Experiments at e^+-e^- flavour factories and LHCb

Part 3: LHCb

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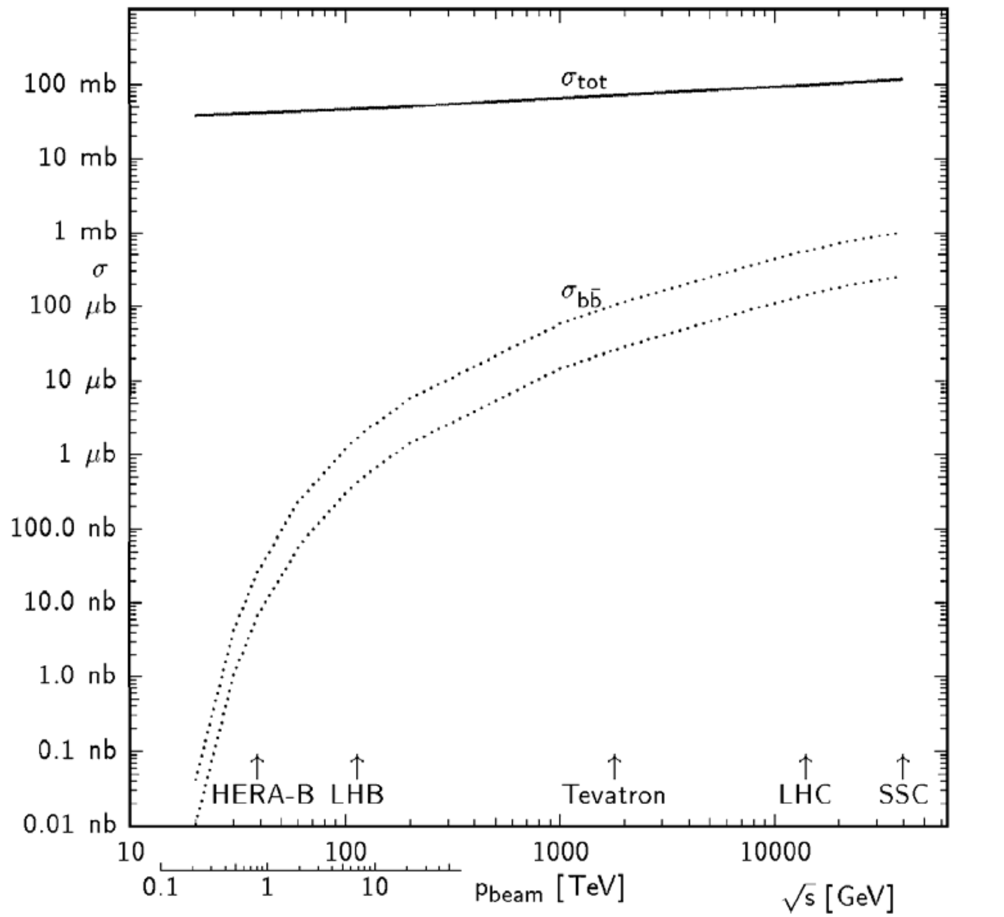
Why hadron machines?

- large bb production rates - compare to 1.1nb at Y(4s)
- large boosts → <L> = <βγ> 480 μm
- in addition to B^0/B^{+-} also B_s, B_c, Λ_b,..

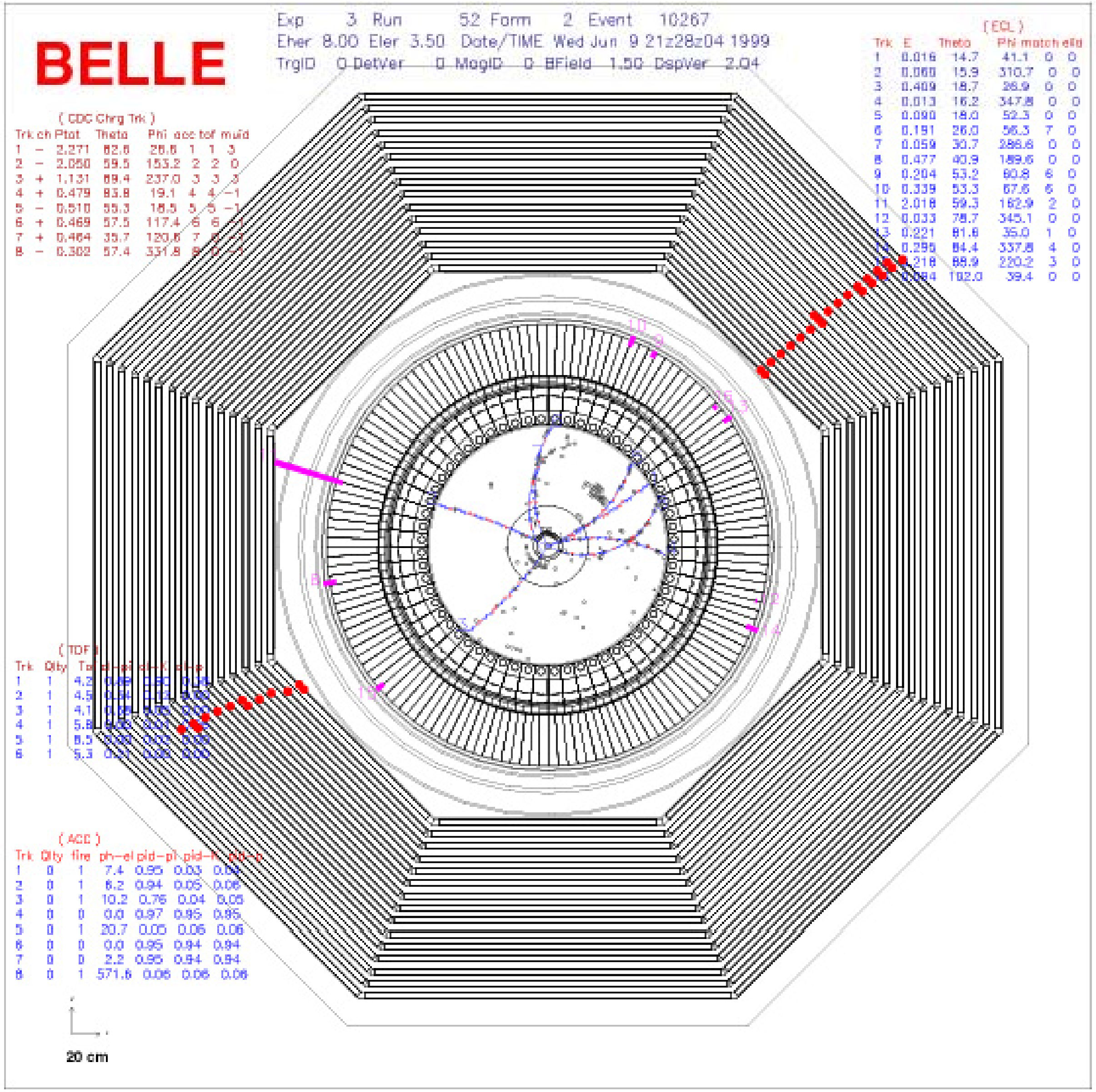
Y(4s)



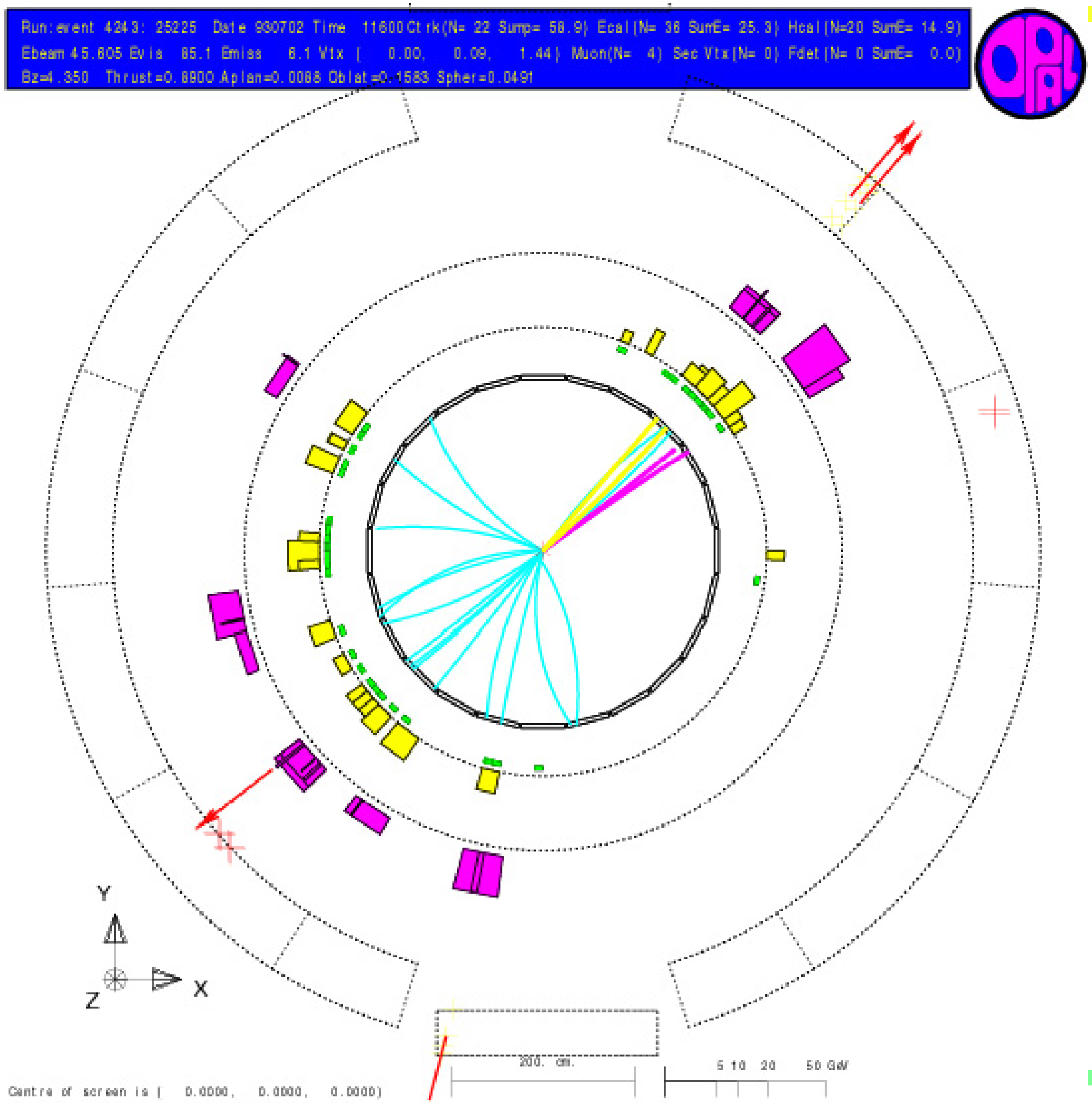
Why hadron machines?

Production	$e^+e^- \to \Upsilon(4s) \to B\bar{B}$	$e^+e^- \to Z^0 \to b\bar{b}$	$pA \to b\bar{b}X$	$p\bar{p} \to b\bar{b}X$	$p\bar{p}(p) \to b\bar{b}X$ forward
Accelerator	CESR, DORIS PEPII, KEKB	LEP, SLD	HERA p	Tevatron	Tevatron, LHC
Spectrometer	CLEO, ARGUS BaBar, BELLE	ALEPH, DELPHI, L3, OPAL, SLD	HERA-B	CDF, D0	BTeV, LHCb
$\sigma(b\bar{b})$	≈ 1 nb	≈ 6 nb	≈ 12 nb	$\approx 50\ \mu$b	$\approx 100\ \mu$b ($\approx 500\ \mu$b)
$\sigma(b\bar{b}):\sigma(had)$	0.26	0.22	10^{-6}	10^{-3}	$2 \cdot 10^{-3}$ ($6 \cdot 10^{-3}$)
B^0, B^+ $B_s^0, B_c^+, \Lambda_b^0$	yes no	yes yes	yes yes	yes yes	yes yes
boost $< \beta\gamma >$	0.06 (0.5)	6	≈ 20	$\approx 2-4$	$\approx 4-20$
$b\bar{b}$ production	B's at rest (in c.m.s)	$b\bar{b}$ back-to-back	$b\bar{b}$ not back-to-back	$b\bar{b}$ not back-to-back	$b\bar{b}$ not back-to-back
multiple events	no	no	yes, 4	yes	yes, 2
trigger	inclusive	inclusive	lepton pairs (high p_t hadrons)	leptons only (high p_t hadrons)	displaced vertex

