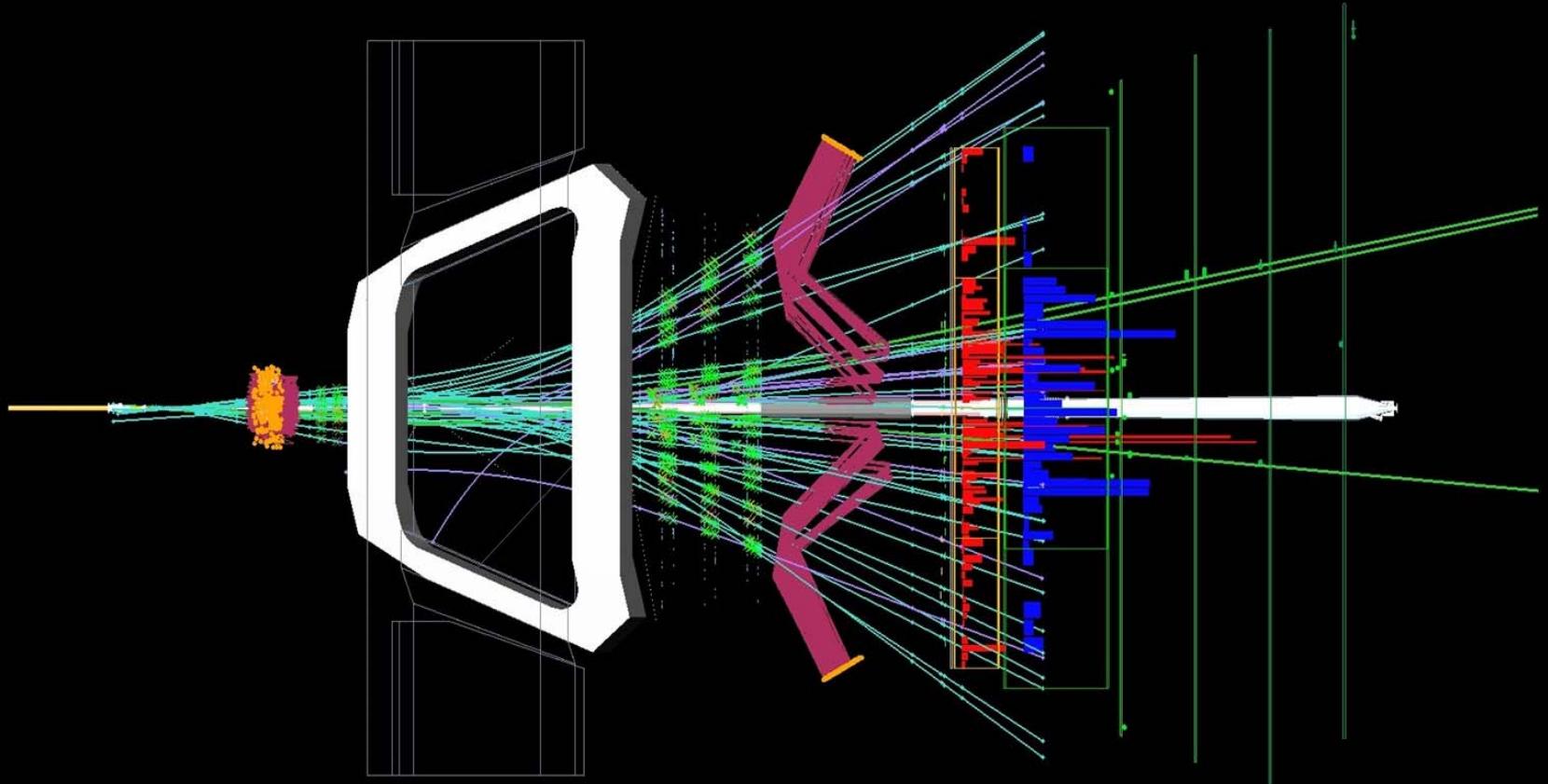


Status of the LHCb experiment and minimum bias physics

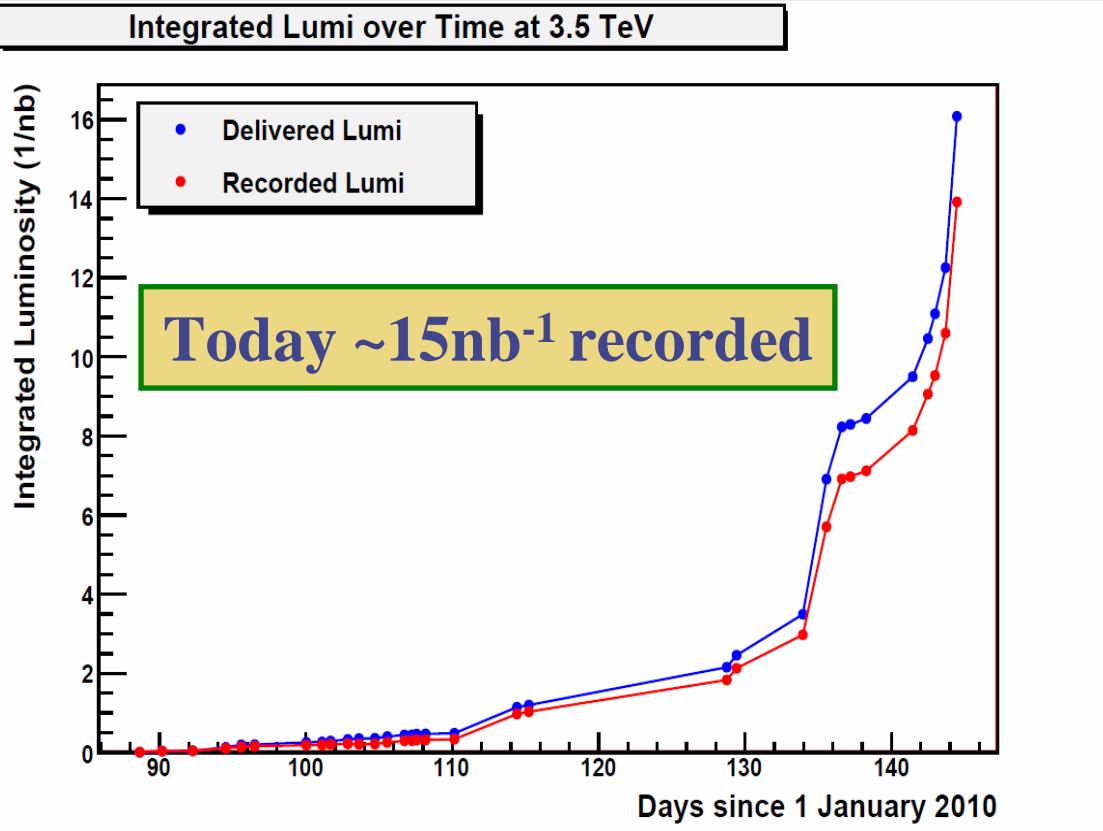


Sebastian Bachman
Heidelberg University
on behalf of the LHCb collaboration

Beauty and Charm at the LHC

LHC is a factory for B- and D-mesons:

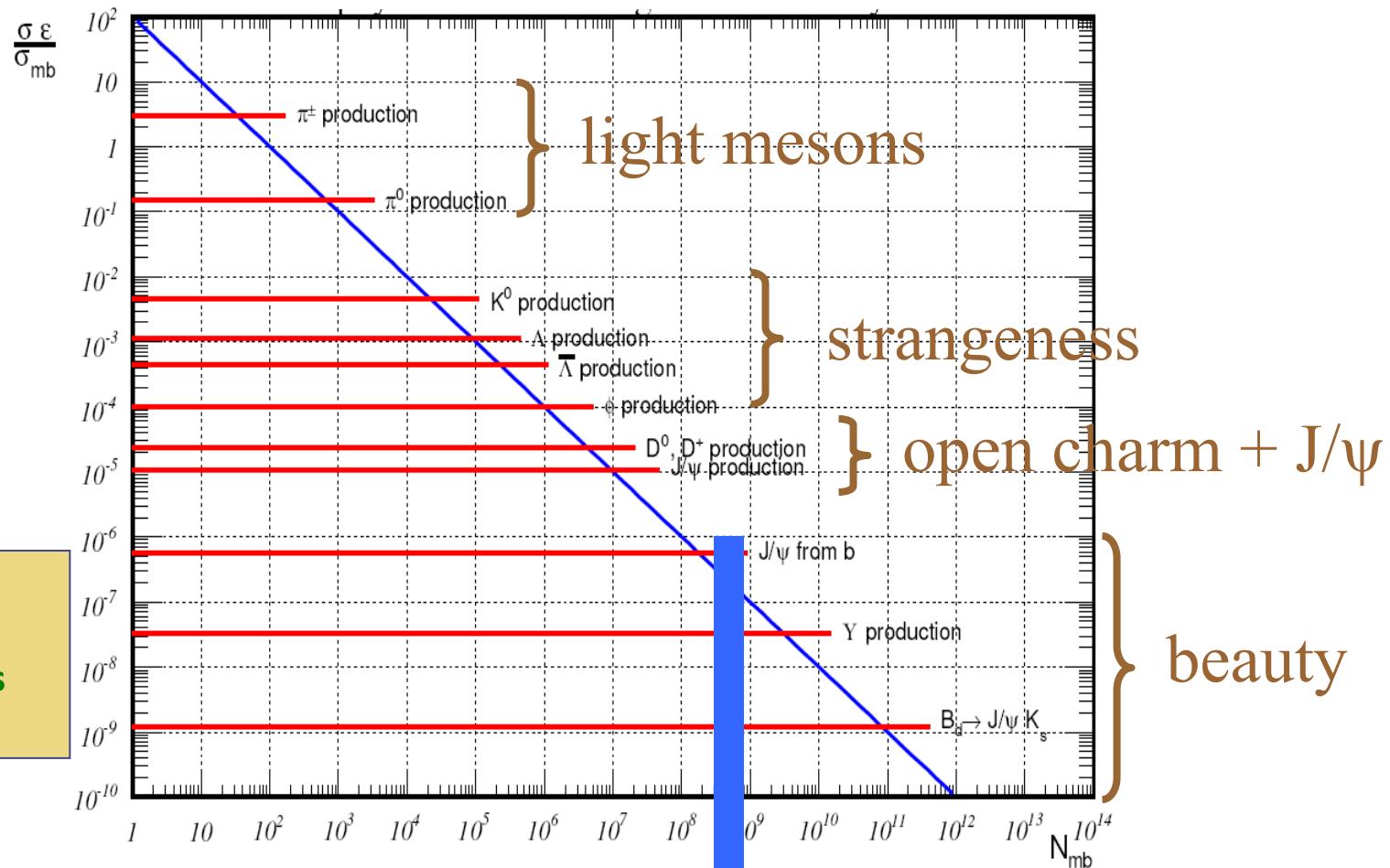
With 1fb^{-1} for 2010/2011 run we expect
 $\sim 2.5 \times 10^{11}$ B-Mesons } $\sqrt{s}=7\text{TeV}$
 $\sim 4 \times 10^{12}$ D-Mesons }



86,5% of delivered luminosity recorded with all detectors in nominal state for data taking.

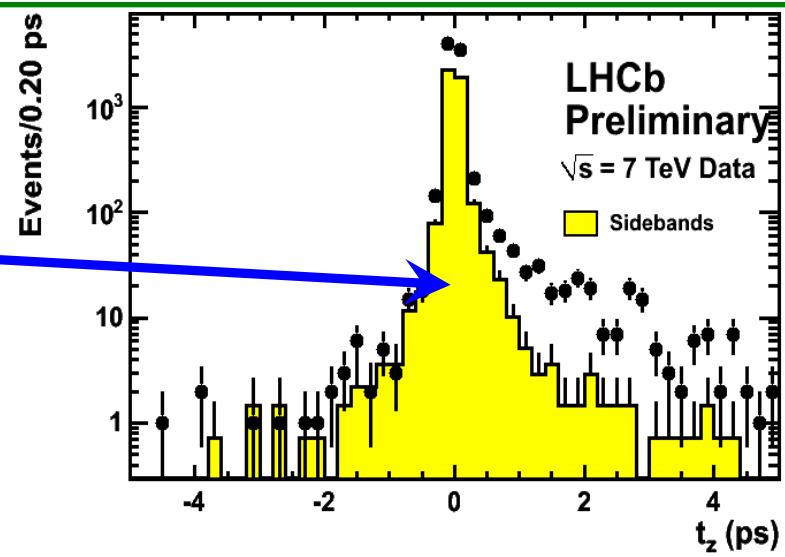
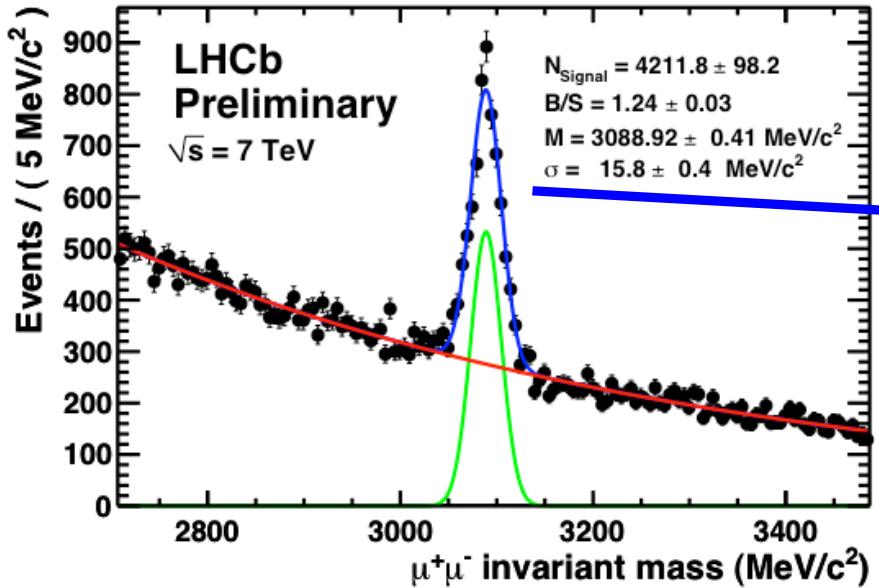
Where we are

Physics reach vs. #minimum bias events



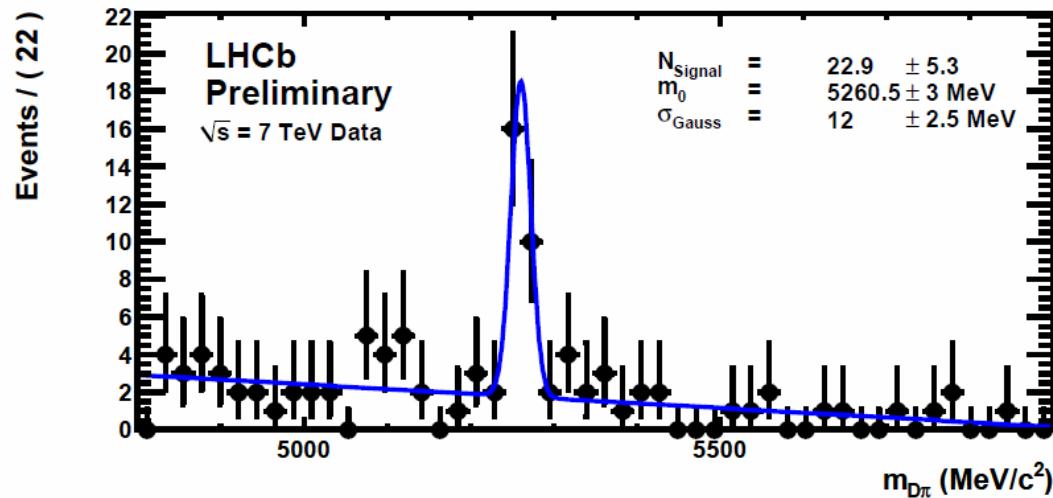
We are here...

