lambda D^0$
$\Lambda_b \to \Lambda D^{0\sim}$ + CC
$\Lambda_b \to \Lambda D^0_{CP}$

I. Dunietz, Z. Phys. C 56 129 (1992)
A. K. Giri, R. Mohata, M. P. Khanna, hep-ph/0112220 (2002)

Summary

- Cracow groups participated in exiting period of design, reoptimization and development of LHCb.
- Now ready to even more exitintg work with experimental data.