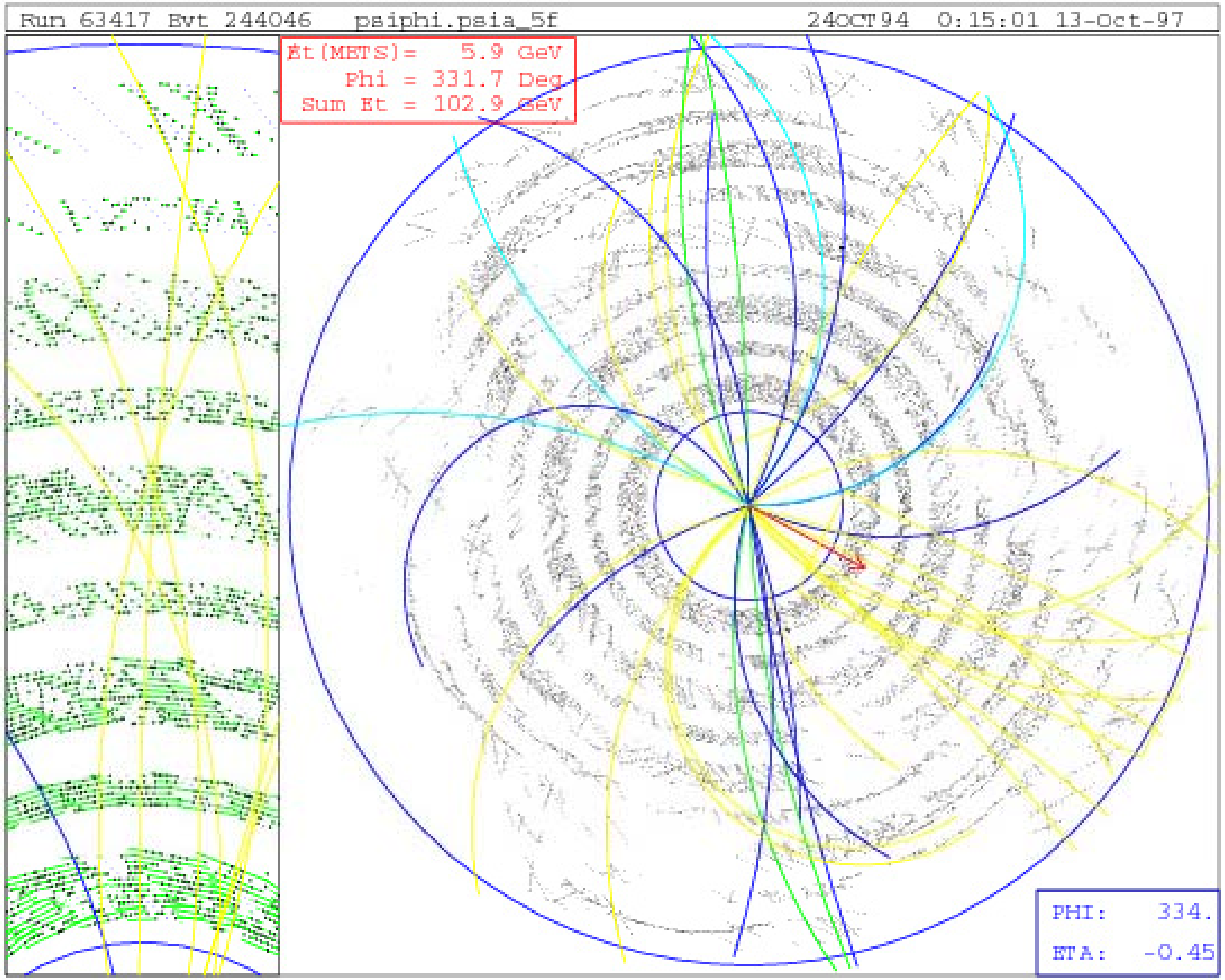
bb events at e^+e^- machines: BELLE



bb events at e^+e^- machines: OPAL at LEP



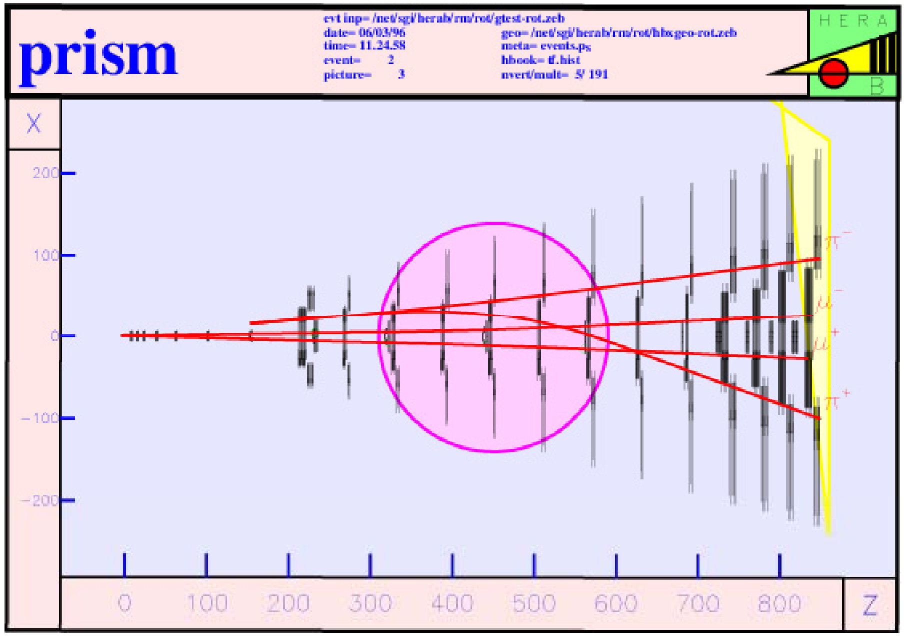
bb event at CDF

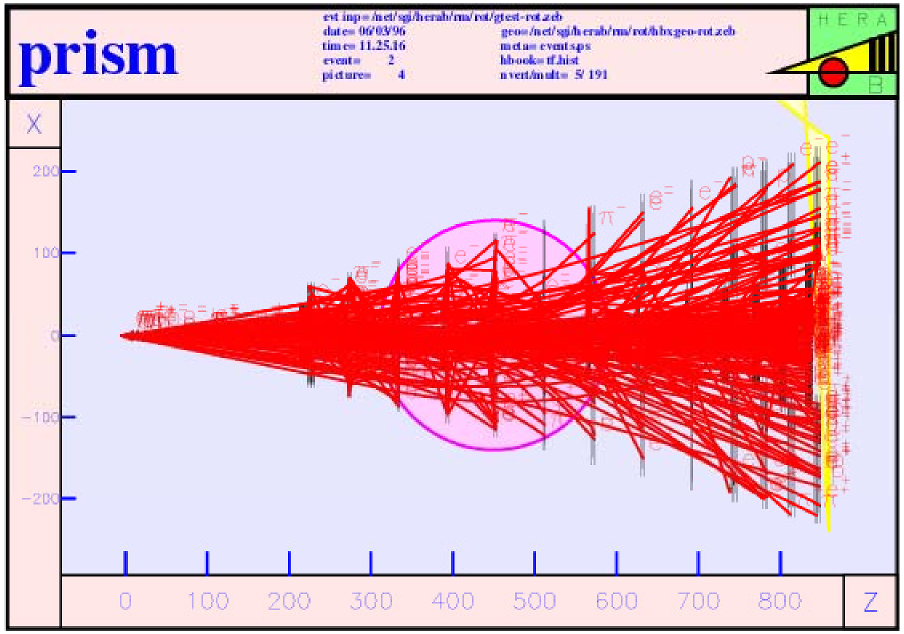


bb event at HERA-B:

Needle

in haystack...

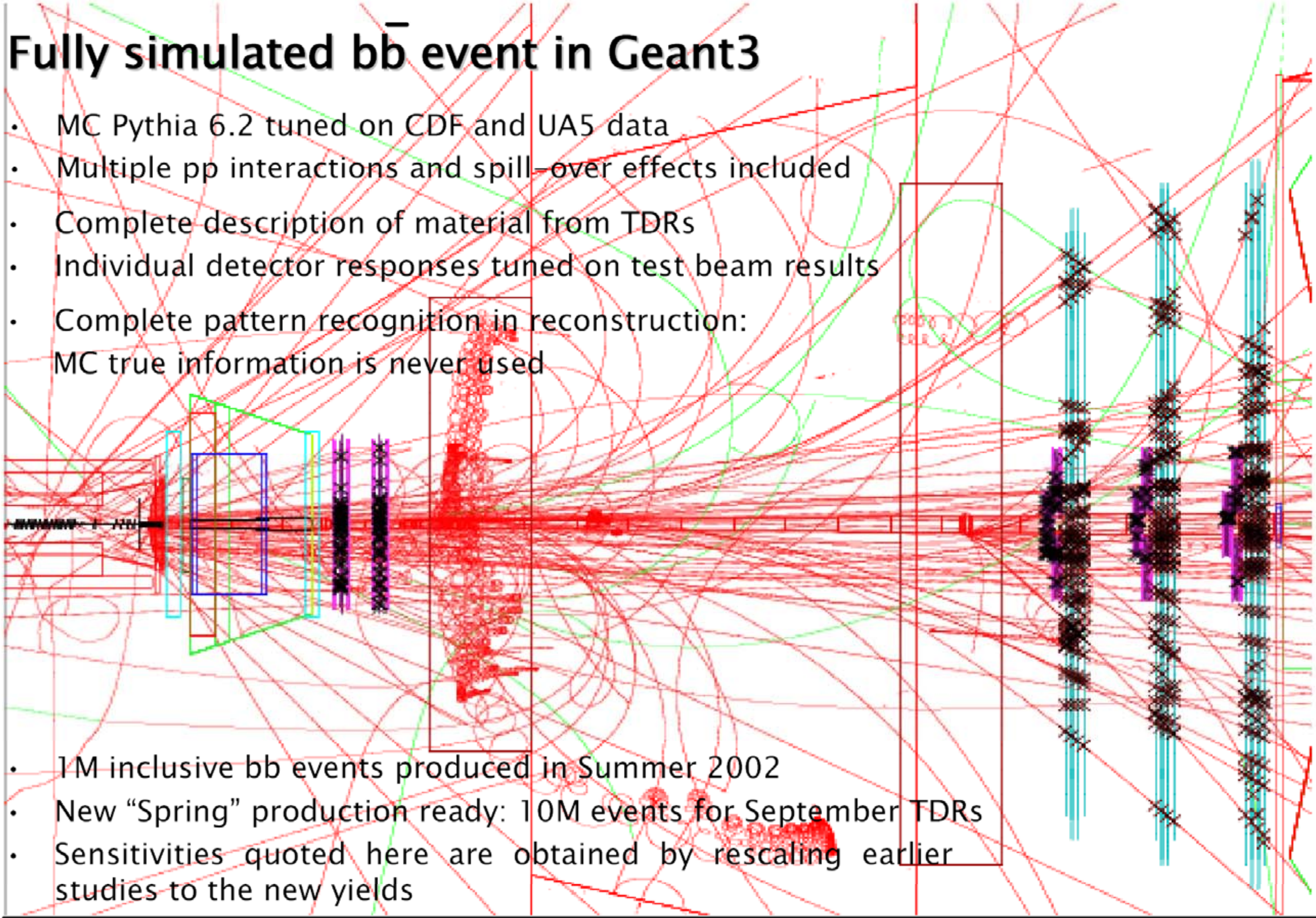




B → J/ψ Ks

and the rest

bb event at LHCb:



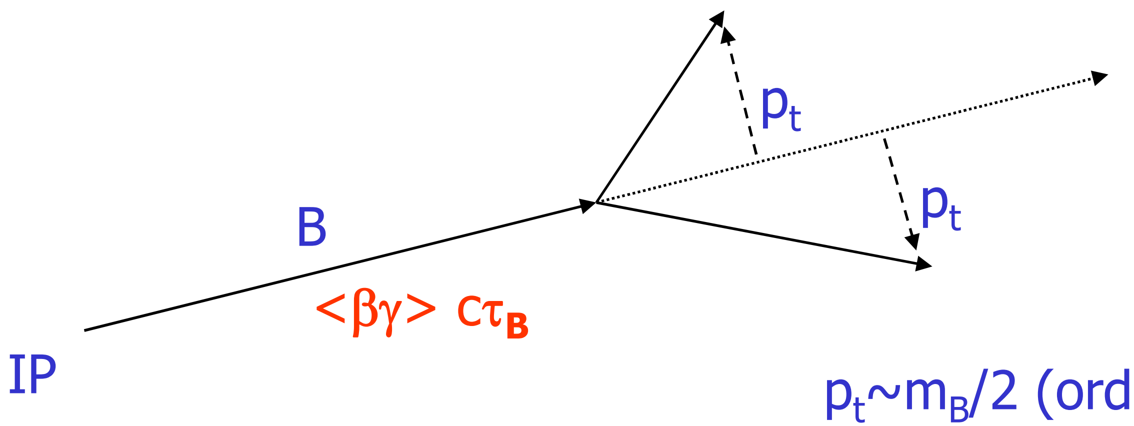
B detection in hadron collisions

What do we have to consider when designing a detector for b mesons and baryons at a hadron machine?