A first glimpse of beauty



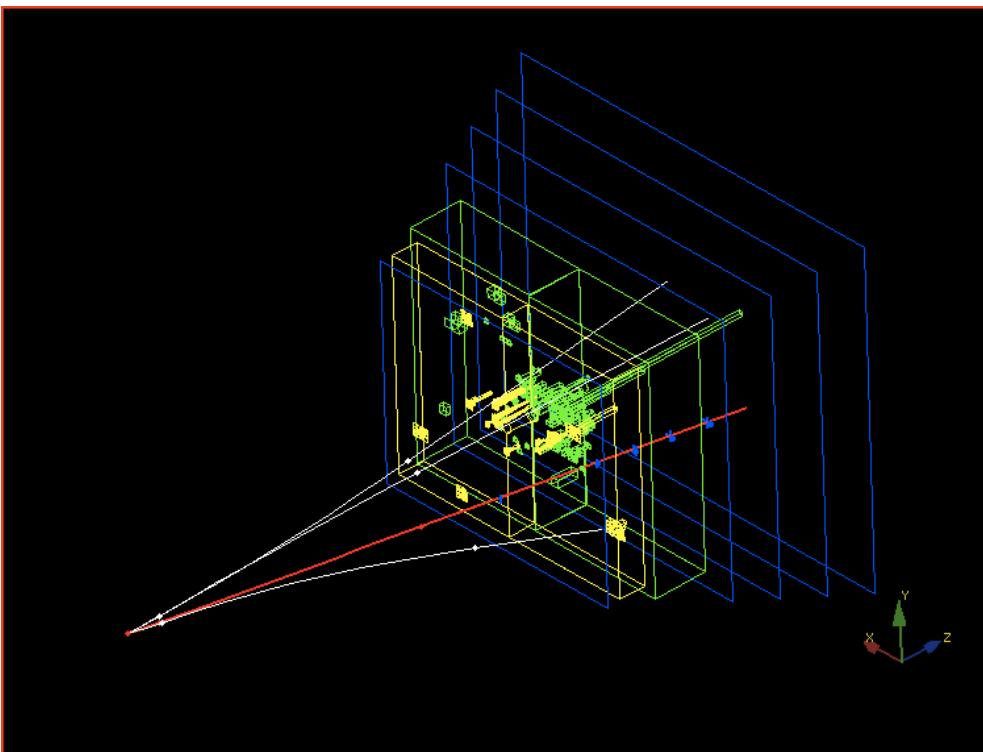
Clear excess of J/ψ candidates
for large positive proper times

$B^0 \rightarrow D^+ \pi^-$
+
 $B^+ \rightarrow D^0 \pi^+$



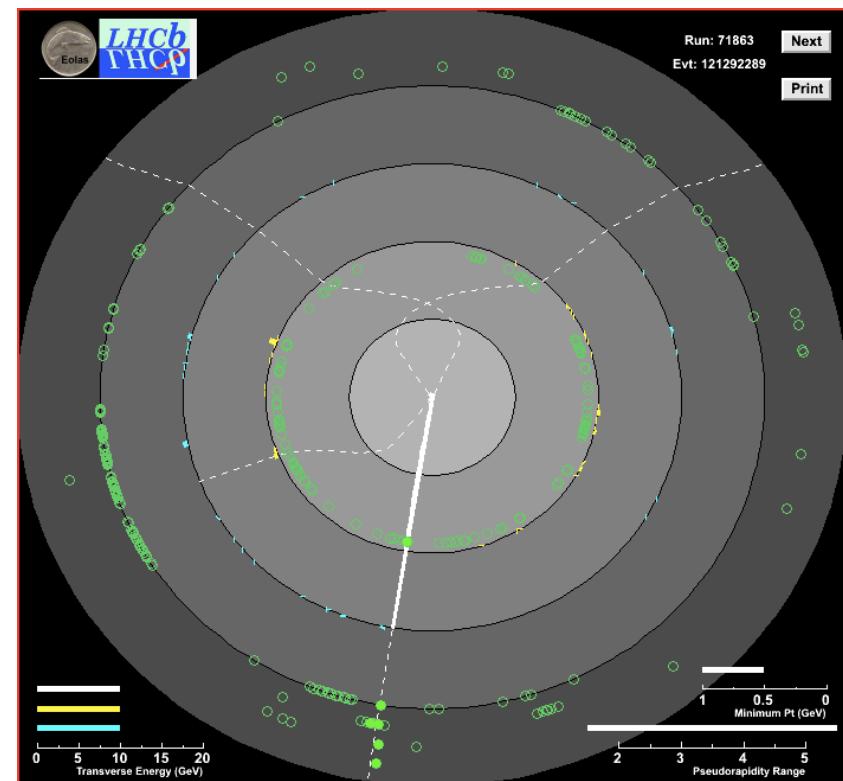
$W \rightarrow \mu\nu$ candidate

$p_T = 39.2 \text{ GeV}/c$

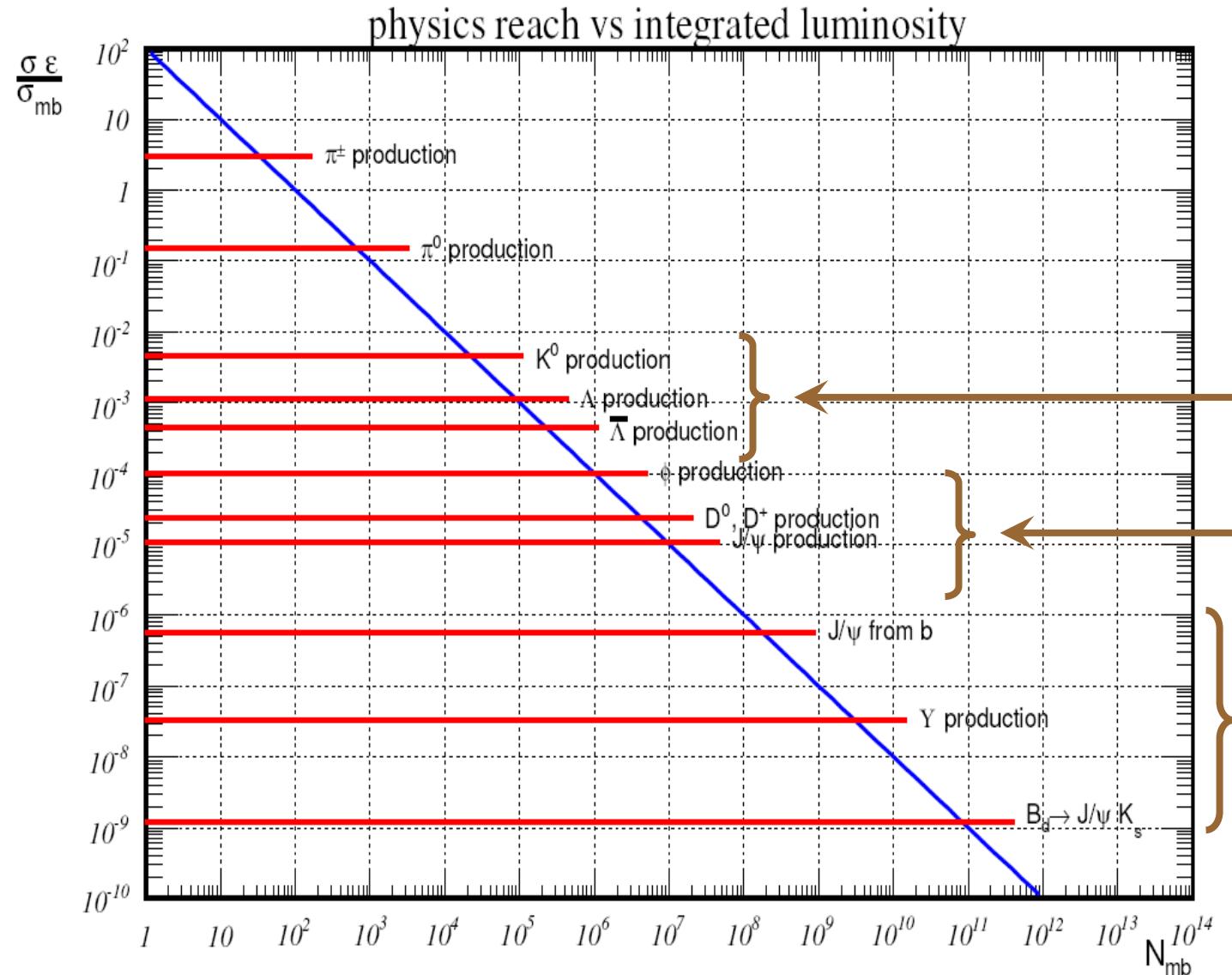


Charge = +1

$\eta = 2.65$



This conference:



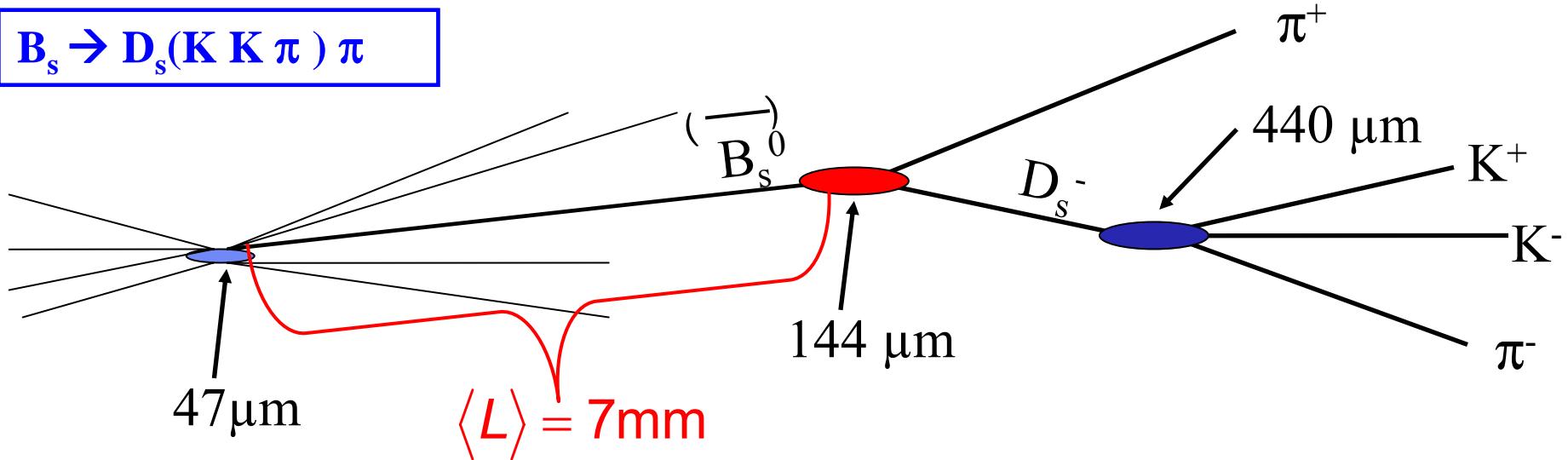
this talk

M.Charles
(this session)

J.van Tilburg
(tomorrow
session)

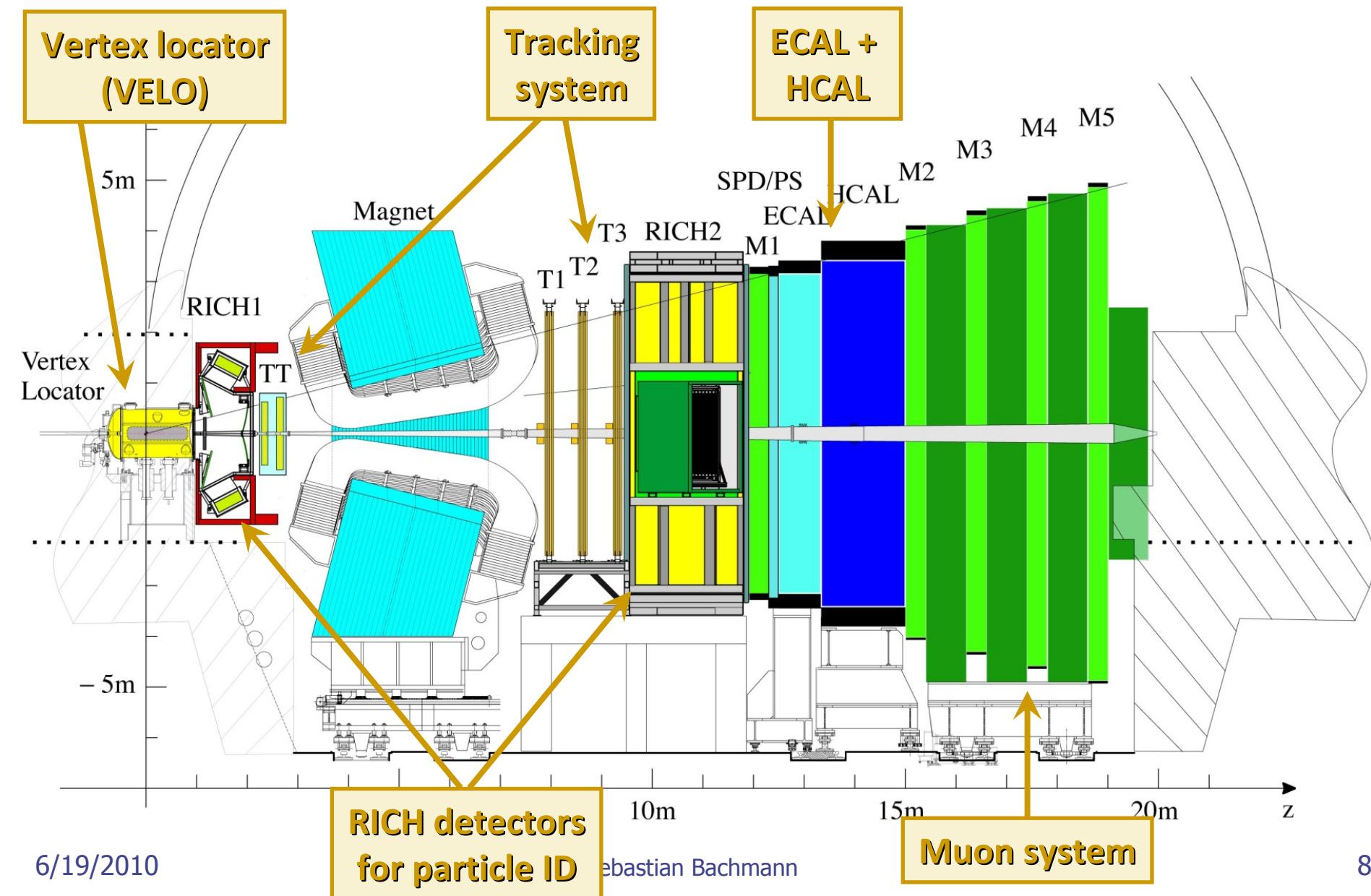
Key ingredients for LHCb

$$B_s \rightarrow D_s(K K \pi) \pi$$



1. Measure proper time:
→ Excellent vertex resolution
2. Background reduction:
→ Robust tracking
+ very good mass resolution
→ Particle identification
3. High statistics:
→ Efficient trigger for hadronic and leptonic final state

LHCb detector

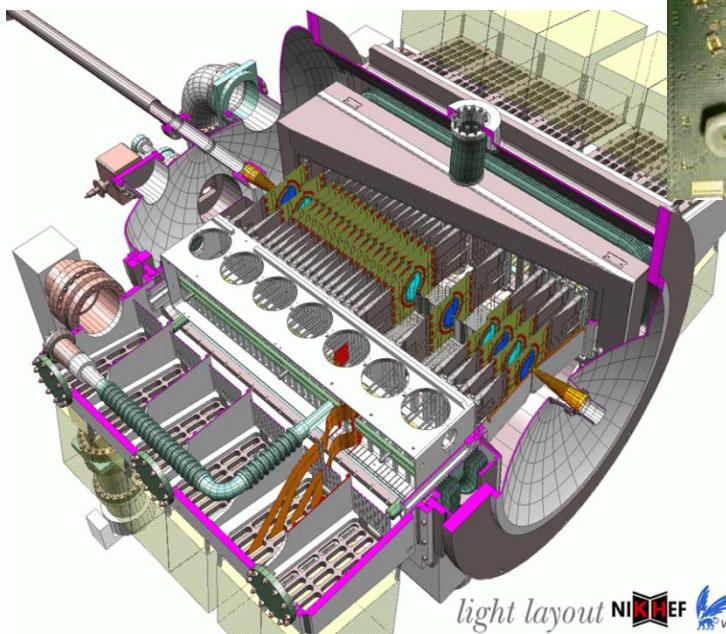
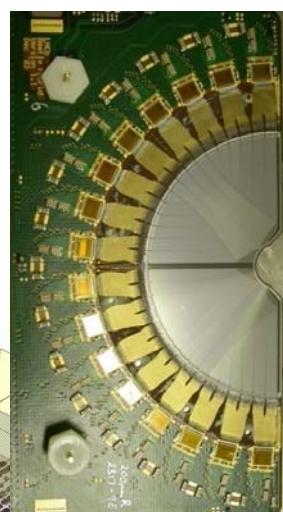