High particle fluxes → radiation hard detectors

Early selection of interesting events → selective triggers

Use the characteristic features of a B decay



$p_t \sim m_B/2$ (order of magnitude)

B detection in hadron collisions

Early selection of interesting events -> selective triggers:

• high p_t decay products: $B \rightarrow \mu\nu X$, $B \rightarrow J/\psi\ Ks \rightarrow \mu^+\mu^- \pi^+\pi^-$, $B \rightarrow \pi^+\pi^-$
$\rightarrow$helps because decay products carry a lot of momentum - typically ~1-2 GeV/c - perpendicularly to the flight direction (p_t), while backgrounds have low p_t

• displaced vertex: $\langle L\rangle = \langle\beta\gamma\rangle c\tau_B = \langle\beta\gamma\rangle$ 480 μm $\rightarrow$ helps because other decay products are promt = originate directly in the interaction point

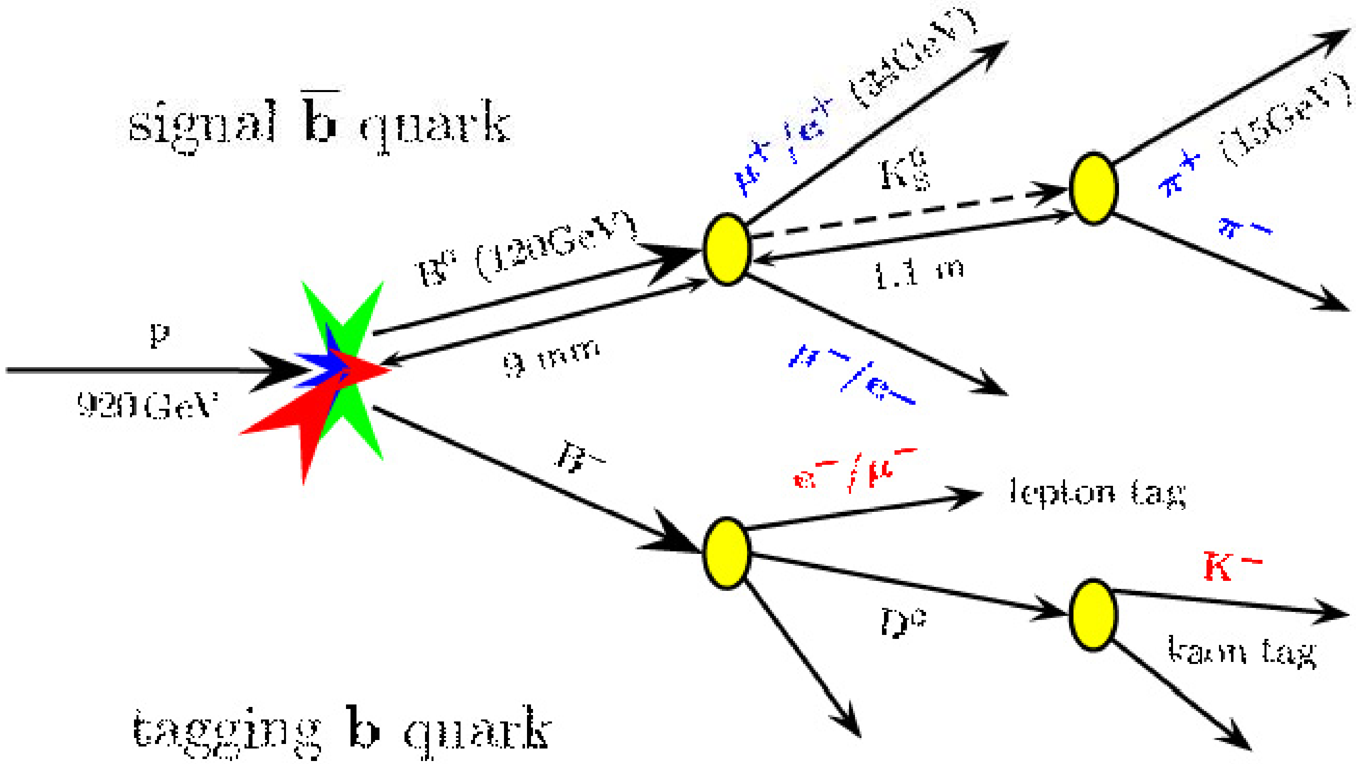
Proof of principle: CDF, D0 at the Tevatron collider.

$\rightarrow$ Slides by M. Kreps

HERA-B

Fixed target B - Factory at HERA (DESY)

Originally designed for measurement of CP violation in $B \rightarrow J/\psi K_S^0$



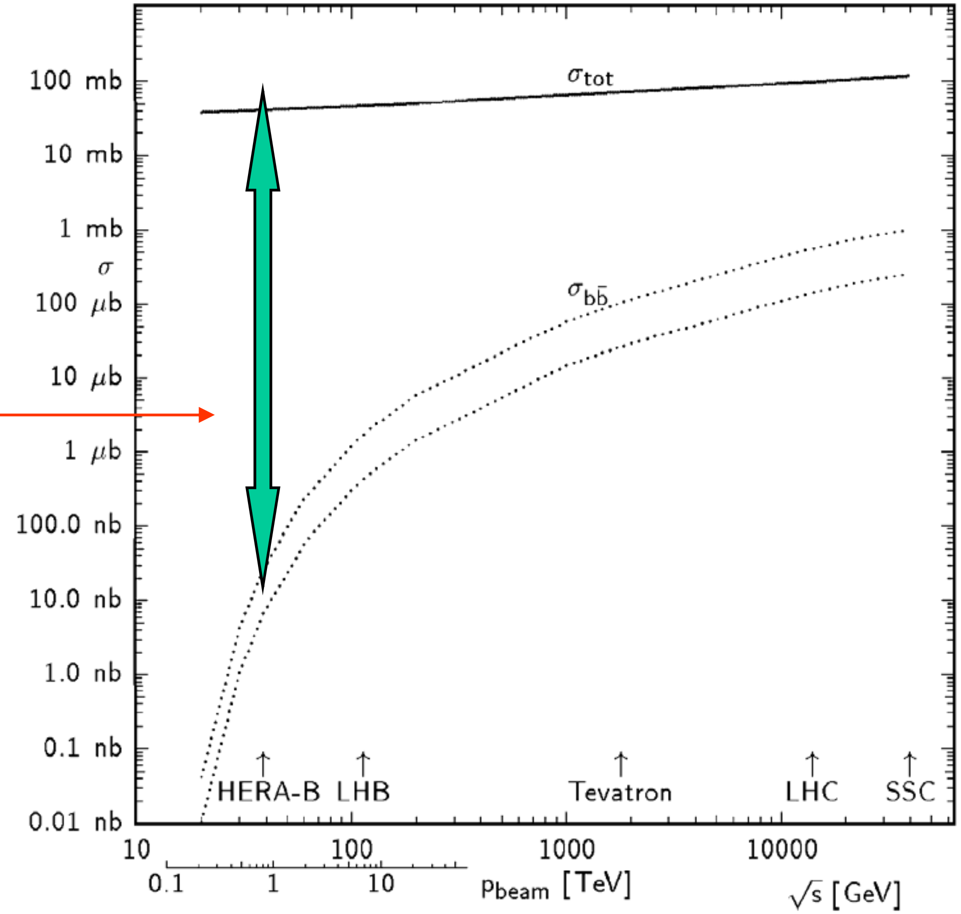
HERA-B

proton energy is 920 GeV, sqrt(s)=42 GeV

σ(b bar-b) ~ 12 nb -> σ(b bar-b)/ σ(inel) ~10^{-6}

BR for interesting decays of ~ 10^{-5}-10^{-4}

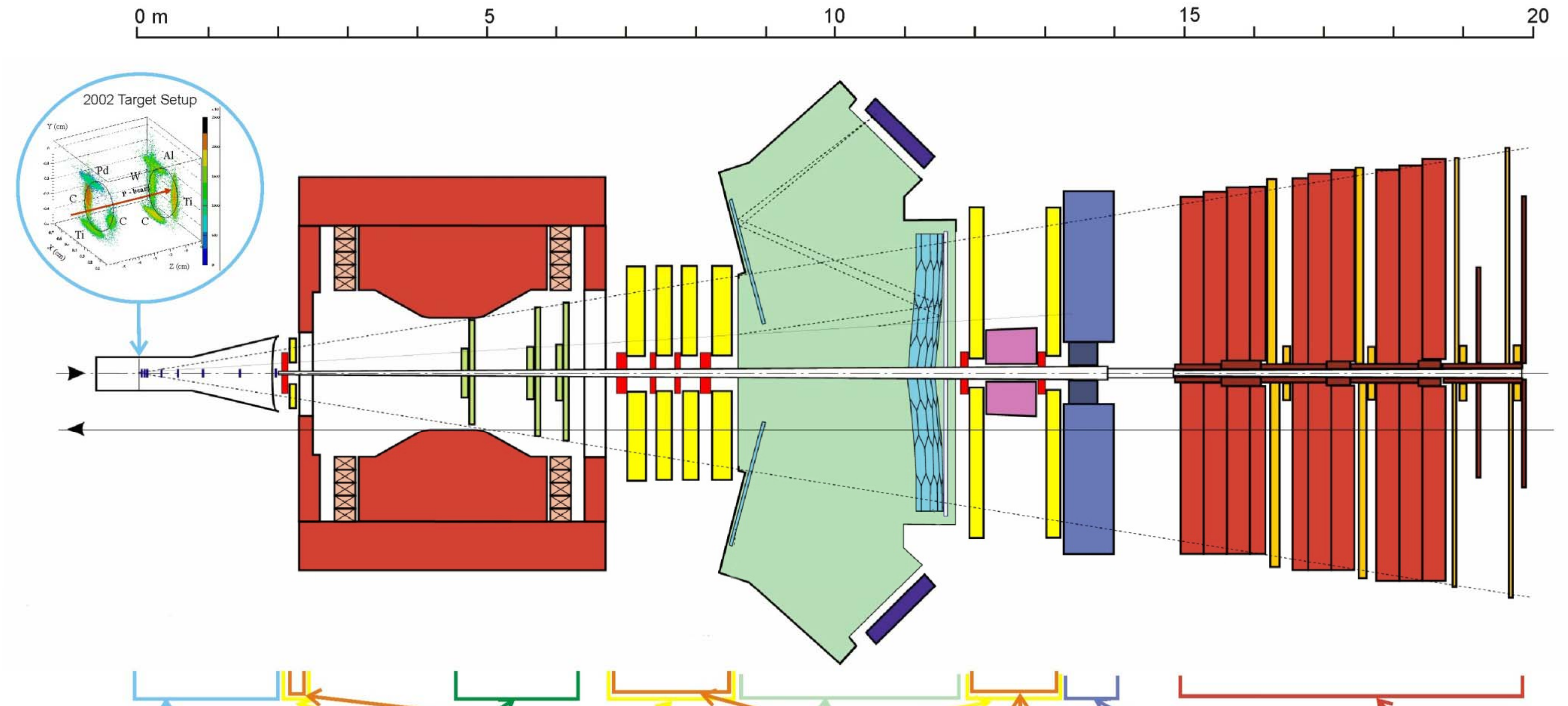
→ 11 orders of magnitude



→ Need multiple events for 40 MHz interaction rate (=0.4 10^8 s^{-1})

→LHC like experiment 10 years before LHC

HERA-B spectrometer



Target & Vertex
8 layers of double-sided Si-microstrips, movable on Roman-Pots; 8 wire-target (see above)

High p_T
3 superlayers gas, pixel and pad chambers; pre-trigger for high p_T tracks

Outer Tracker
7 superlayers of honeycomb drift chambers, 5 and 10mm cells

RICH
Spherical mirror inside C_4F_{10} radiator, Lens-enhanced multianode PMT focal plane.