1. Measure proper time: → Excellent vertex resolution

2. Background reduction:
 - Robust tracking
 - + very good mass resolution
 - Particle identification
3. High statistics:
 - Efficient trigger

Vertex locator (VELO):

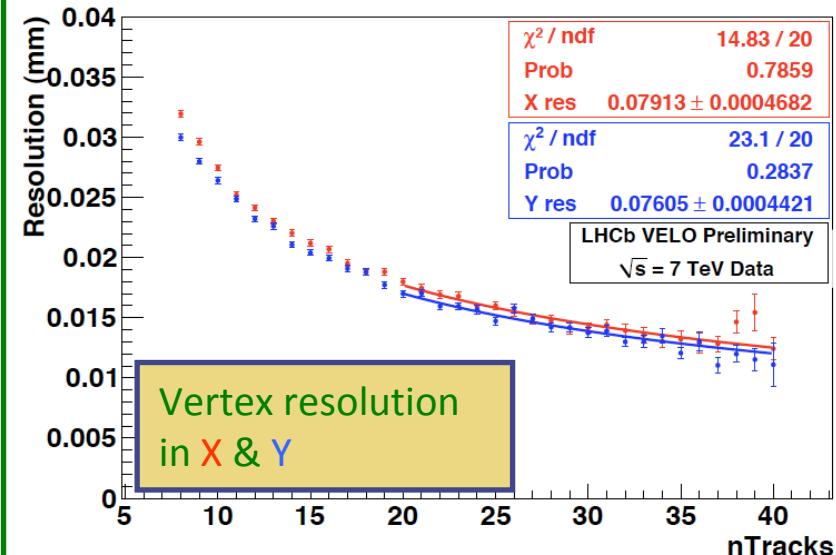
- 21 sensors, r-phi geometry
- moved in when beam stable
- approaches beam at 8mm



light layout NIKHEF
vu

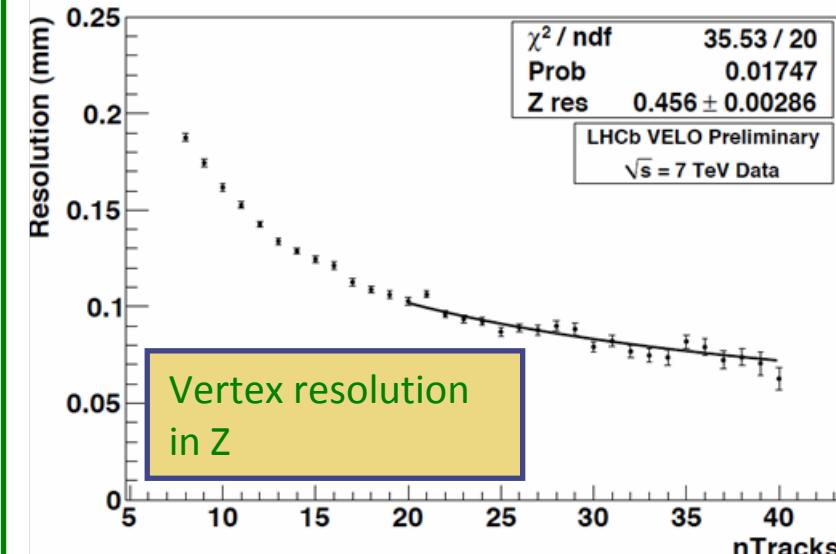
Vertex resolution:

X and Y resolution



Vertex resolution
in X & Y

Z resolution



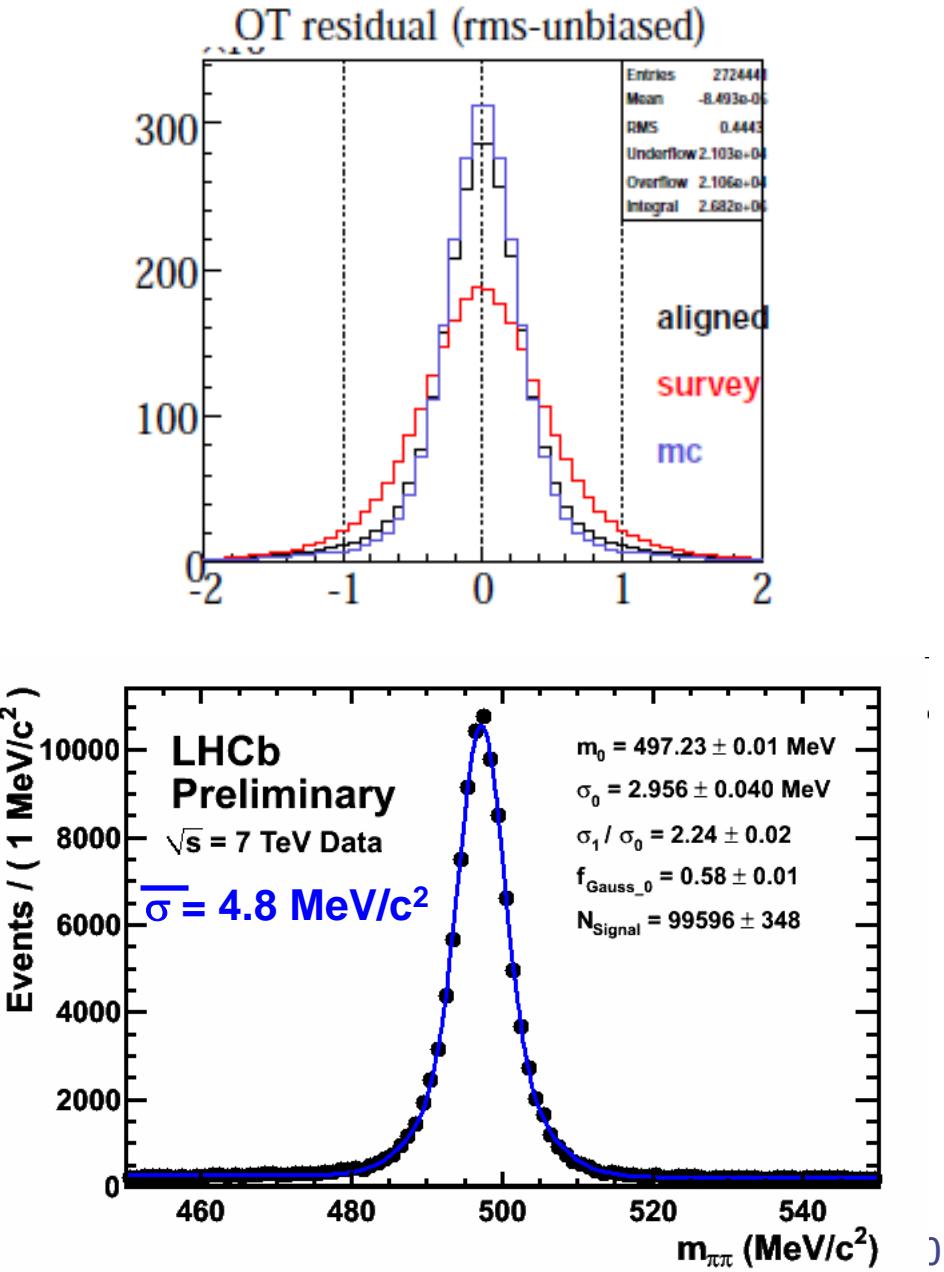
Vertex resolution
in Z

Tracking performance:

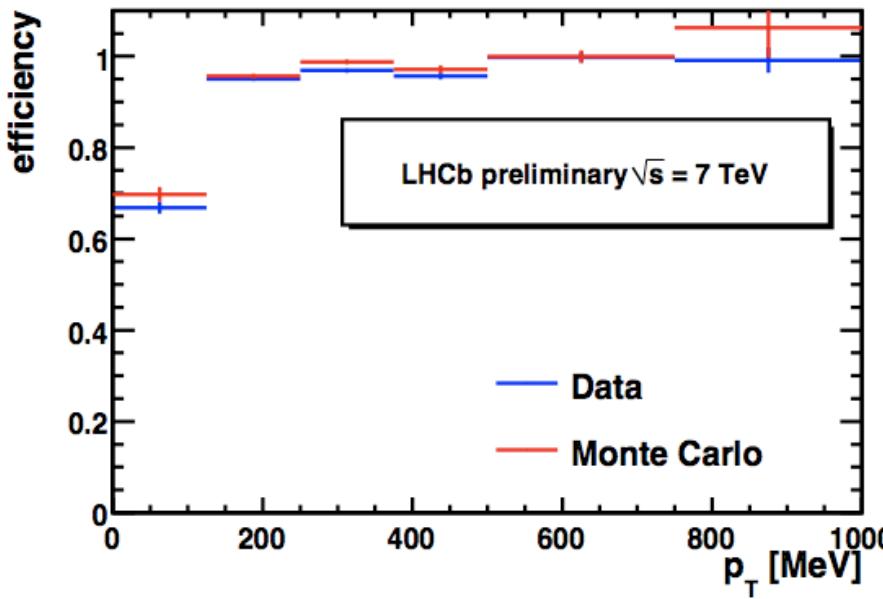
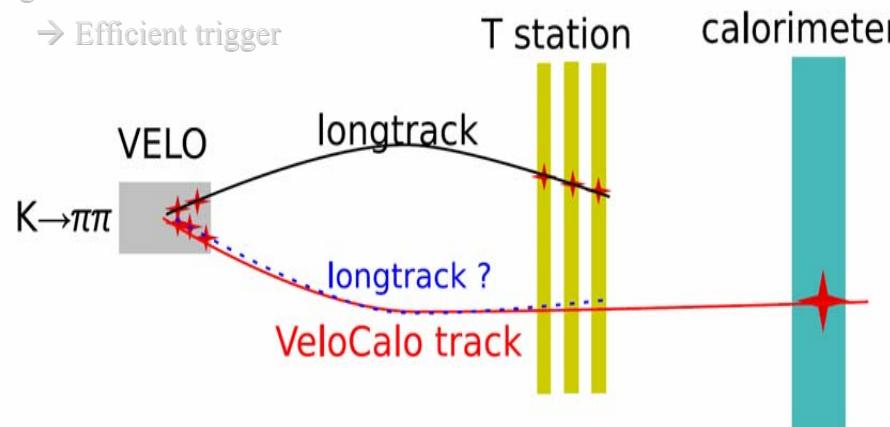
1. Measure proper time:
→ Excellent vertex resolution
2. **Background reduction:**
 - Robust tracking
 - + very good mass resolution→ Particle identification
3. High statistics:
→ Efficient trigger

Tracking system

- magnet with $\int B dl = 4\text{Tm}$
- tracking station made of Si-sensors before magnet
- 3 tracking stations behind magnet with Si-sensors (inner region) and straw tube detectors (outer region)



- Measure proper time:
→ Excellent vertex resolution
 - Background reduction:**
 - Robust tracking
 - + very good mass resolution
 - Particle identification
3. High statistics:
→ Efficient trigger



Tracking efficiency:

Strategy: Determine ϵ from MC
Use data for validation

1. Select K_s from long track + VeloCalo track
 2. Check if tracks are found in tracking stations
 3. Determine efficiency from
- $$\epsilon = \frac{\# \text{ tracks } (\text{VELO} + \text{IT/OT+CALO})}{\# \text{ tracks } (\text{VELO} + \text{CALO})}$$

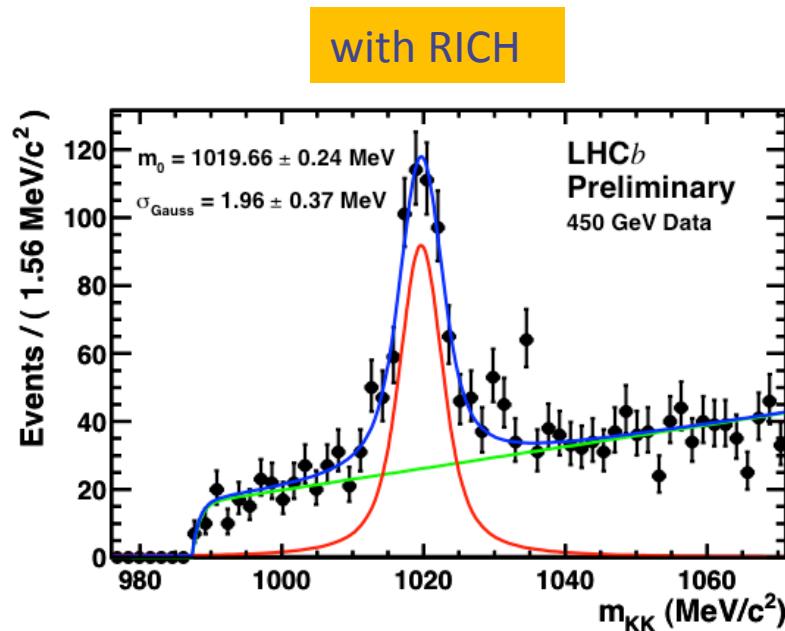
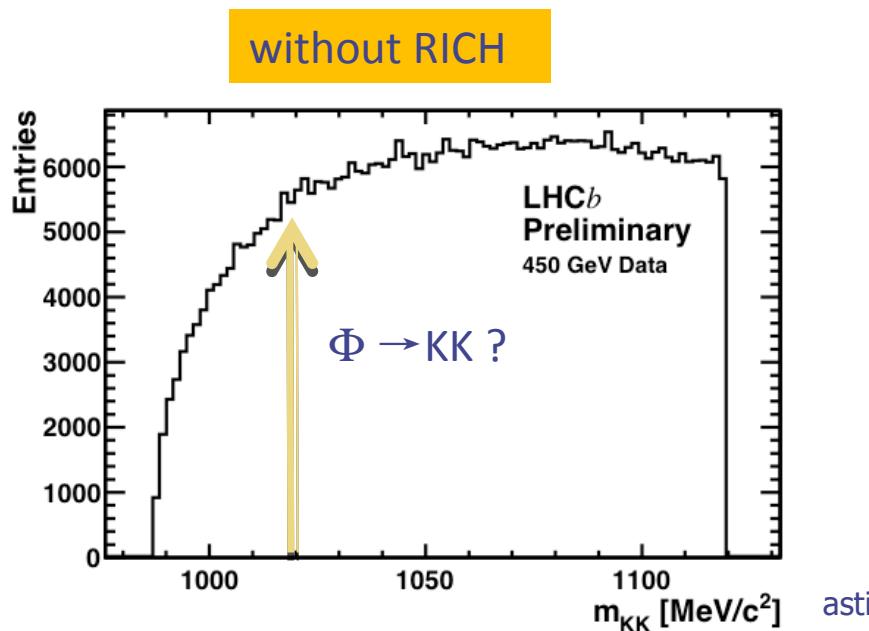
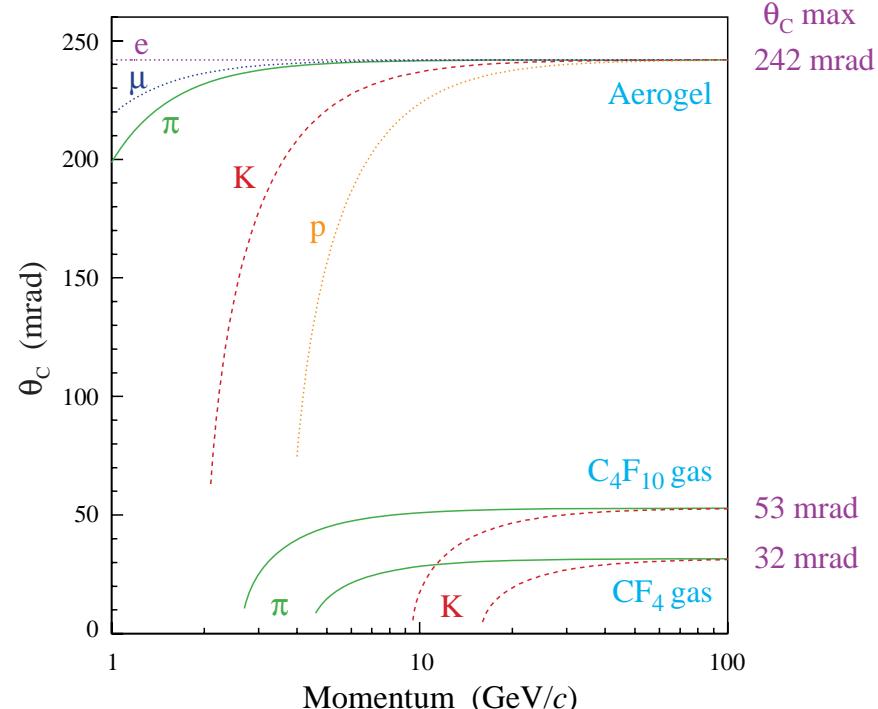
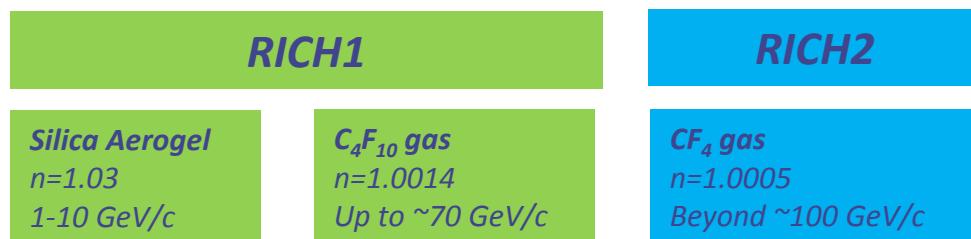
Limitations of method:

- VELO tracking eff. is not probed
- Restrictive phase-space, i.e. K_S decay products phase space

- Measure proper time:
→ Excellent vertex resolution
- Background reduction:
→ Robust tracking
+ very good mass
resolution

→ Particle identification (RICH)

- High statistics:
→ Efficient trigger



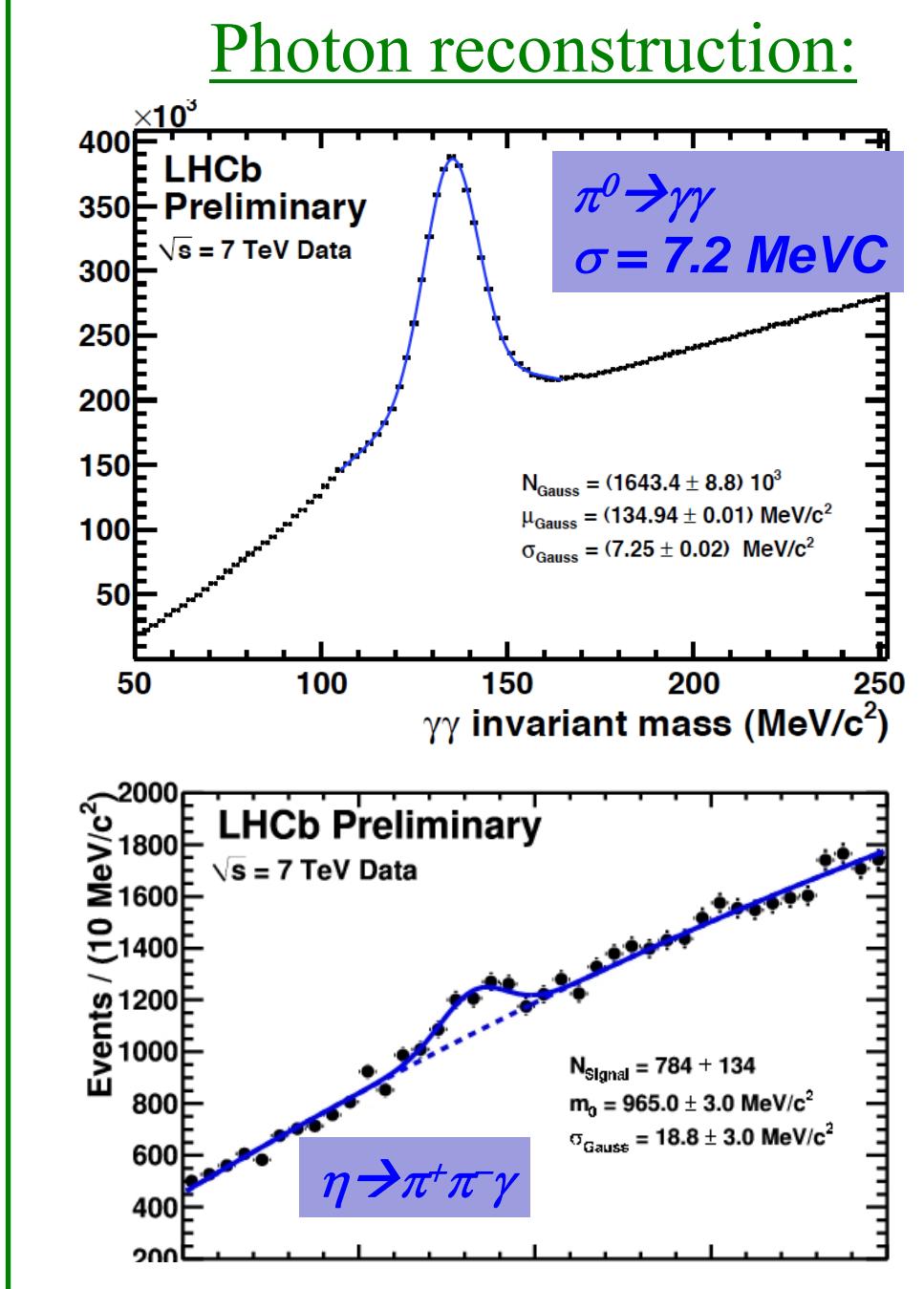
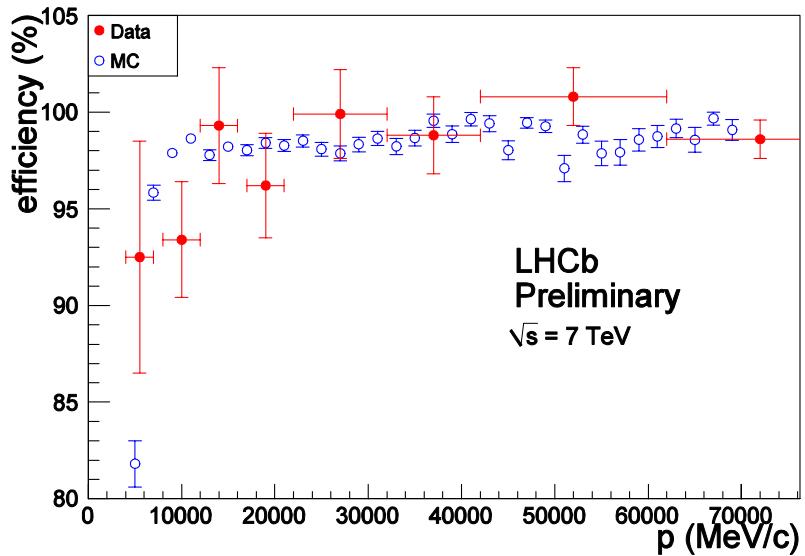
1. Measure proper time:
→ Excellent vertex resolution
2. Background reduction:
→ Robust tracking
+ very good mass resolution
3. High statistics:
→ Efficient trigger

→ Particle identification

PID with muon system:

Calibration:

$J/\Psi \rightarrow \mu^+ \mu^-$ (tag & probe):

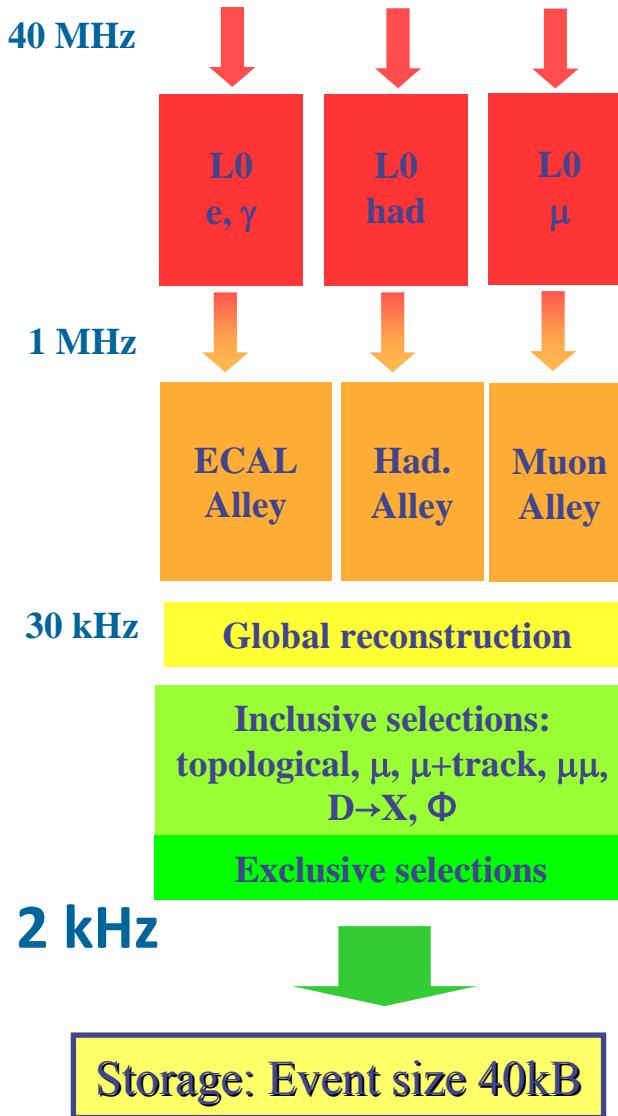


1. Measure proper time:
→ Excellent vertex resolution
2. Background reduction:
→ Robust tracking
+ very good mass
resolution
3. → Particle identification

3. High statistics: → Efficient trigger

2010 run:

- o reduced luminosity allows to use lower cuts
→ improved efficiencies
- o good opportunity for charm physics.
- o special “micro-bias” trigger.



Level-0

‘High-pt’ signals in calorimeter & muon Systems.

HLT1

Confirm L0 signals by matching L0 candidates to tracks.

HLT2

Full detector information available.

HLT2 does full reconstruction and loose selection of B- and D-candidates.

Minimum bias physics

First physics@LHCb:

- Production measurements,
e.g. strange, charm, bottom.
- Multiplicities of charged
particles
- Particle/Antiparticle
asymmetries

This talk:

Strangeness production, i.e.

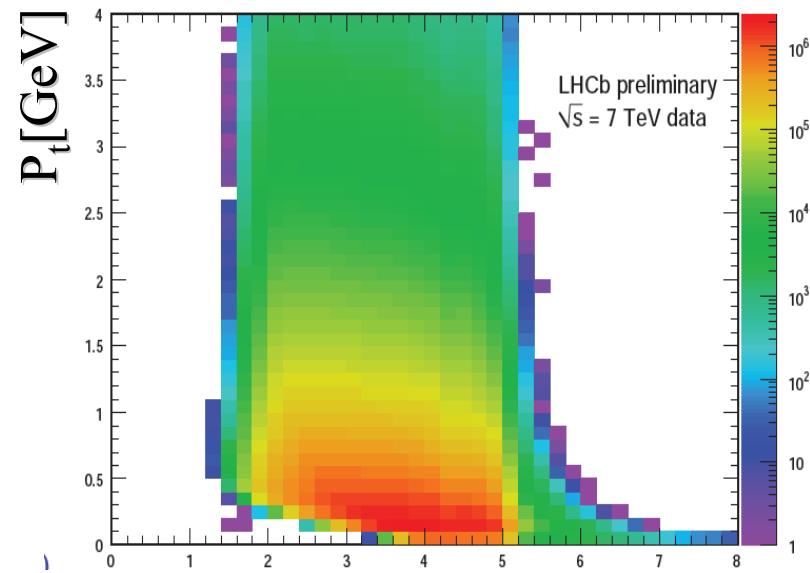
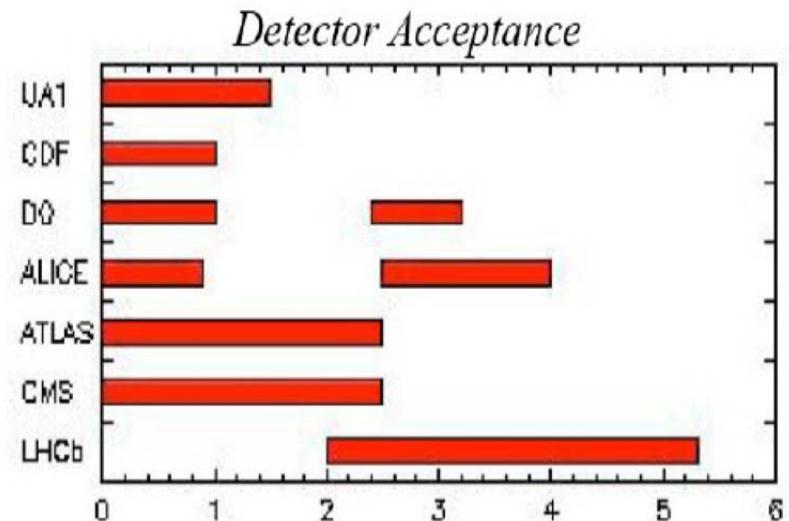
- K_s production @
 $\sqrt{s}=900\text{GeV}$ (2009 data)
- Measurement of $\bar{\Lambda}/\Lambda$ ratio
at $\sqrt{s}=900\text{ GeV}$ and
 $\sqrt{s}=7\text{ TeV}$ (2010 data)

Motivation:

- o Strange quarks are no valence quarks
→ excellent test field for fragmentation models
- o Particle/Antiparticle ratios help to understand
 1. which partons are carriers of the baryon number,
 2. the baryon number flow in inelastic hadronic collisions.