Inner Tracker
7 superlayers of Micro Strip Gas Chambers with GEM-foil

Electromagnetic Calorimeter
W/Pb scintillator sandwich, shashlik WLS readout with PMTs; energy-cluster pre-trigger

Muon System
4 superlayers of gas-pixel, tube & pad chambers; pad-coincidence pre-trigger

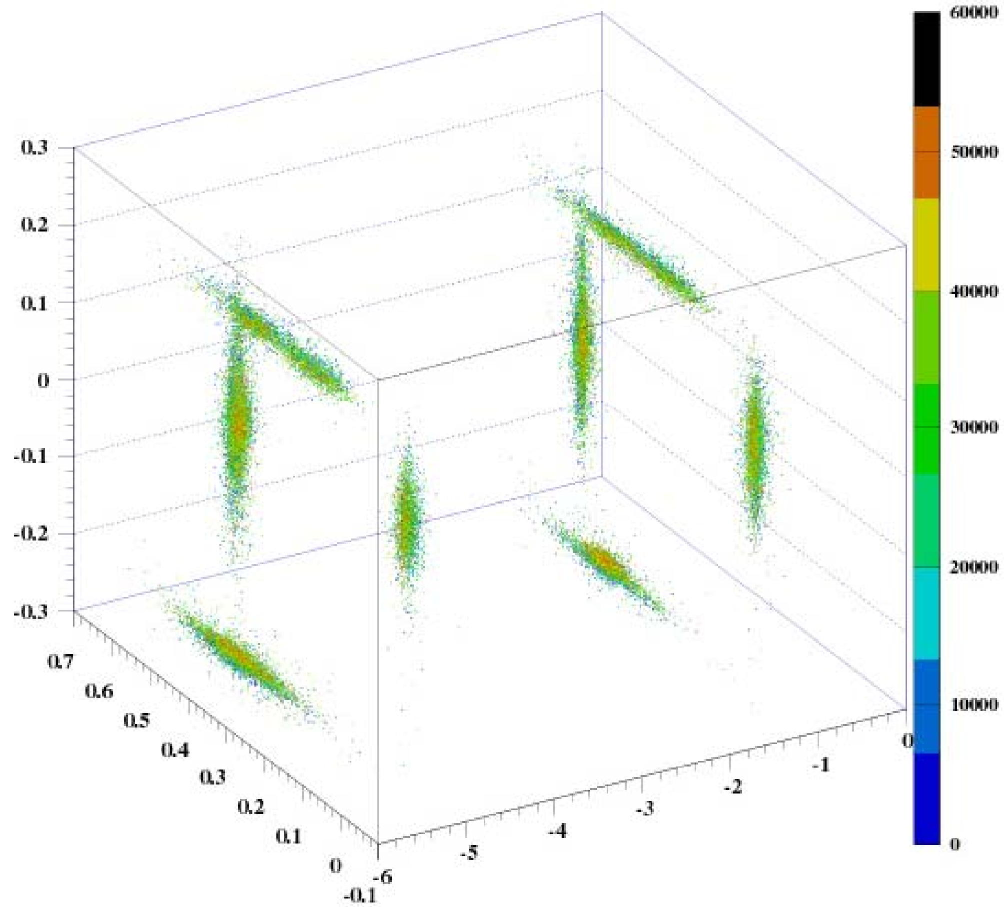
HERA-B: SVD

Silicon vertex detector: 8 double-sided silicon detector layers with retractable geometry (to move out of the beam during injection)

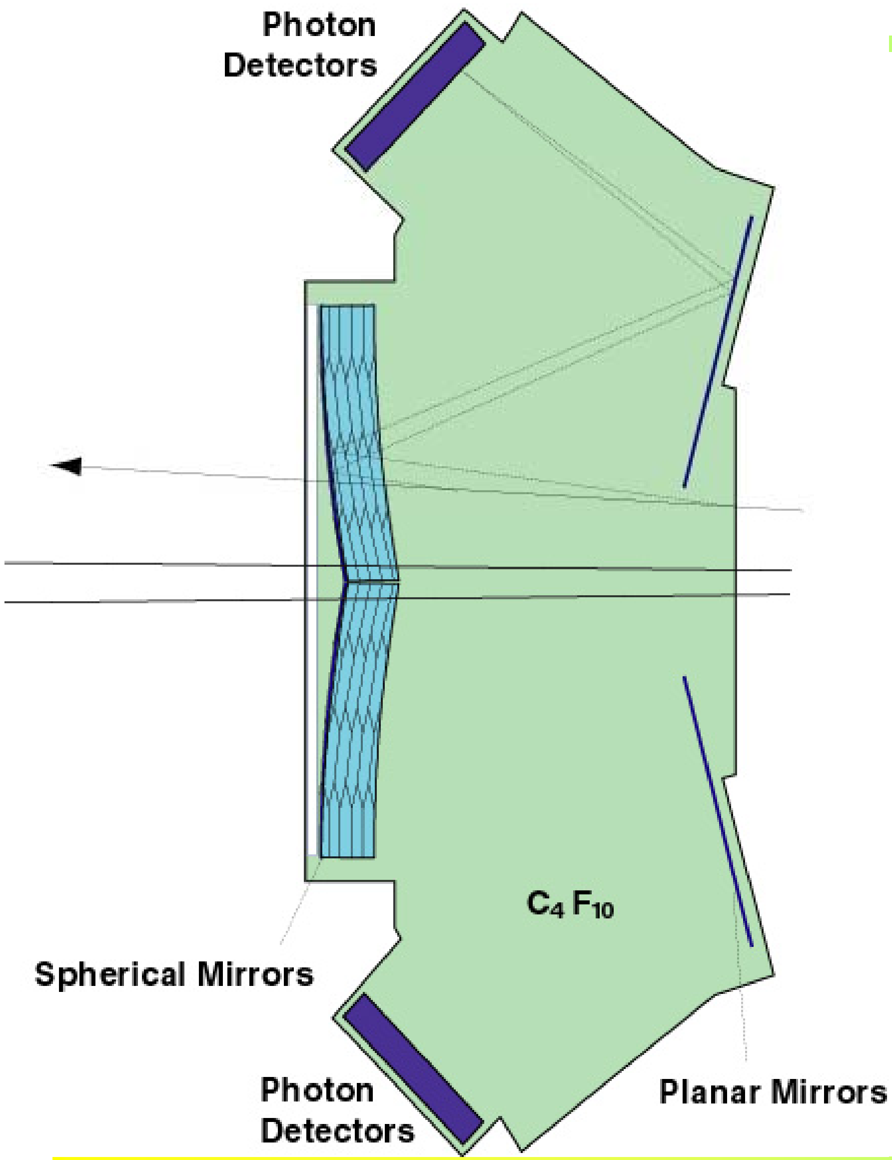
Excellent and reliable operation.

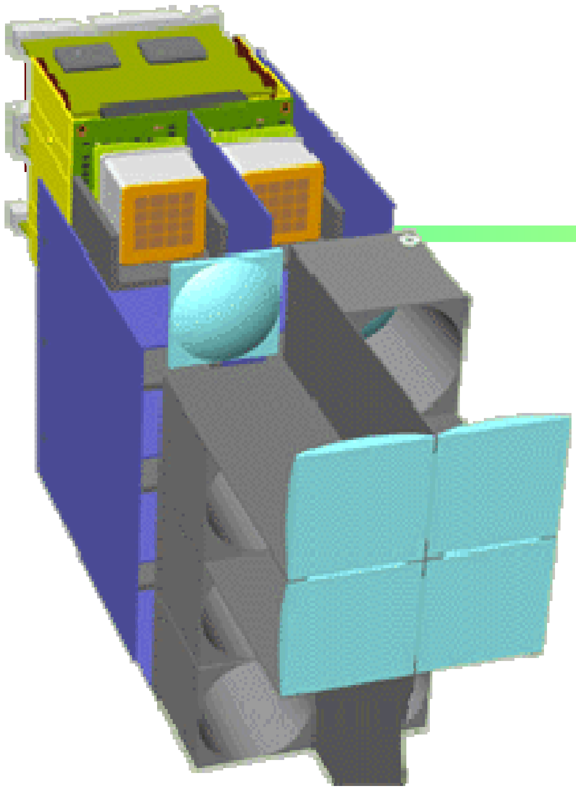
Reconstructed vertices

On eight target wires ->

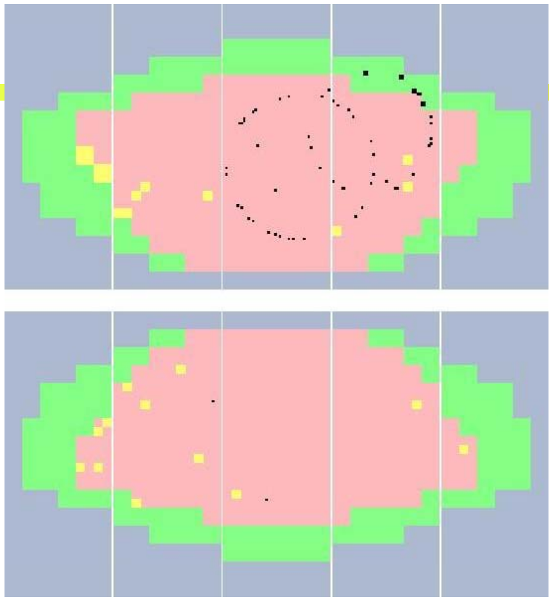


HERA-B RICH


Photon
Detectors
$C_4 F_{10}$
Spherical Mirrors
Photon
Detectors
Planar Mirrors

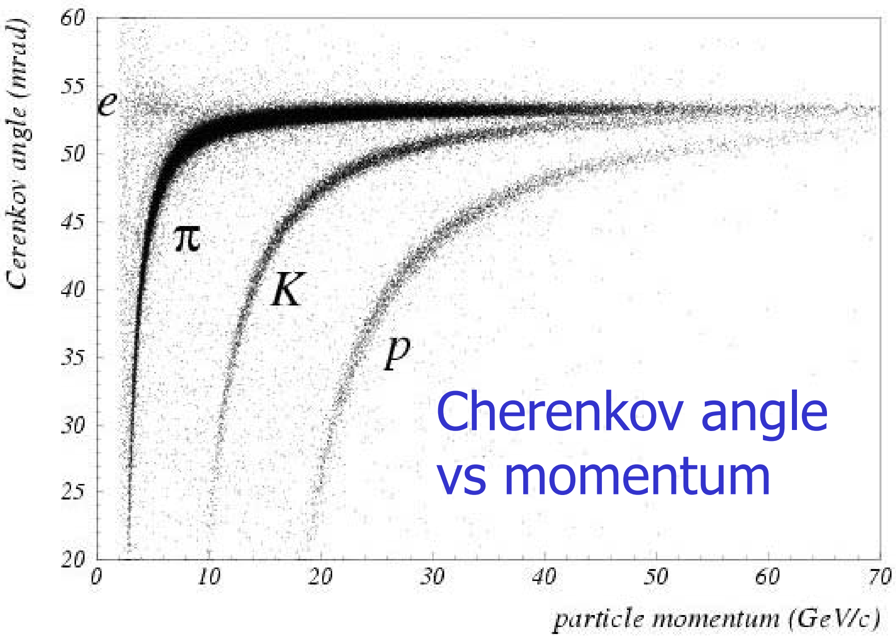


HERA-B RICH



Event display with two isolated rings

→ no noise



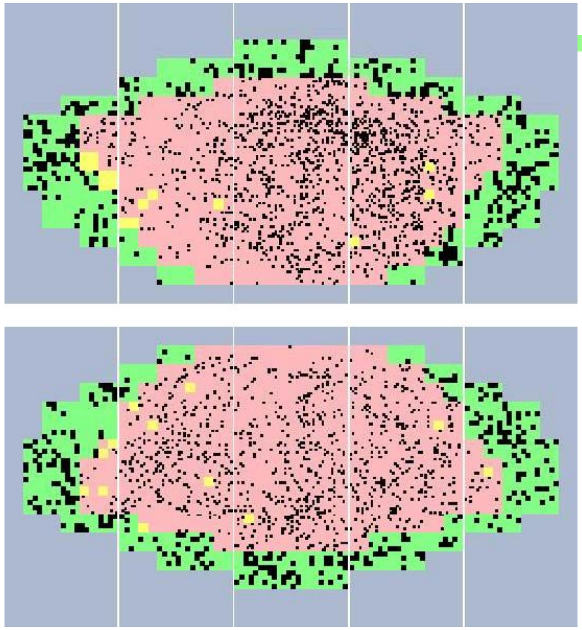
Cherenkov angle vs momentum

Light collection system (imaging!) to:

-Adapt the pad size

-Eliminate dead areas

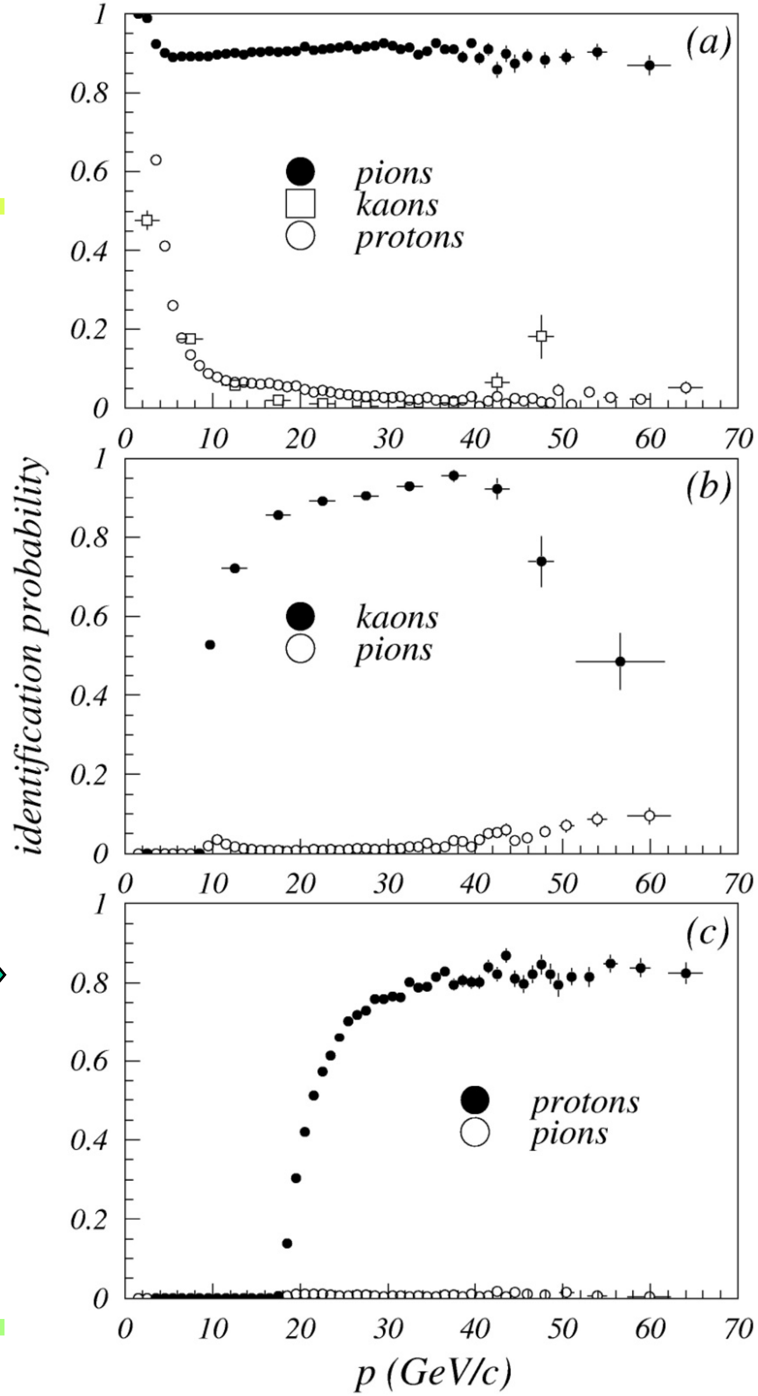
HERA-B RICH



Typical event

Still: it works actually very well!

pion, kaon and proton efficiency and probability



NIM A516 (2004) 445

The Dilepton Trigger

HERA-B detector: data is read out and buffered for 12 μs (proton bunches cross every 96 ns, 0.5 interactions/BX)

5 MHz

Pretriggers: ECAL cluster or hit coincidence in muon detector as trigger seed (custom hardware)

3 MHz

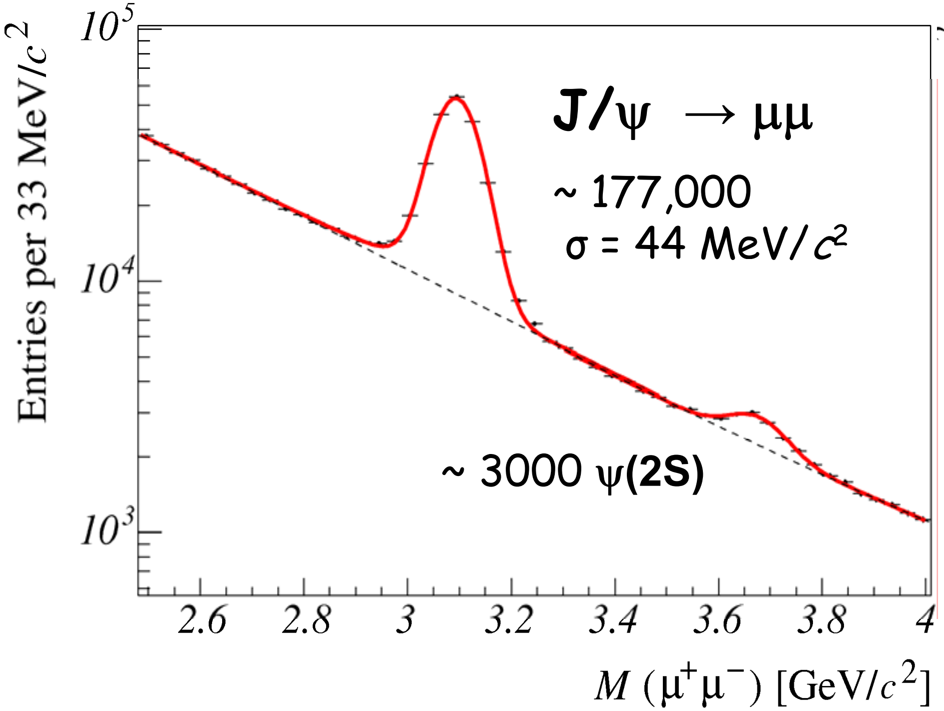
First Level Trigger (FLT): Track trigger in hardware using tracking detectors behind magnet, seeding by pretriggers

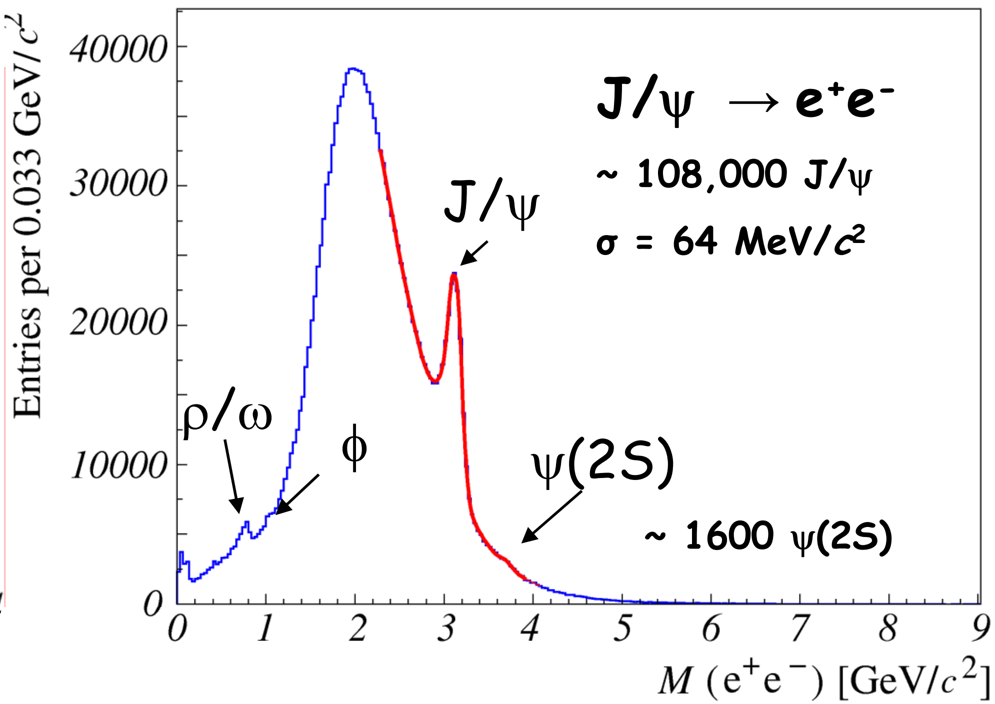
20 kHz

Second Level Trigger (SLT): FLT tracking confirmed, extrapolation to vertex detector, vertex fit (PC farm)

100 Hz

HERA-B: J/ψ Production





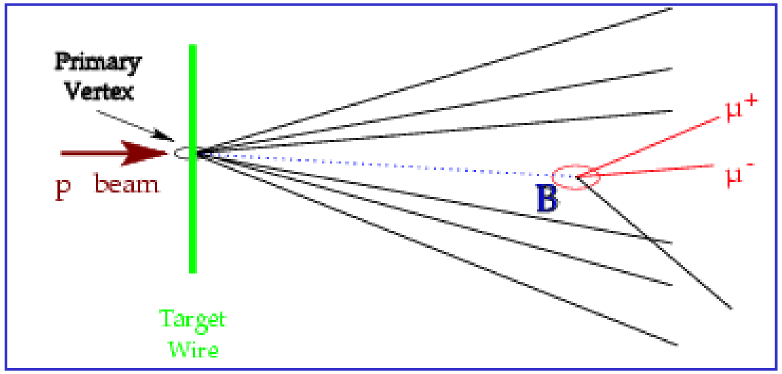
HERA-B: Open Beauty Production

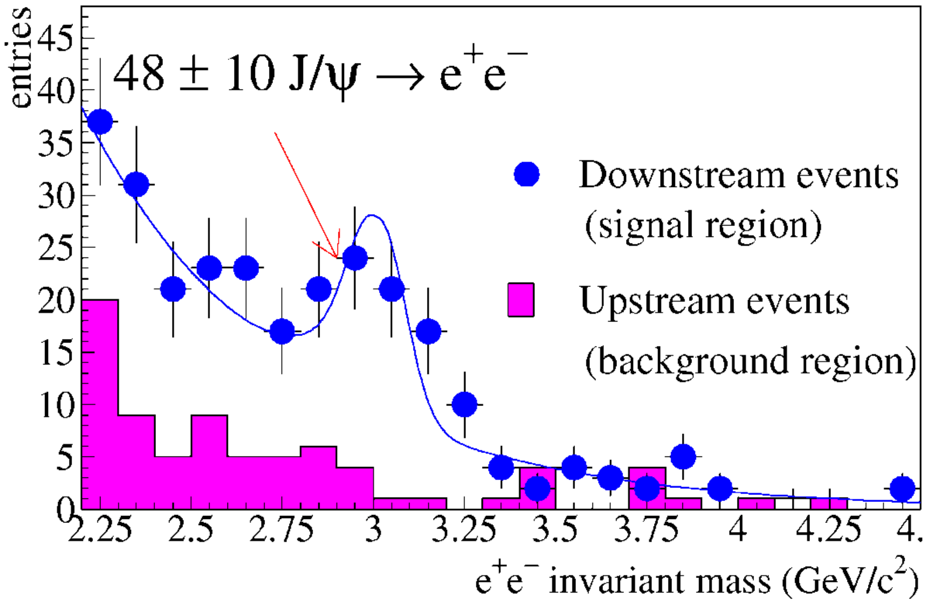
Detached vertex analysis

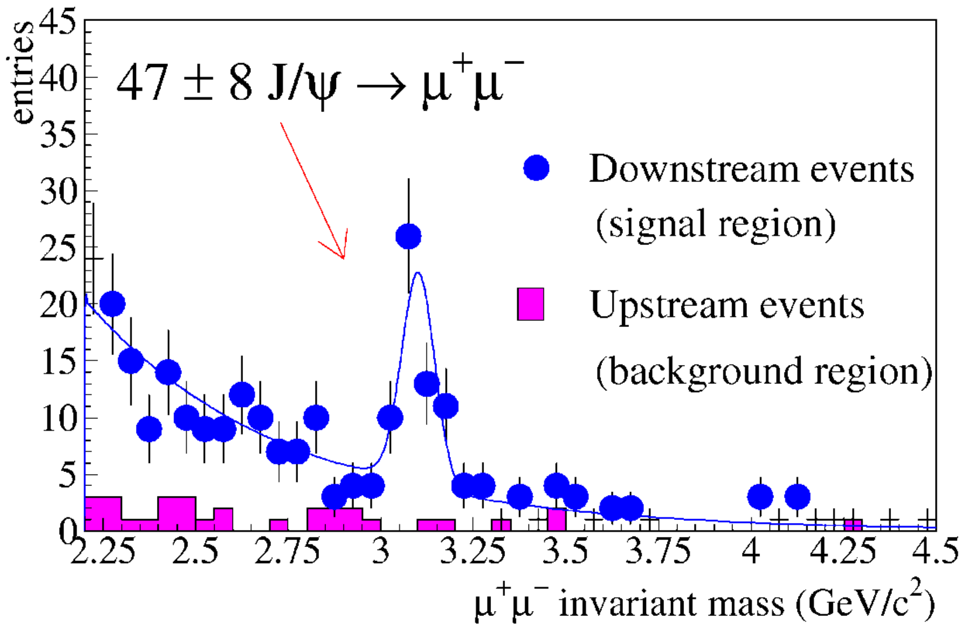
$pA \to b\,\bar{b} + X$

$\hookrightarrow J/\psi + X'$

$\hookrightarrow e^+ e^-, \mu^+\mu^-$







HERA-B Summary

- First LHC like experiment before the LHC
- Designed with a very ambitious goal
- Many components behaved extremly well (e.g. SVD, RICH)
- Several critical components were less successful (tracking)
- Trigger efficiency (which heavily relied on the tracking system efficiency) was >10x lower than expected

→No precision tests in B physics were possible

- Still: a solid physics program could be carried out (i.e. bb and cc production cross sections, a limit on D->$\mu\mu$, pentaquark searches)
- HERA-B experience: An important input for LHC experiments

HERA-B Summary 2

First LHC like experiment before the LHC → messages for the LHC experiments

-do not use micro-strip gas chambers (MSGC)