Acceptance@LHCb

LHCb covers unique range in rapidity (2-5) and p_t (down to 200MeV)



Prompt K_s production: Analysis idea

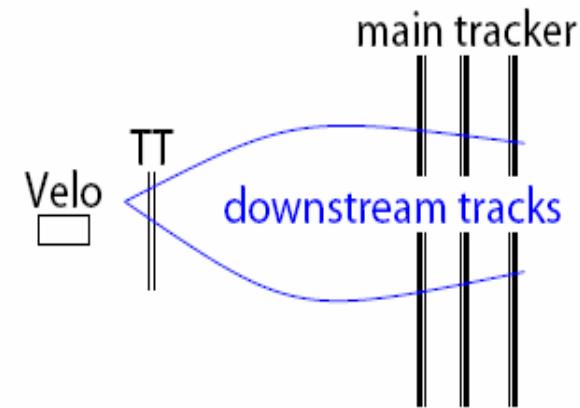
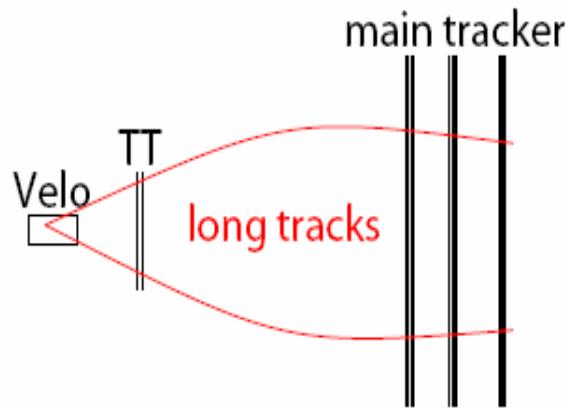
Measure σ_{K_s} in bins of p_t and y :

$$\frac{d^2\sigma_{K_s}(p_t, y)}{dp_t dy} = \frac{N_{K_s}(p_t, y)}{\int L dt \cdot \varepsilon_{trig}(p_t, y) \cdot \varepsilon_{reco}(p_t, y) \cdot \Delta p_t \cdot \Delta y}$$

- o $N_{K_s}(pt, y)$ and $\int L dt$ from data.
- o $\varepsilon_{reco}(pt, y)$ and $\varepsilon_{trig}(pt, y)$ from MC
 - + data driven validation

Event selection: Long vs. downstream tracks

Two approaches for event selection:



Particles reconstructed in
Velo, TT and main tracker:

Pro: better resolution

Con: less statistics

(most K_s decay outside VELO,
VELO half open @900GeV)

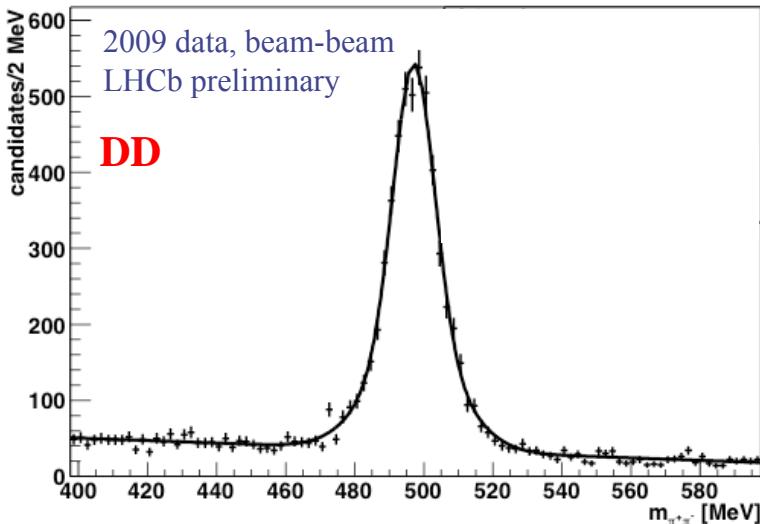
Particles reconstructed in
TT and main tracker:

Pro: better statistics

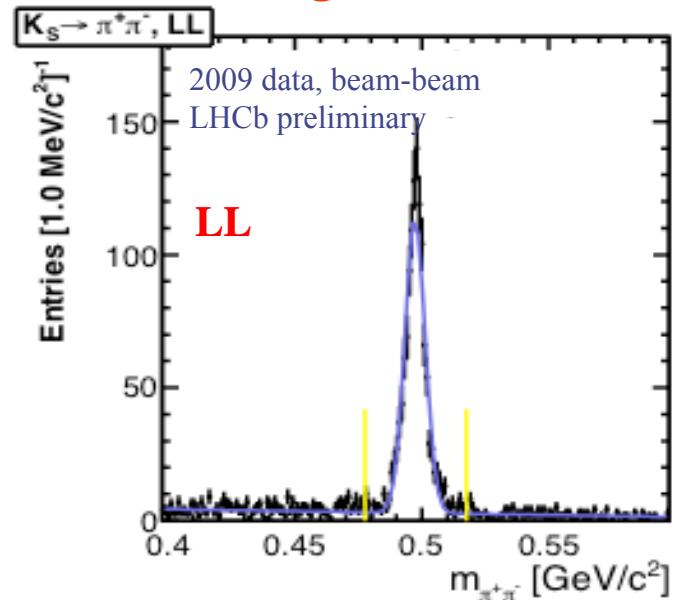
Con: worse resolution

Event selection:

Downstream tracks:



Long tracks:



	DD	LL
Mass resolution (MeV/c ²)	~ 9.3	~ 4.0
Total yield in beam-beam	4864 ± 84	1196 ± 36
Total yield in beam-gas	56 ± 10	15 ± 6

- o Take most precise result for each bin in p_t and y
- o Signal extraction from fit, sideband subtraction used for study of systematics
- o Beam gas interactions reduced by cuts on vertex region and statistically subtracted

Luminosity measurement

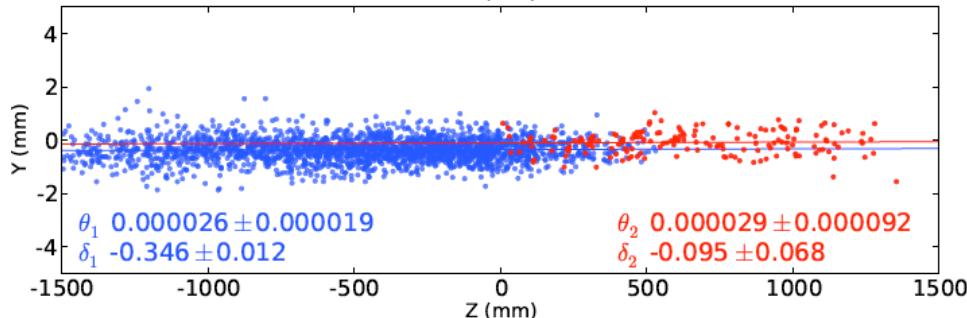
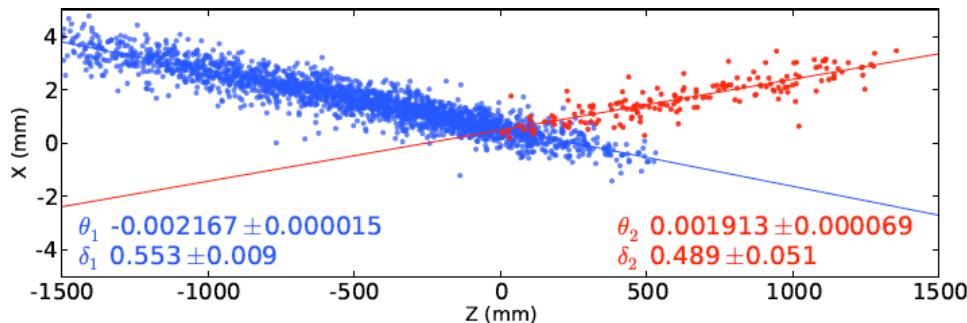
- Luminosity is given by:

$$L = f \sum_{i=1}^N \frac{n_{1i} \cdot n_{2i}}{4\pi \sigma_{x,i} \cdot \sigma_{y,i}}$$

(some refinement needed, e.g. crossing angle due to LHCb dipole magnet, differences in transverse size, beams not head-on...)

- Idea:

1. Get beam currents from machine measurements (BCT).
2. Use Velo to measure beam size, positions and angles in beam-gas.



Measured luminosity
in data sample:

$$L_{\text{int}} \text{ (2009)} = 6.8 \pm 1.0 \mu\text{b}^{-1}$$

Dominant systematic uncertainties:

Currents: 12%

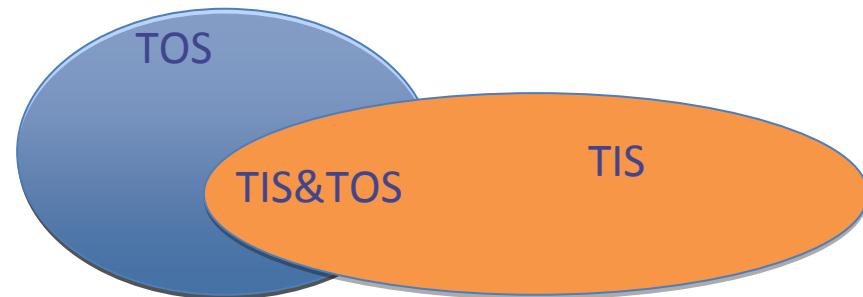
Width: 5%

Positions: 3%

Angles: 1%

Trigger efficiency

- Trigger efficiency measured on data
Use two uncorrelated classes
of events:
 - trigger on Signal (TOS)
 - trigger independent of signal (TIS)

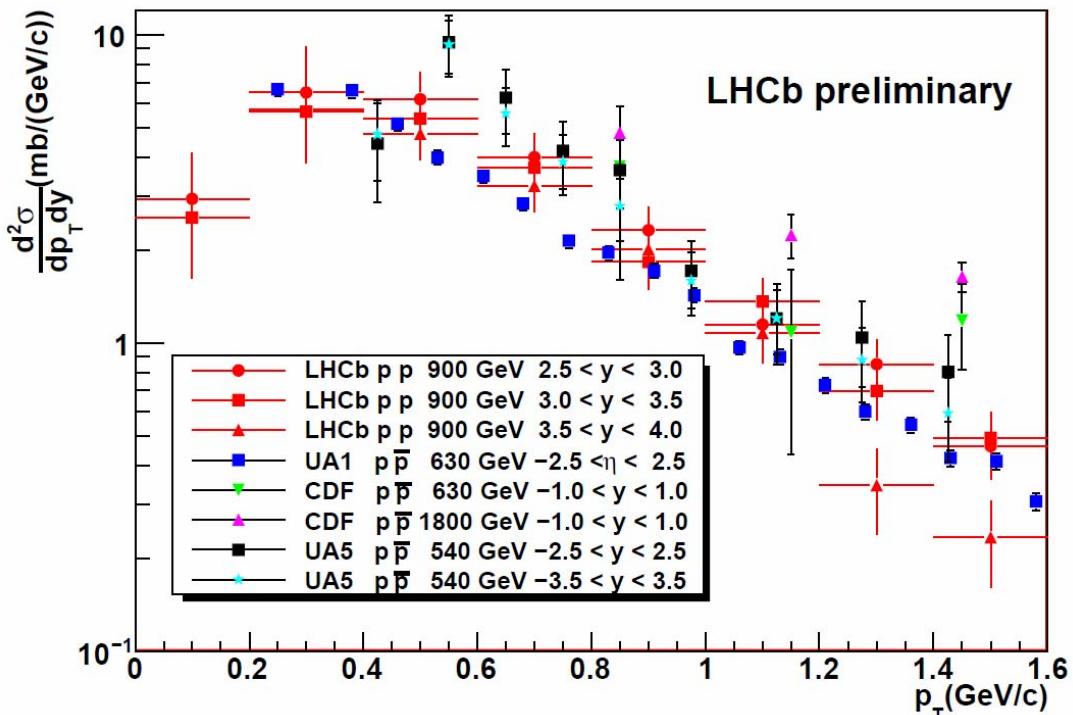
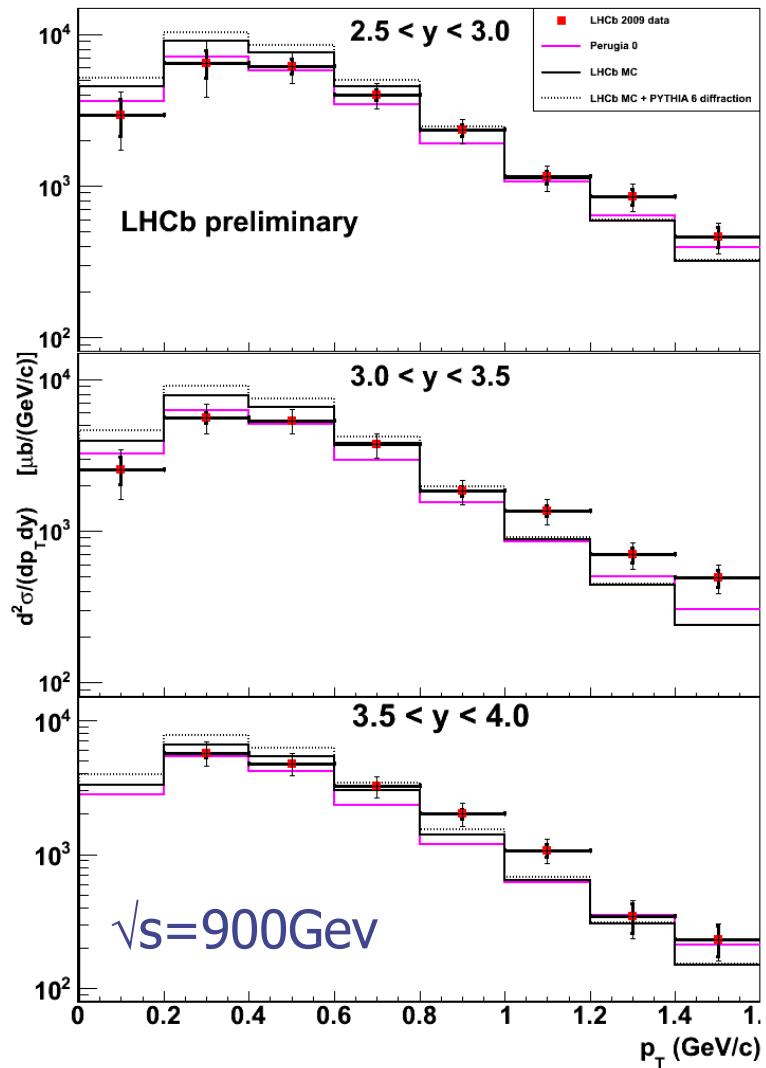


$$\varepsilon_{trig}^{TOS}(p_t, y) = \frac{N_{TIS} \cap N_{TOS}}{N_{TIS}}$$

$$\varepsilon_{trig}^{TIS}(p_t, y) = \frac{N_{TIS} \cap N_{TOS}}{N_{TOS}}$$

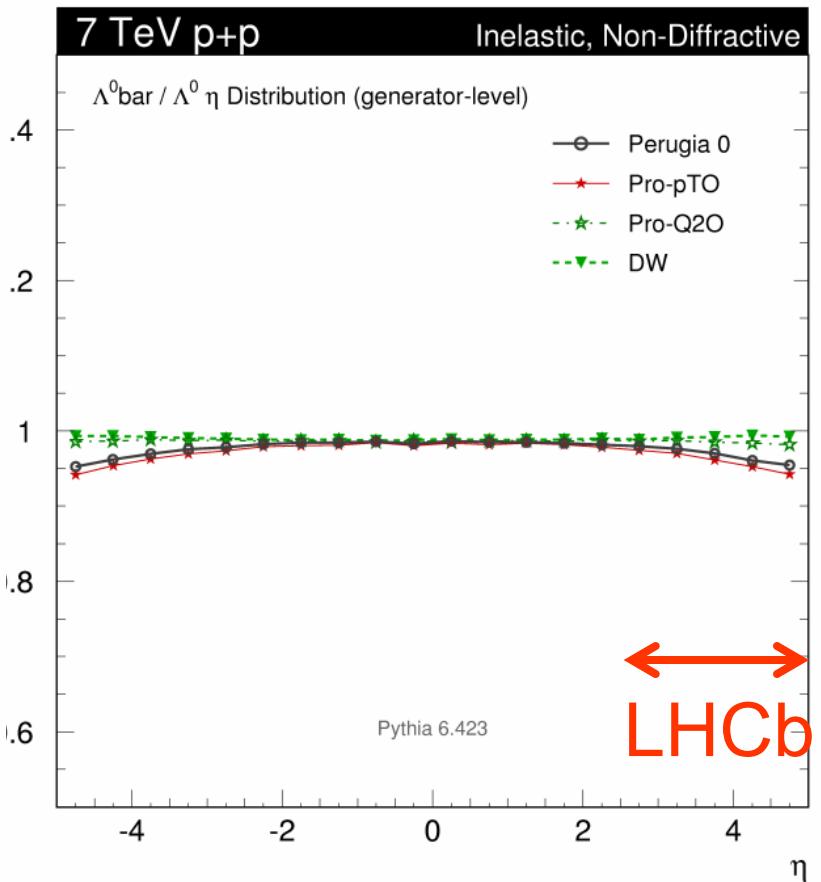
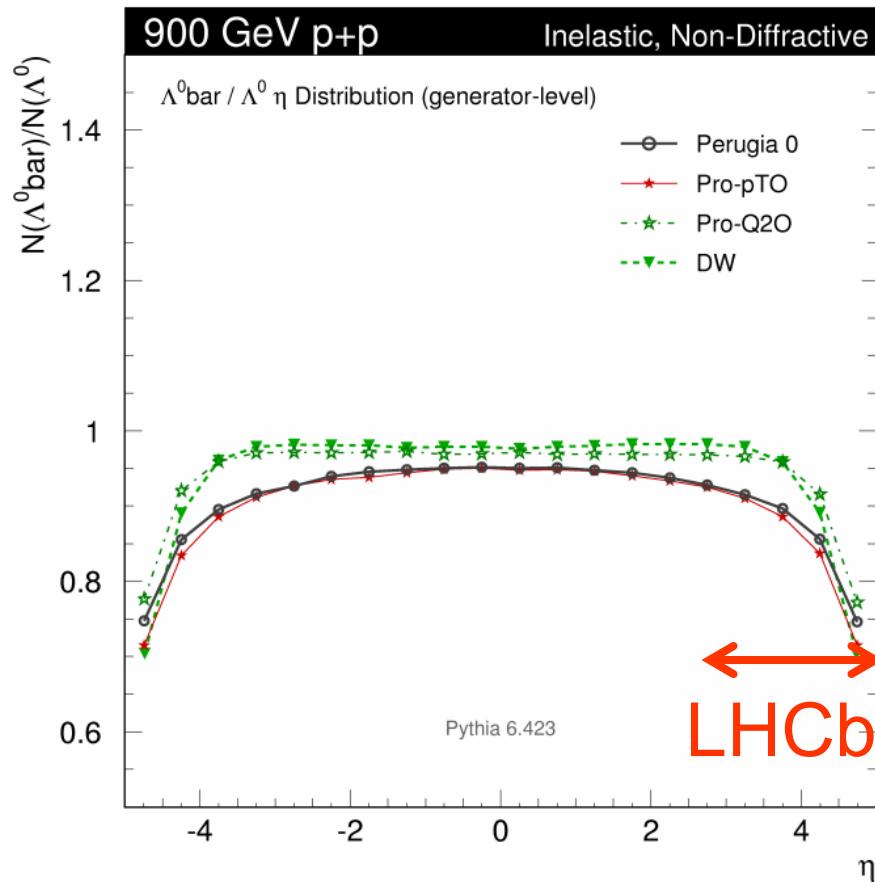
- no measurement in bins of (p_t , y)
due to lack of statistics
→ use trigger emulation of MC
and crosscheck with data in
1D projections.