-large area trackers are not easy

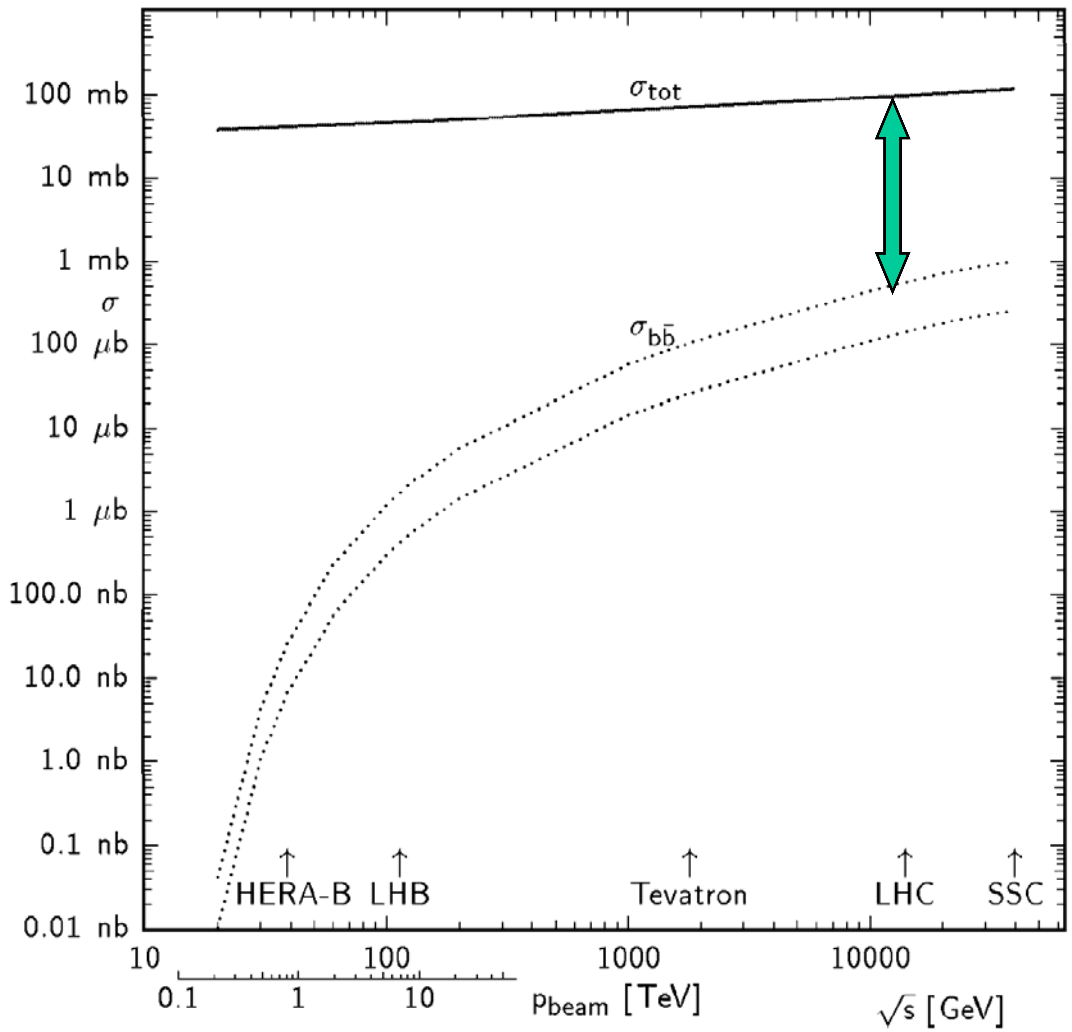
-trigger processors can get saturated by high occupancy events which are not necessarily interesting

-RICH counters are more robust than anticipated

-retractable SVD works reliably

b-production in pp collisions at LHC

Cross section for bb pair production much higher at LHC



b-production in pp collisions

- Pairs of $b\bar{b}$ quarks are mostly produced in the forward/backward direction:

$$\boxed{\sigma_{b\bar{b}} = 500\mu b}$$

$10^{12} b\bar{b}$ produced per year

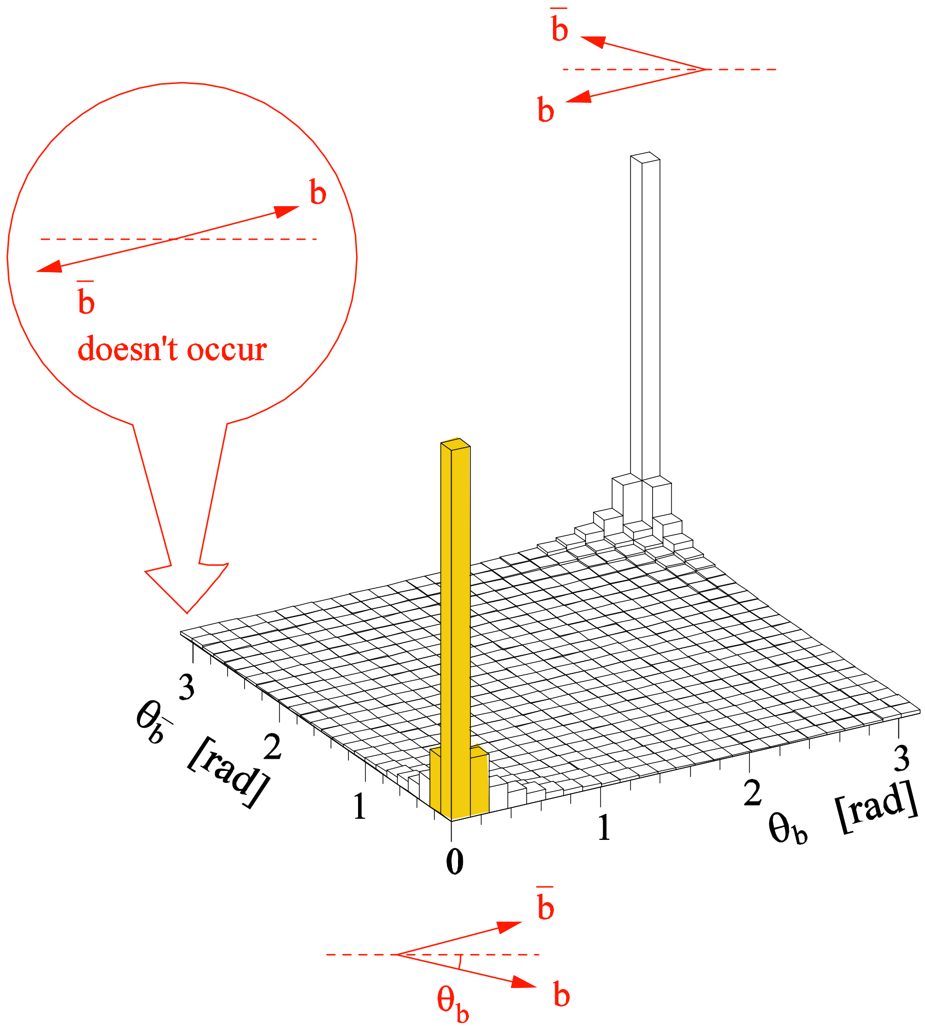
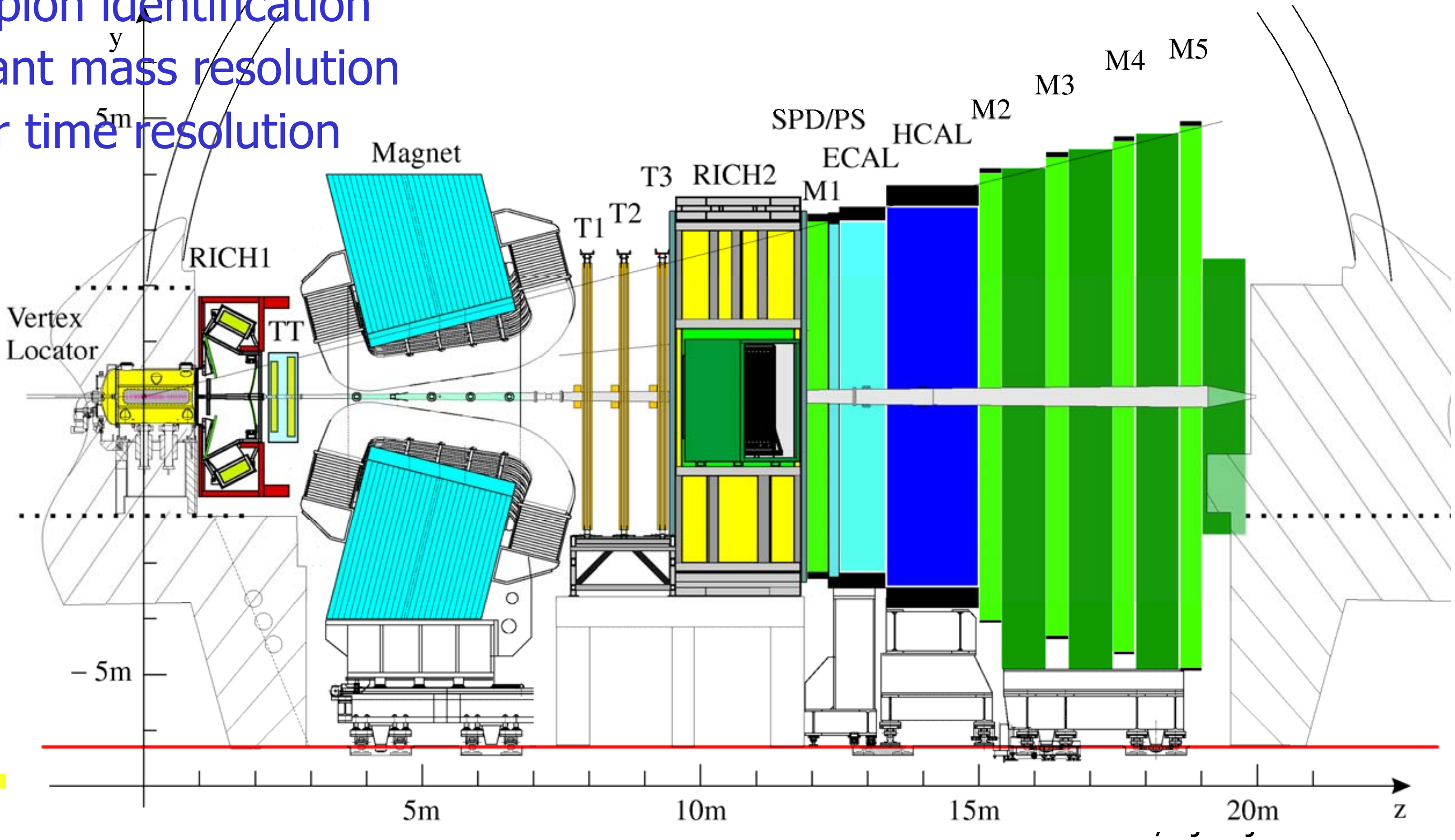


Figure 2.1: Polar angles of the b- and $\bar{b}$-hadrons calculated by the PYTHIA event generator.

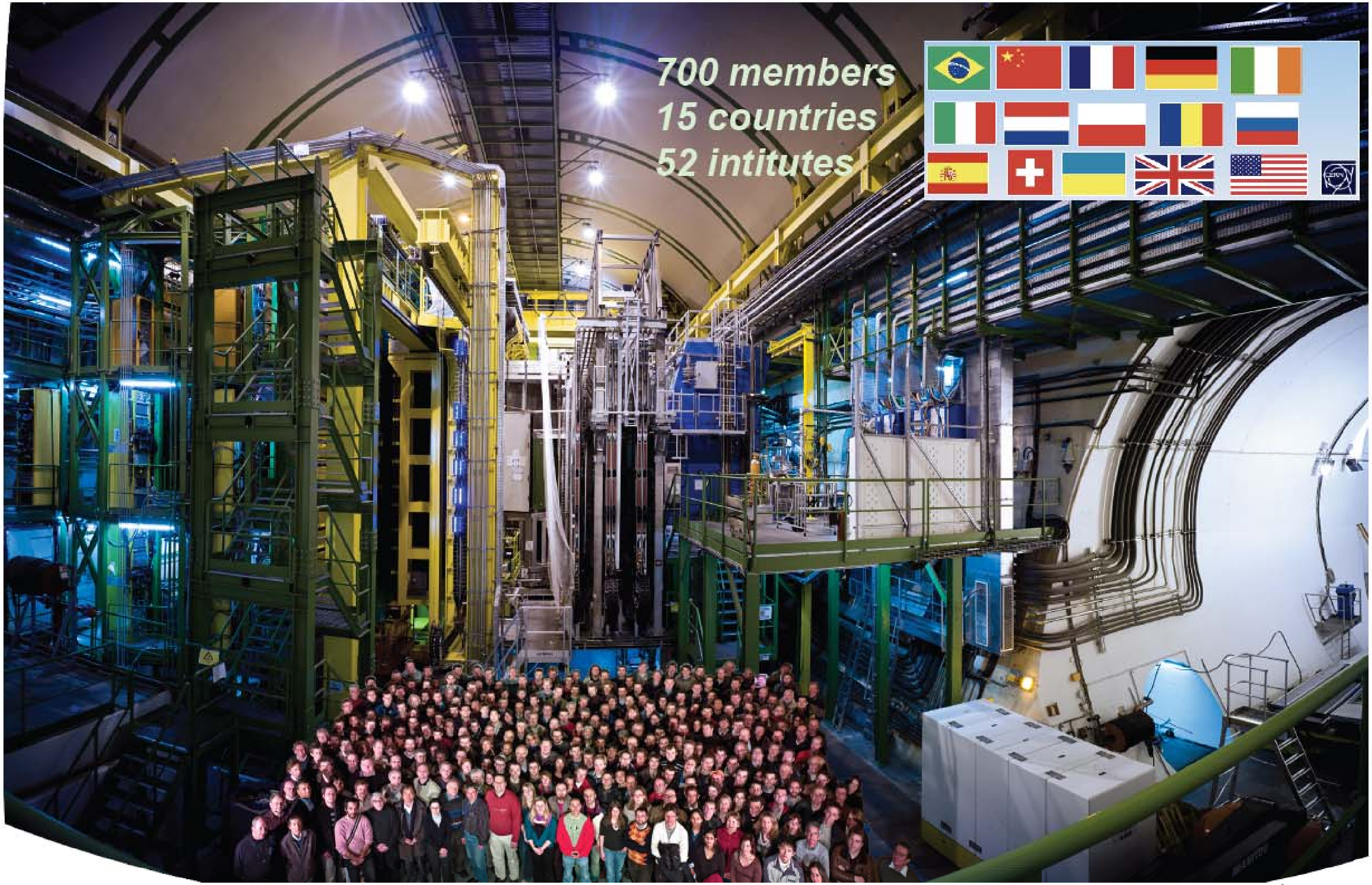
LHCb

LHCb is a forward spectrometer:

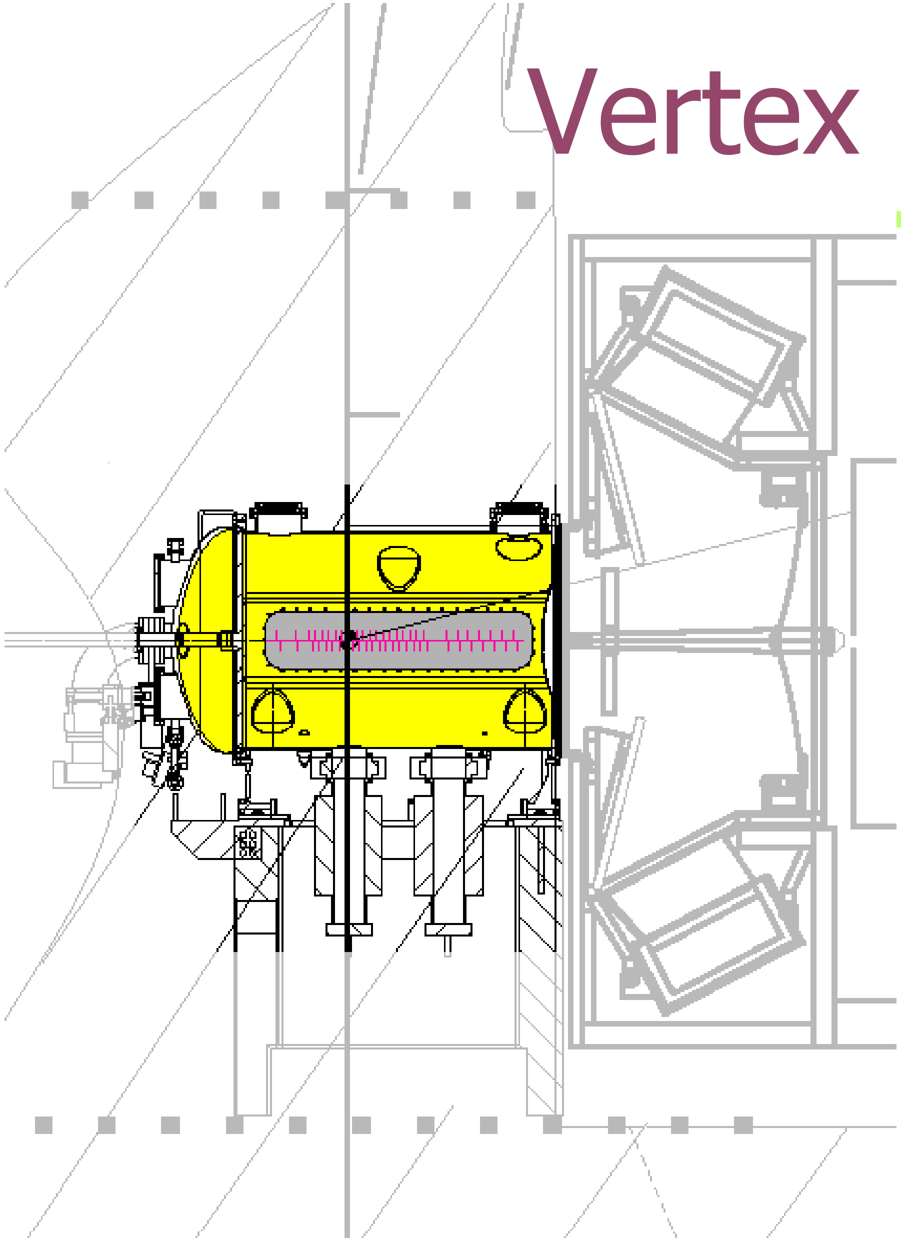
- Acceptance 10-300 mrad
- Efficient B-mesons trigger
- Good Kaon/pion identification
- Good invariant mass resolution
- Good proper time resolution



LHCb Collaboration



Vertex locator...

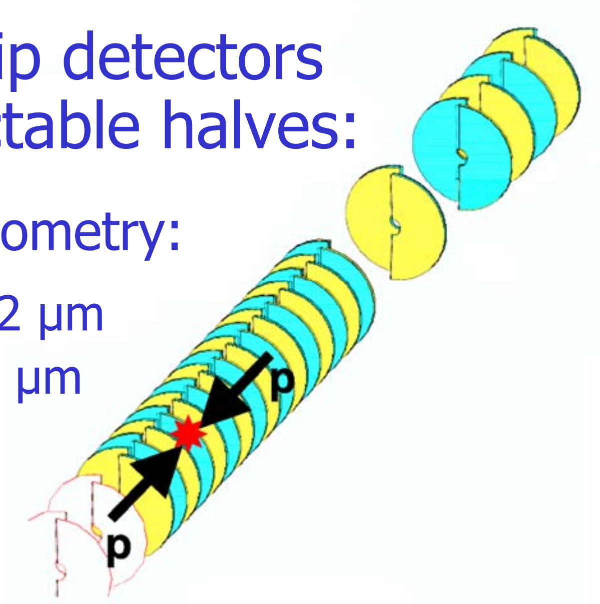


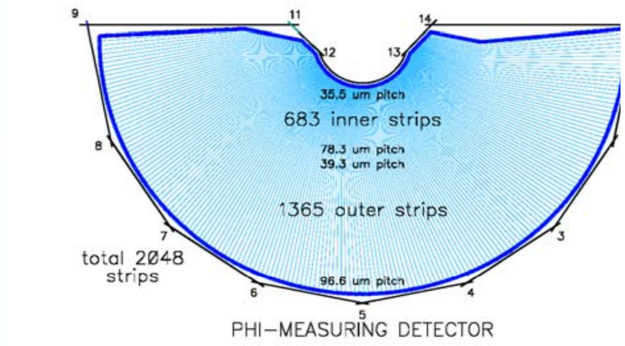
Key element surrounding the IP:

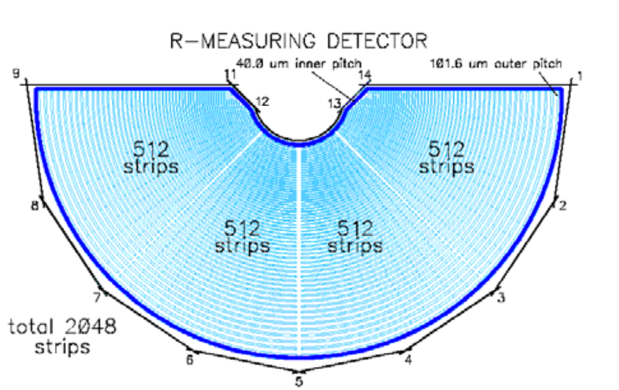
- Measure the position of the primary and the $B_{d,s}$ vertices
- Used in L1 trigger.

Vertex locator

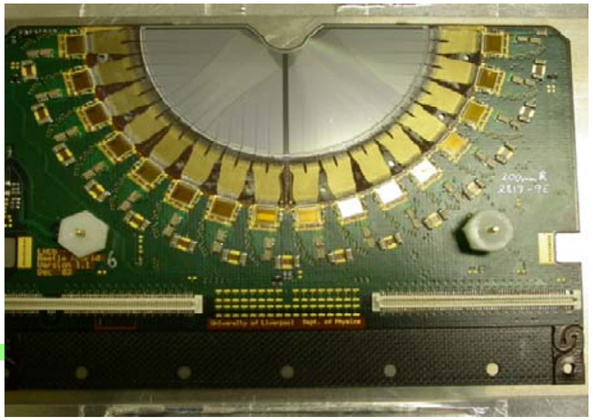
- 21 pairs of silicon strip detectors arrange in two retractable halves:
  - Strips with an R-φ geometry:
    - R strip pitch: 40-102 μm
    - φ strip pitch: 36-97 μm
  - 172k channels.





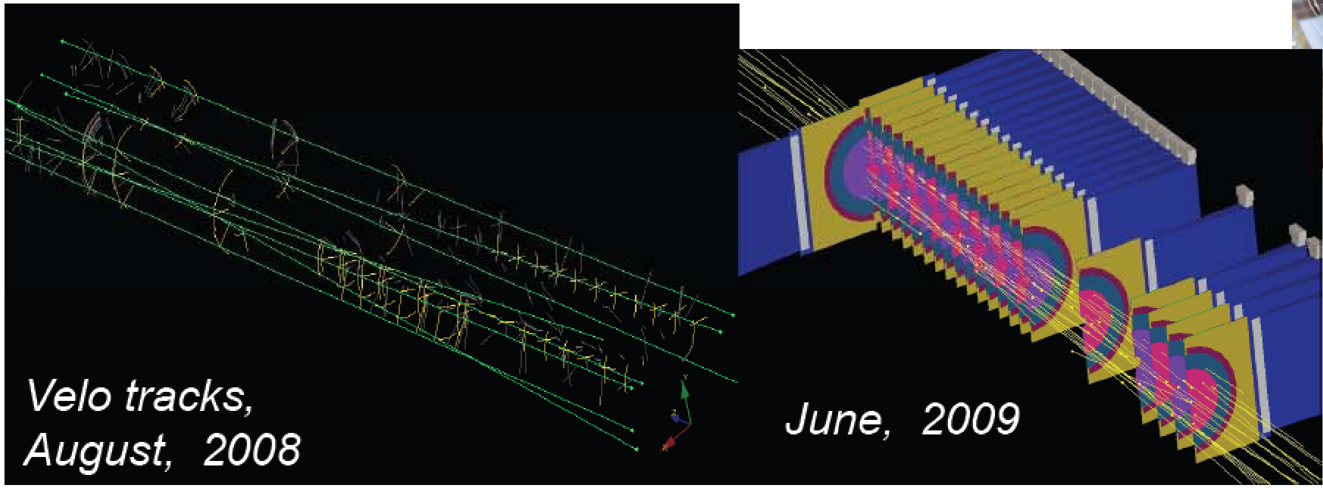


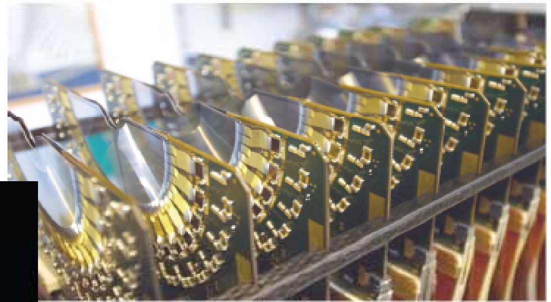
- Operated:
  - In vacuum, separated from beam vacuum by an Al foil
  - Close to the beam line (7 mm)
  - Radiation ≤ 1.5×10^{14} n_{eq}/cm^2 per year
  - Cooled at -5 °C