Results for prompt K_s production



- o Statistical error $\sim 10\%$ (dependent on bin)
- o Main systematic uncertainties:
 - luminosity (15%)
 - data/MC agreement (10%)
 - fit stability (4%)
 - stability of selection cuts (4%)
 - trigger (2,5%)

Predictions for $\bar{\Lambda}/\Lambda$ ratio



taken from <http://home.fnal.gov/~skands/leshouches-plots/>

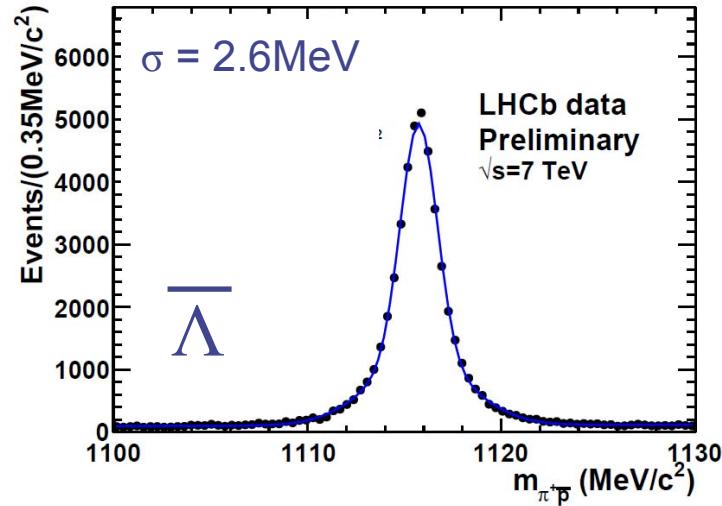
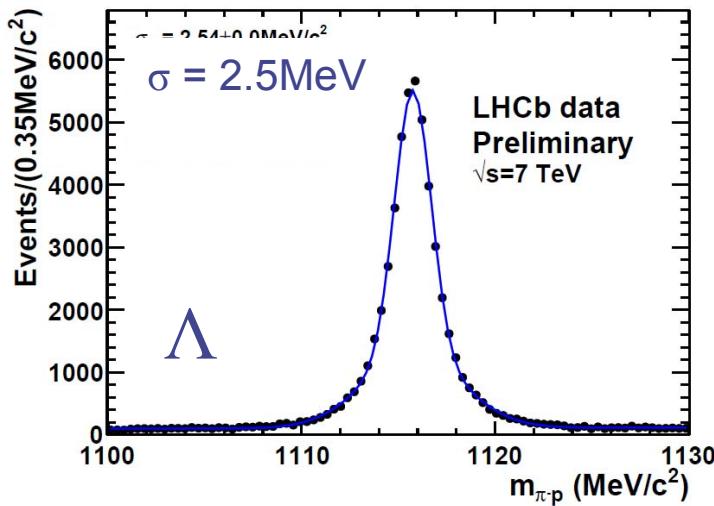
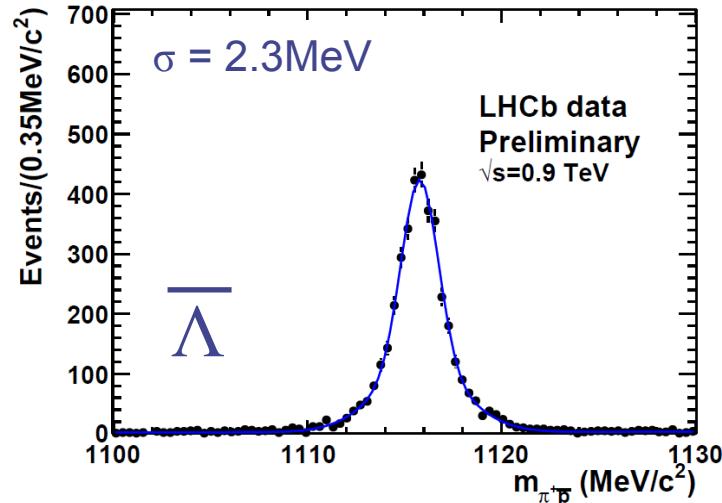
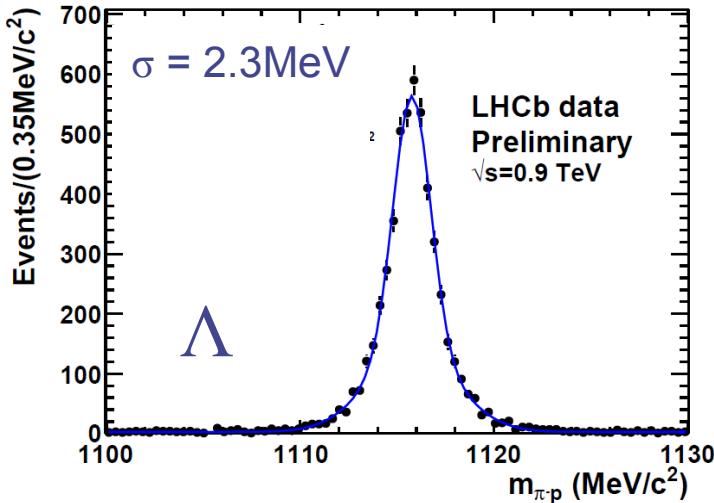
Event selection

- Event selection similar to K_s analysis,
but using only long tracks.
- Armenteros-Podolansky variable used for
selection of $\bar{\Lambda}$ and Λ .
- No PID used.
- Pointing of Λ 's to primary vertex required.
- Data for both magnet polarities analysed seperately
 \rightarrow consistent results

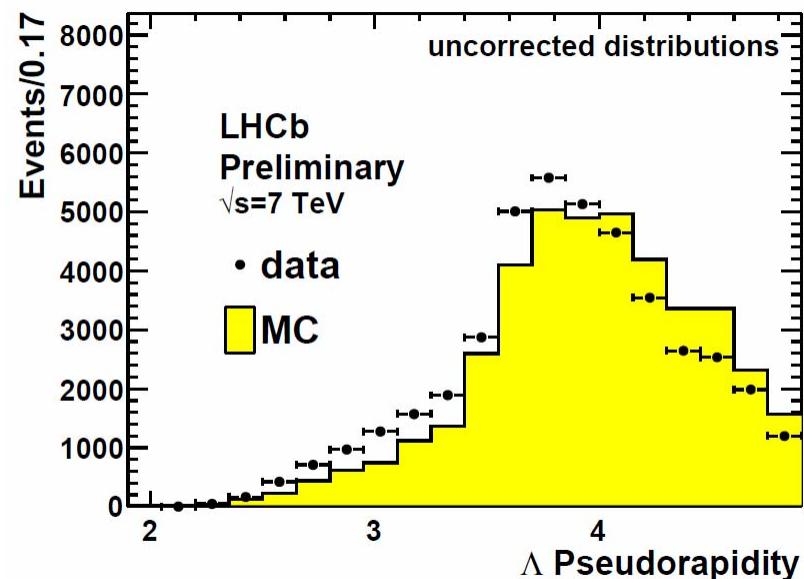
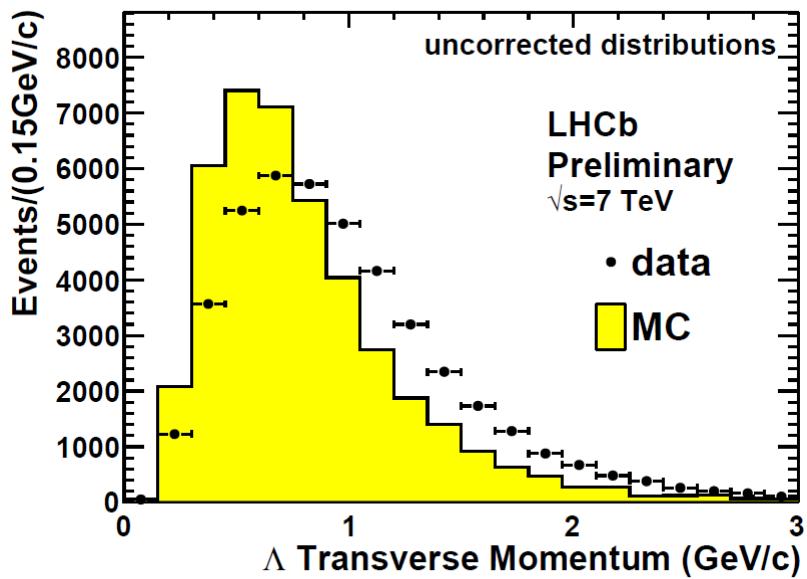
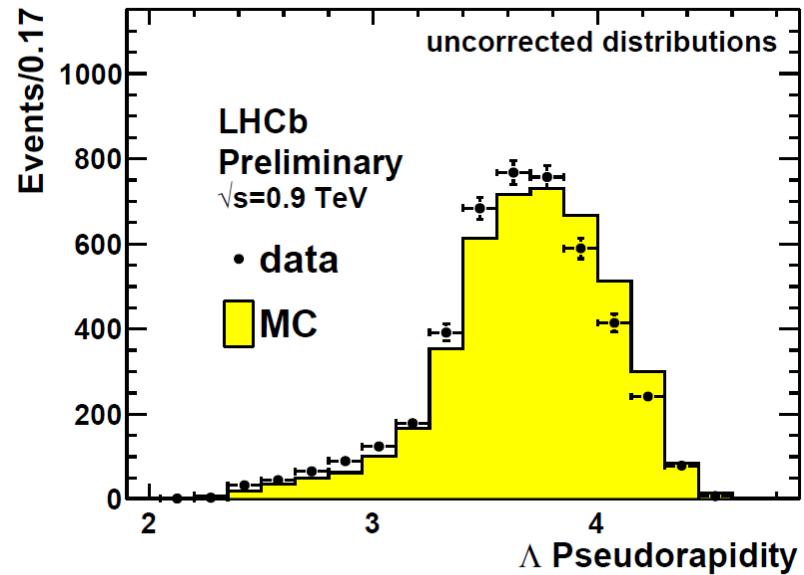
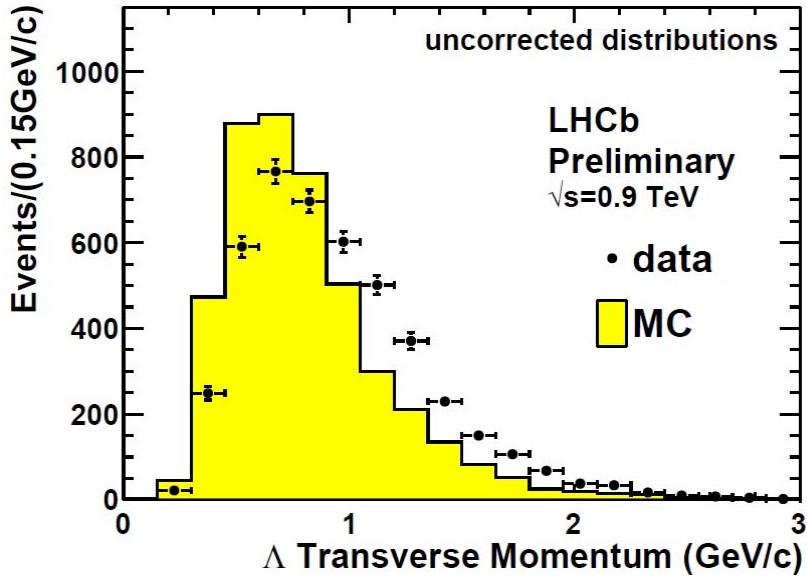
Selected events:

	0.9 TeV field up data	0.9 TeV field down data	7 TeV field up data	7 TeV field down data
Λ	4803	4421	20790	24815
$\bar{\Lambda}$	3629	3173	19115	22077

Invariant mass for Λ and $\bar{\Lambda}$



p_T and pseudorapidity

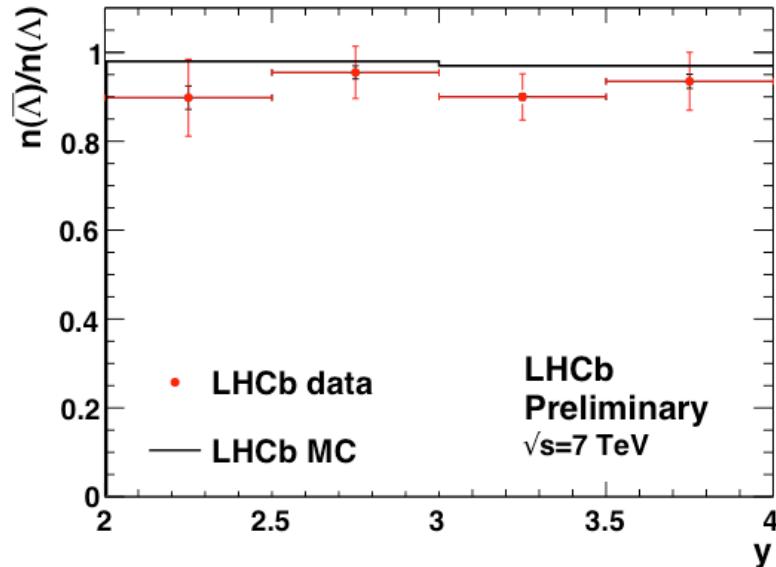
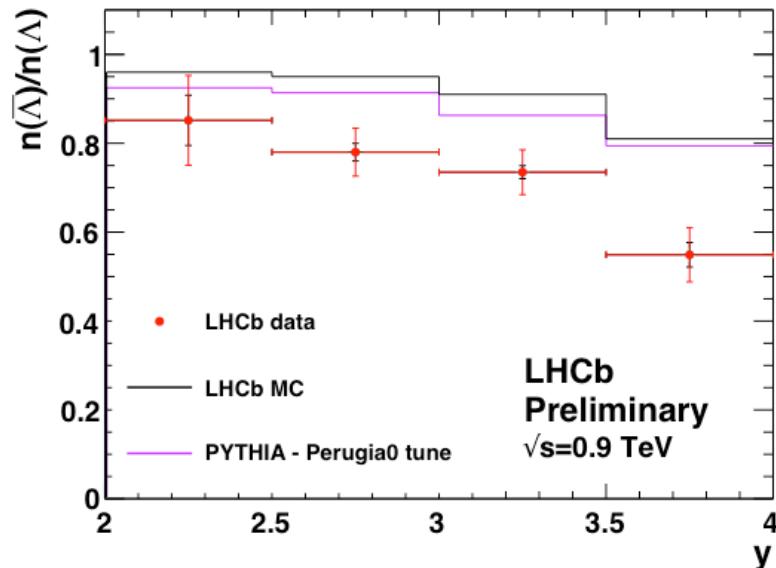


Efficiency corrected ratios for prompt Λ 's

- Numbers corrected for non-prompt Λ 's coming from Ξ 's.
- No correction for diffraction
Perugia tunes do not include diffraction,
LHCb tune includes diffraction.
- Plots include both statistical and systematic error.
- Field up and down results were averaged.

Systematic uncertainties:

- Re-weighting of p_t -distributions to match data (2%)
- difference in proton/anti-proton cross section
~10% below 10GeV, reproduced by MC
(effect reduced by kinematic selection)
→ contribution to systematic error 2%



Conclusion

- ✓ LHCb had an excellent start into the LHC era
- ✓ By and by the landscape of the SM re-appears:
Many signals from strange, charm and bottom,
as well as W-production seen by LHCb.
- ✓ LHCb is able to extend measurements on minimum bias physics
to lower p_t and higher values of y .
 - Deviations from PYTHIA predictions observed in some kinematic regions:
 - K_s and Λ spectrum tend to be harder than predicted
 - prompt $\bar{\Lambda}/\Lambda$ ratio tends to be lower at $\sqrt{s}=900\text{GeV}$,
fair agreement at $\sqrt{s}=7\text{TeV}$
 - valuable input for tuning of MC's
- ✓ Other results on minimum bias physics expected soon:
 - p/anti-p ratio
 - meson/baryon ratios, i.e. a measurement of the $(\bar{\Lambda} + \Lambda)/K_s$ -ratio
 - multiplicities of charged particles

Backup

Reality check: s and Ldt in 2010-11

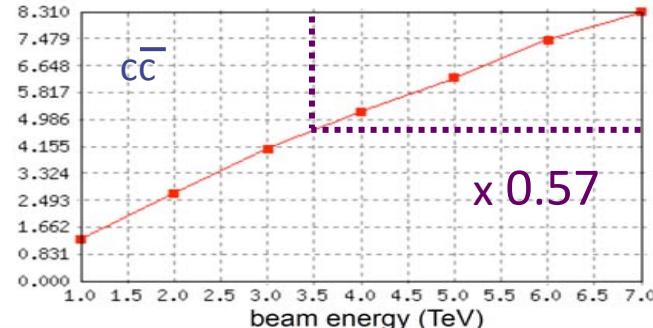
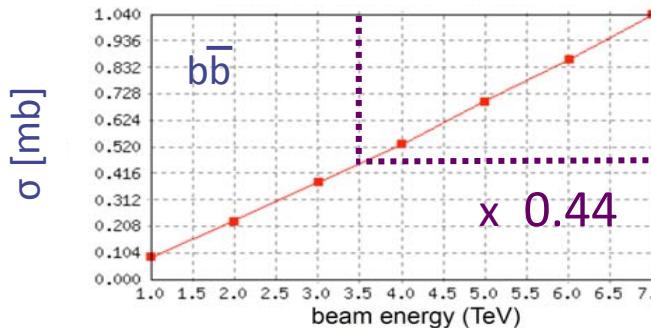
All LHCb simulation studies until recently assumed $E_{cm}=14$ TeV & annual event yields of 2 fb^{-1} . How do parameter values of 2010-11 run affect the physics reach?

Beam Energy

LHCb physics reach is not seriously compromised

Compare expected cross-sections

by de-scoped parameters of 2010-11 run



Pythia 6.4

Small penalty in statistical precision (but all MC predictions shown today assume, for historical reasons, bb cross-section of 500 μb at 14 TeV – conservative ?)

Luminosity

LHCb design luminosity is $2 \times 10^{32} \text{ cm}^{-2}\text{s}^{-1}$ – will be in this regime in 2011 !
Lower luminosities of 2010 allows for lower trigger thresholds – see later

LHCb Operation

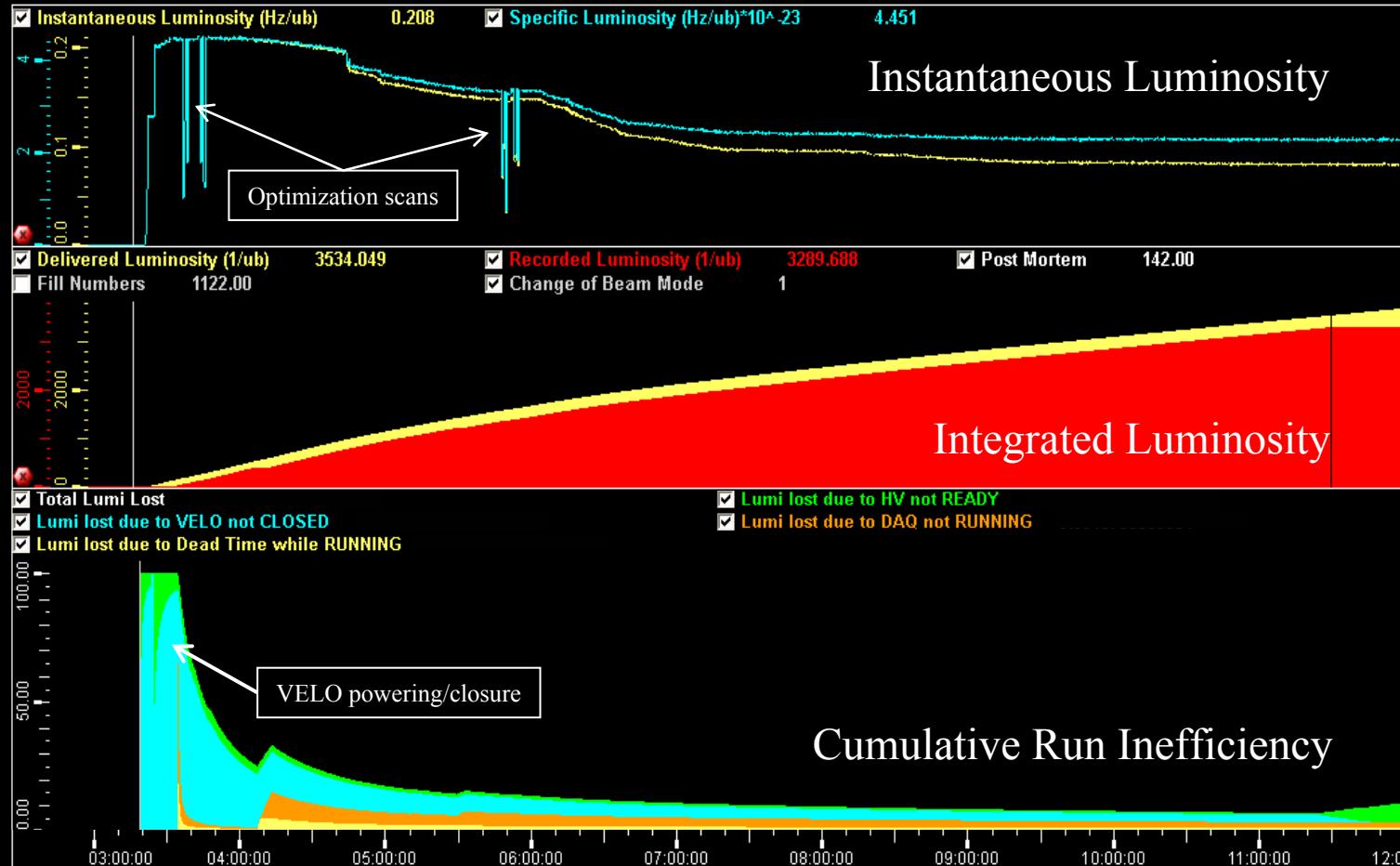


LHCb Run Summary

Period of Analysis:

From 24/5 19:14 to 25/5 14:25

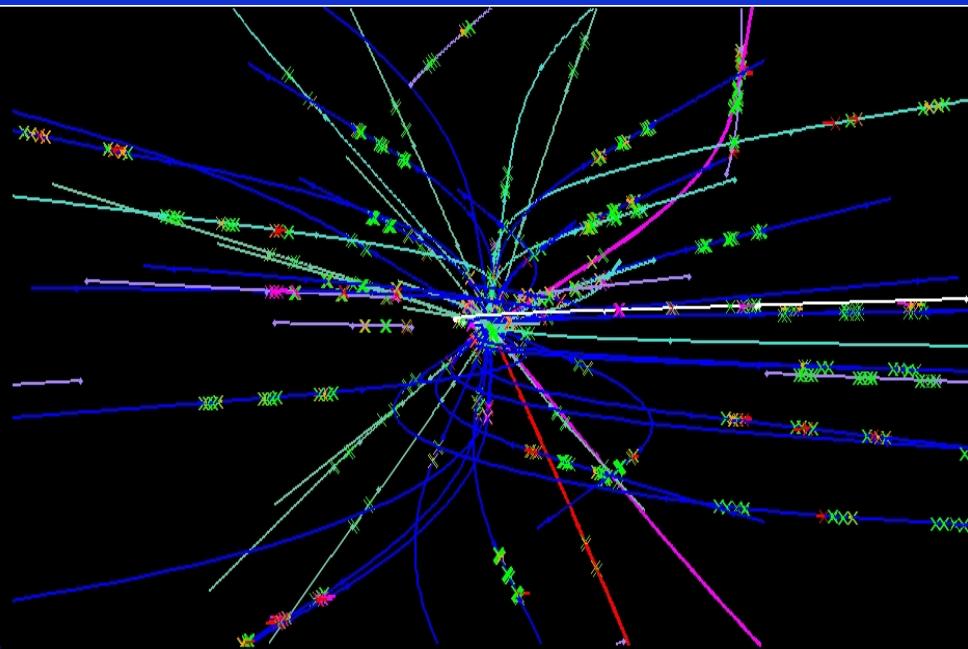
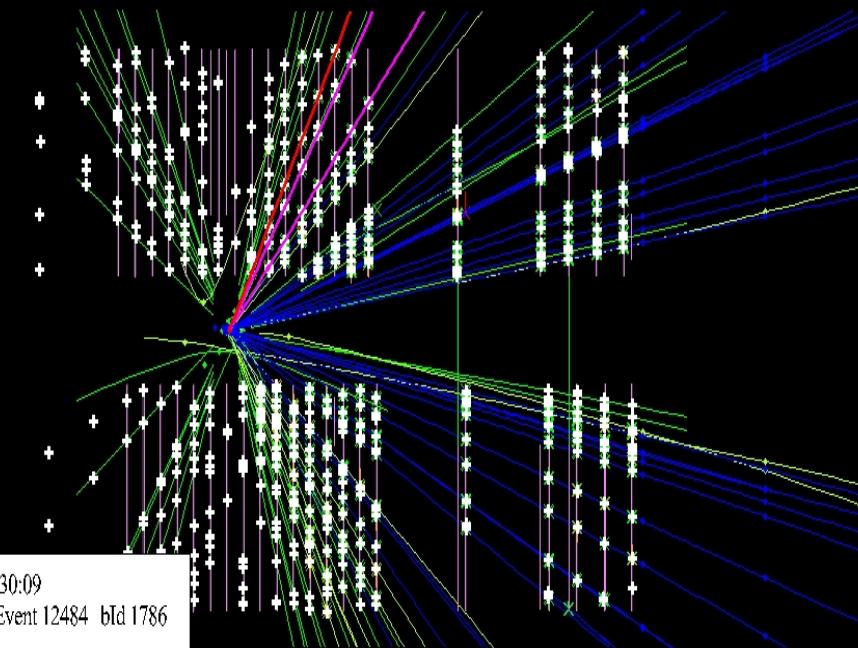
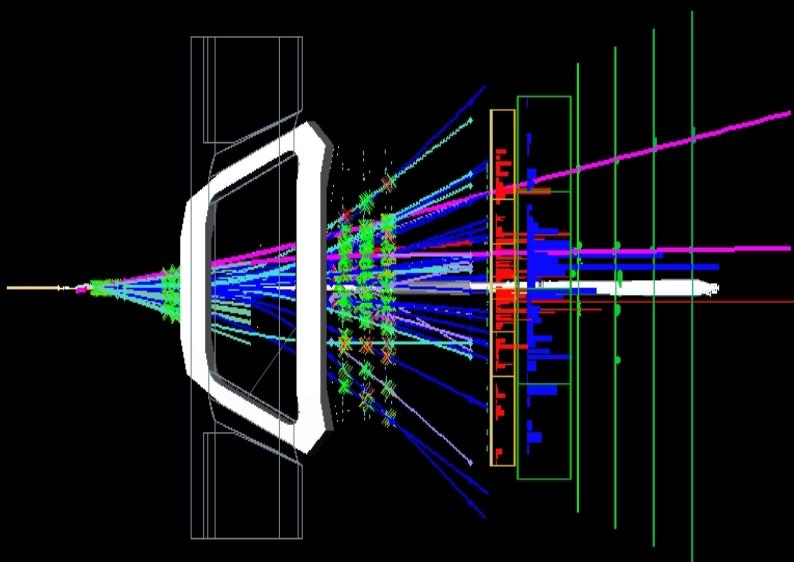
FillNumbers, 1122 on 24/5 at 19:14



Beam Modes:

NO_BEAM on 24/5 at 19:3
INJECTION on 24/5 at 21:6
RAMP on 25/5 at 1:6
PHYS_ADJUST on 25/5 at 2:24
PHYSICS on 25/5 at 3:16
NO_BEAM on 25/5 at 12:37

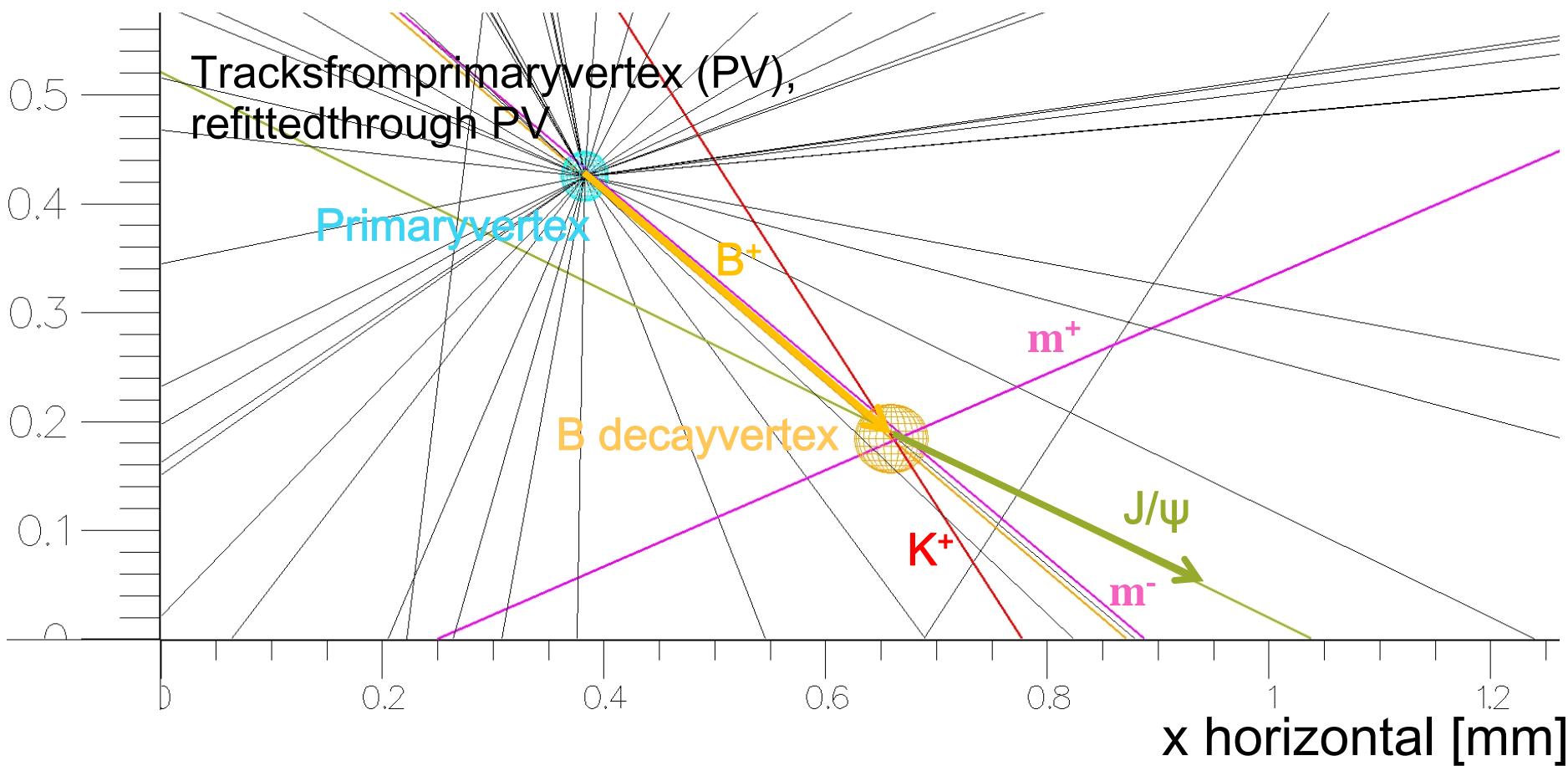
A fully reconstructed $B \rightarrow J/\psi K^+$



$B \rightarrow J/\psi K^+$: Zoom into vertex region

N.B.: All observables far from cut values defined before data-taking

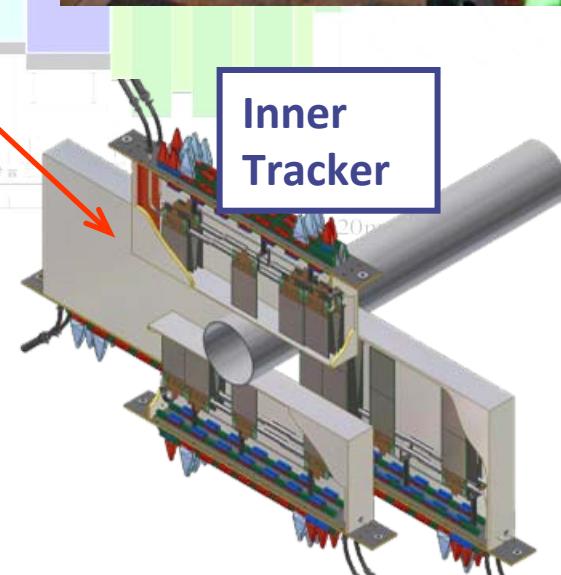
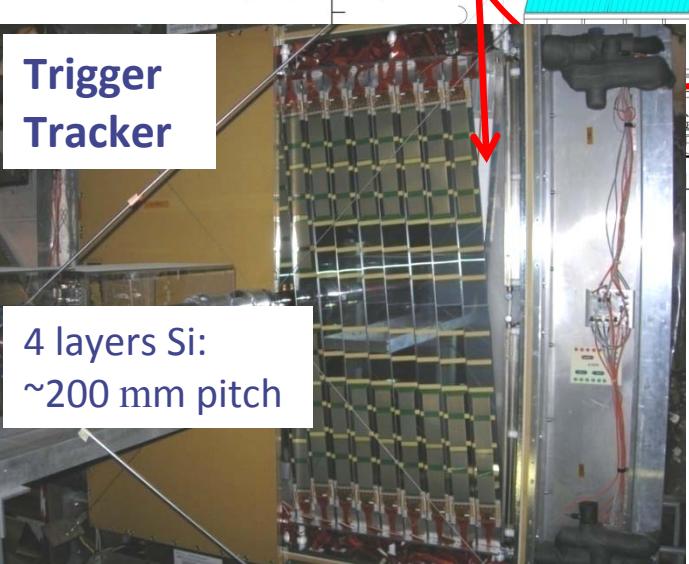
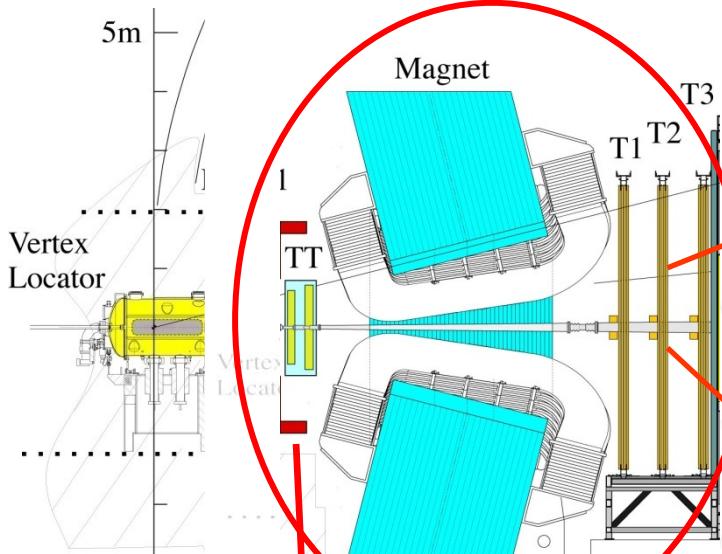
y vertical [mm]



Momentum measurement:

1. Measure proper time:
→ Excellent vertex resolution
2. **Background reduction:**
→ Robust tracking
+ very good mass resolution

$$S_p/p \sim 0.5\%$$



1. Measure proper time:
→ Excellent vertex resolution
2. Background reduction:
→ Robust tracking
+ very good mass resolution

→ Particle identification (RICH)

3. High statistics:
→ Efficient trigger

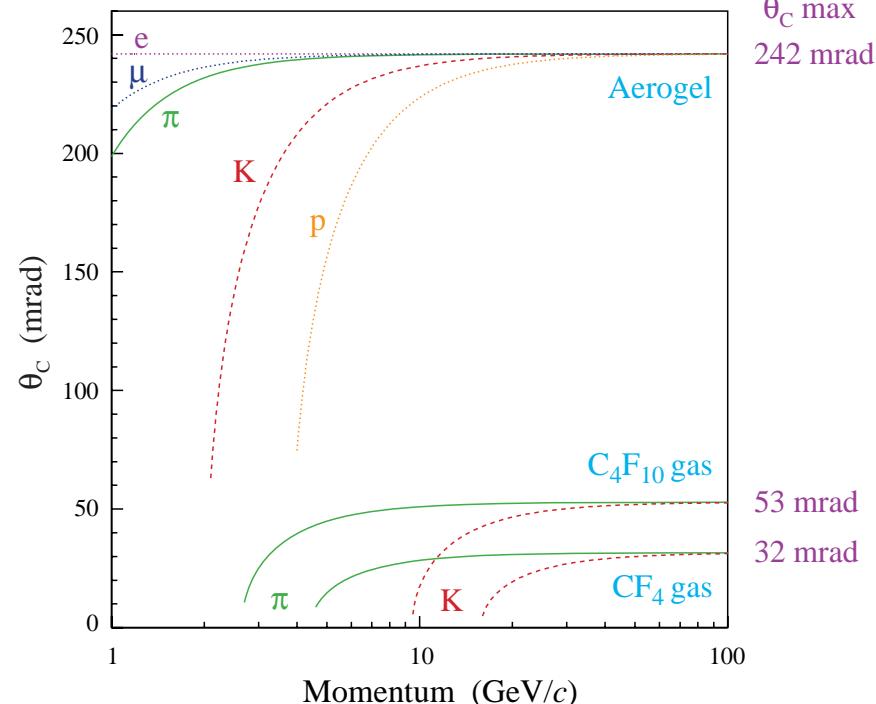
RICH1

Silica Aerogel
 $n=1.03$
1-10 GeV/c

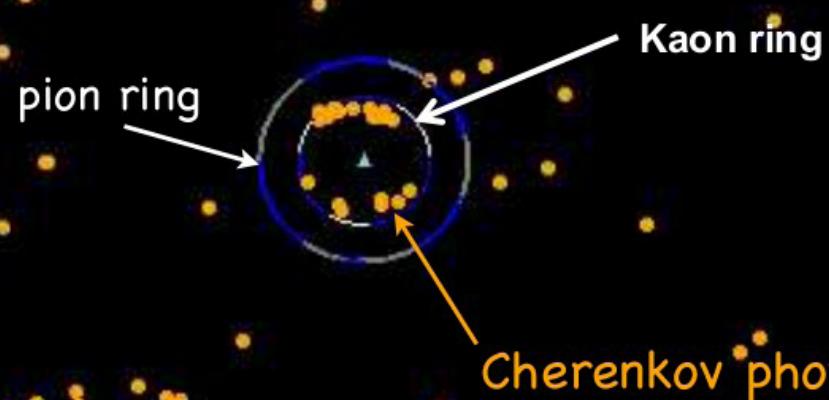
C₄F₁₀ gas
 $n=1.0014$
Up to ~70 GeV/c

RICH2

CF₄ gas
 $n=1.0005$
Beyond ~100 GeV/c

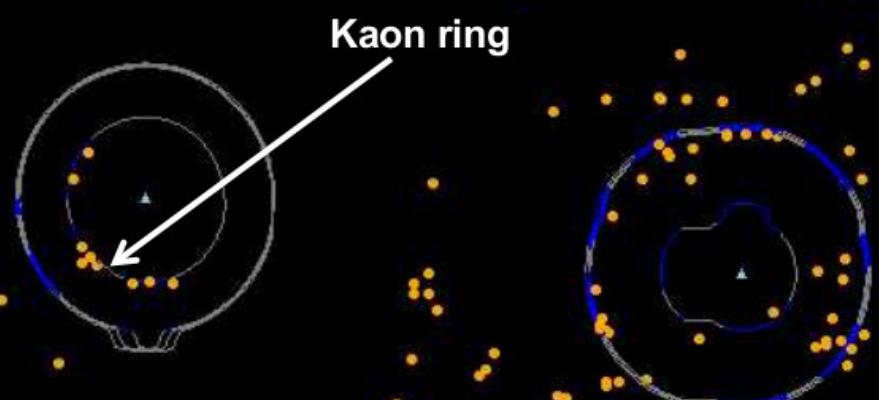


LHCb data
(preliminary)



RICH 1

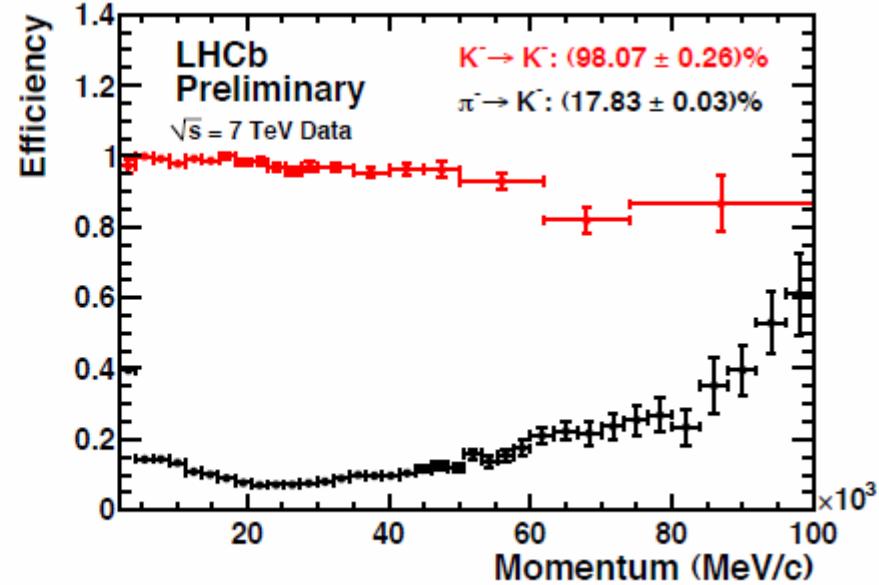
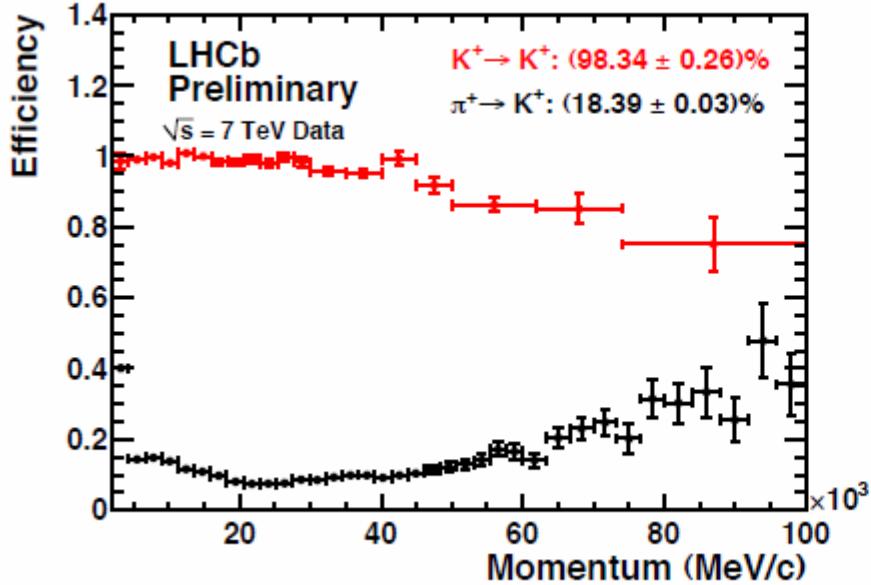
LHCb data
(preliminary)



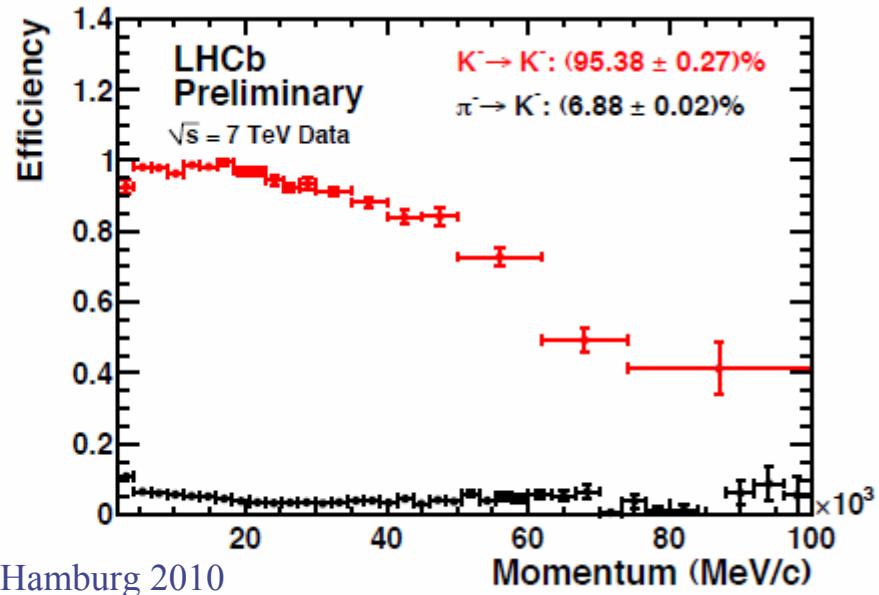
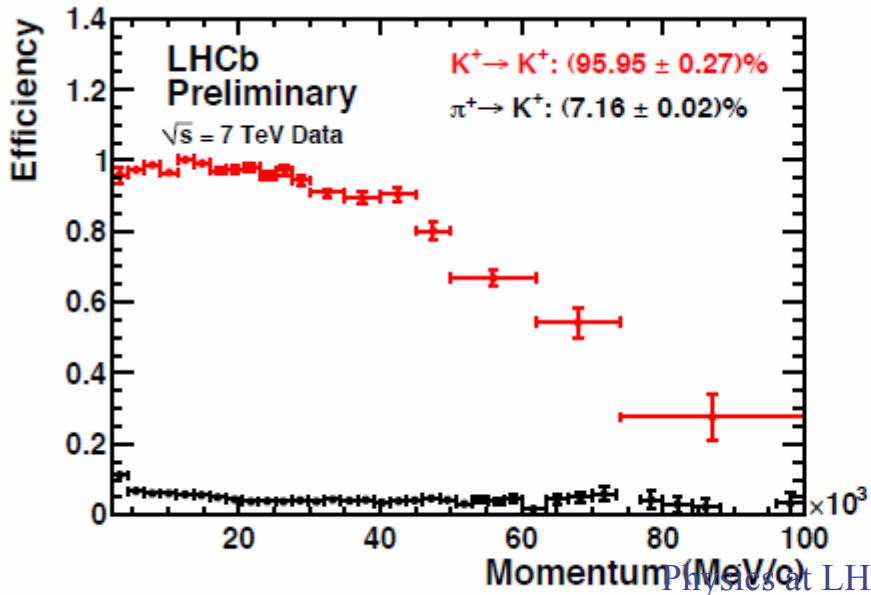
RICH 2

PID with RICH

$\Delta \log \mathcal{L}(K - \pi) > 0$



$\Delta \log \mathcal{L}(K - \pi) > 5$



Feynman x_F