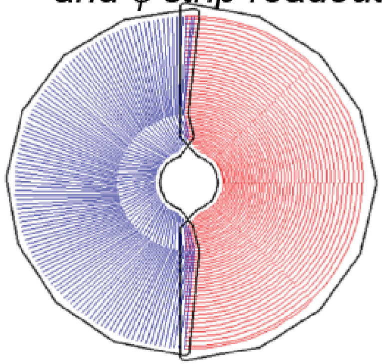
VELO alignment

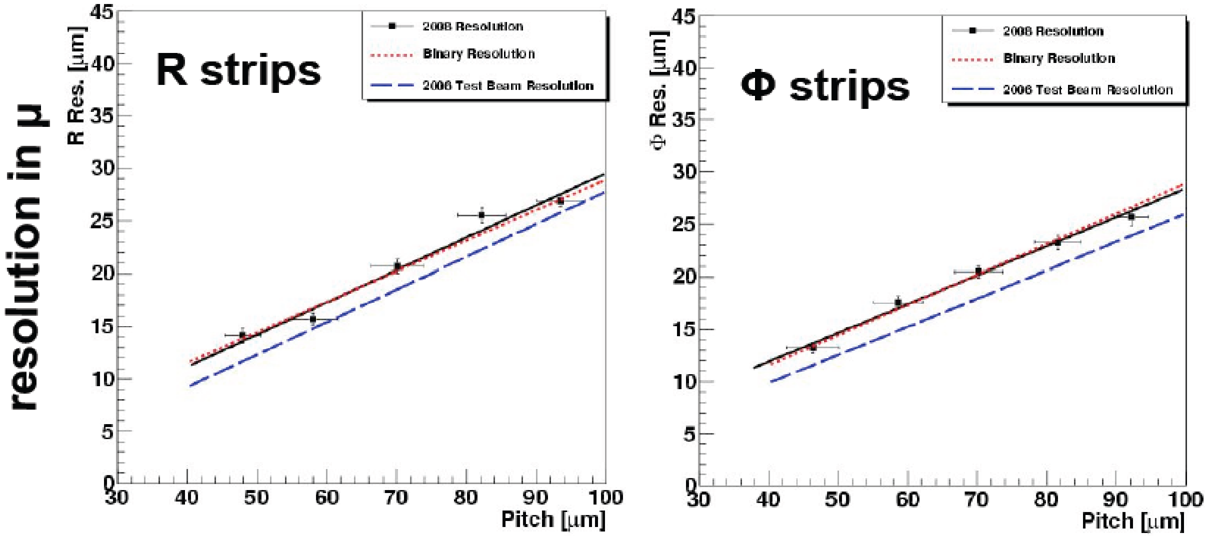
TED tracks perfect for VELO alignment: cross detector almost parallel to z-axis





21 stations of Si wafer pairs with r and ϕ strip readout

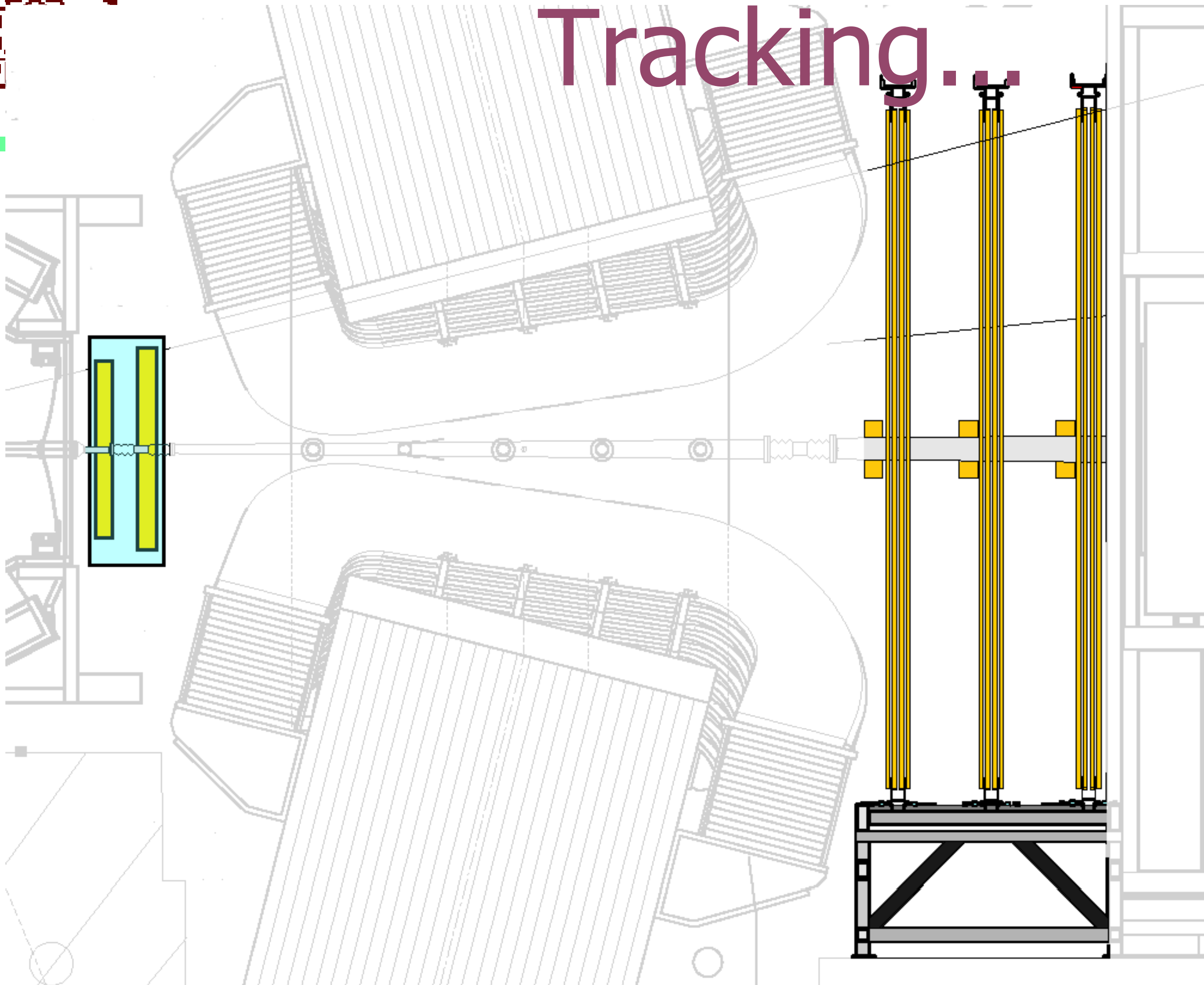




Resolution estimated from VELO hit residuals agrees well with expectations

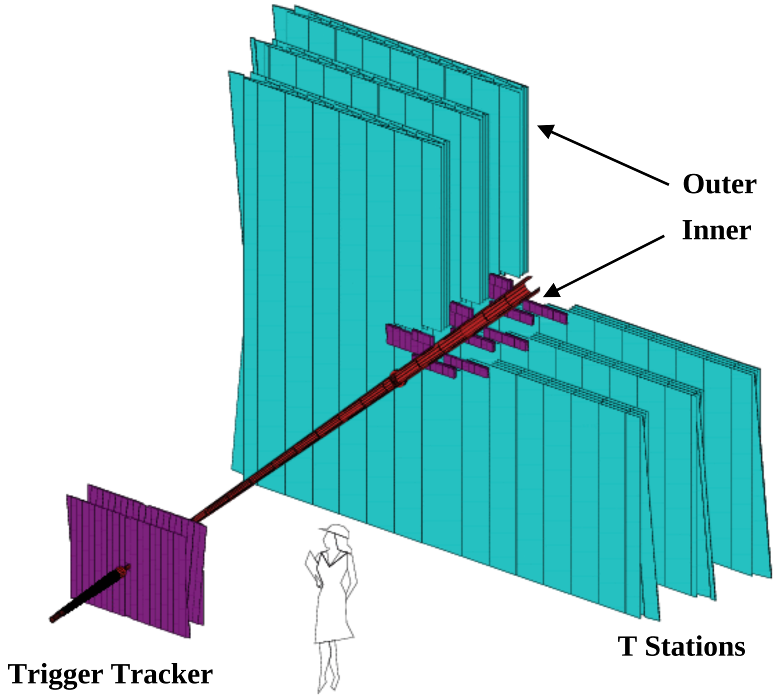
Further improvement possible

Tracking...



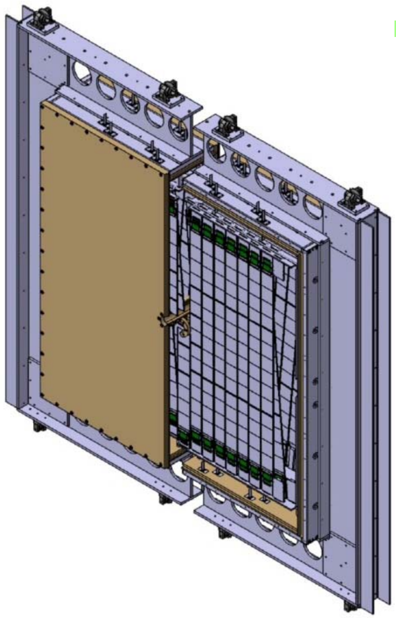
Key elements to find tracks and to measure their momentum.

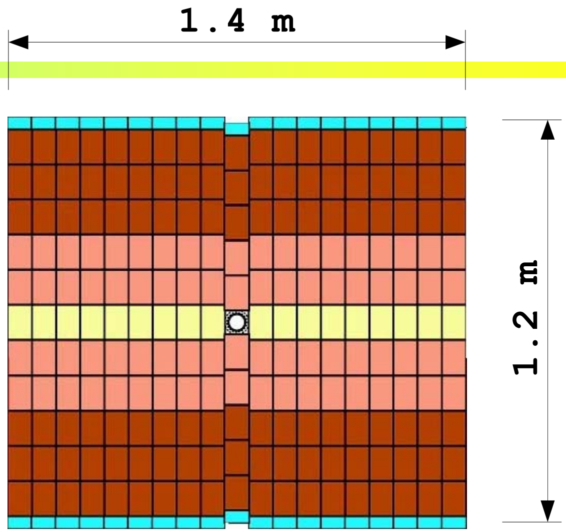
Overview of the tracking system



- Trigger Tracker:
    - Microstrip silicon detector
    - 144k channels
- Three T stations:
    - Inner tracker:
        - Microstrip Silicon detector
        - 130k channels
    - Outer tracker:
        - Straw tube (5 mm)
        - 56k channels

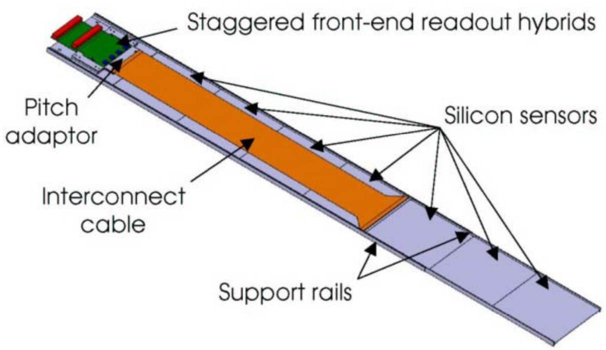
Trigger Tracker



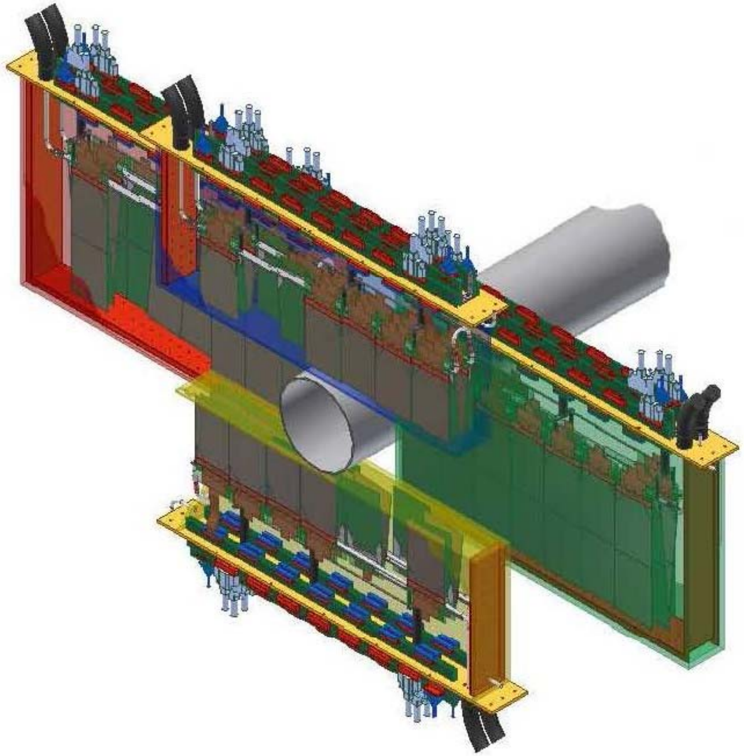


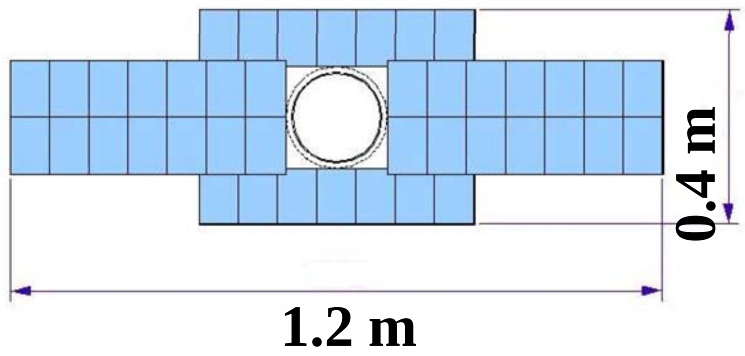
0° layer

- Microstrips silicon detector
  - Two groups of two layers (0°, +5°, -5°, 0°) separated by 30 cm
  - Strip pitch 198 μm
    Strip length 11, 22 and 33 cm
  - Radiation ≤ 9×10^{12} n_{eq}/cm^2 over 10 years
  - Cooled at -5 °C



T Station: inner tracker part

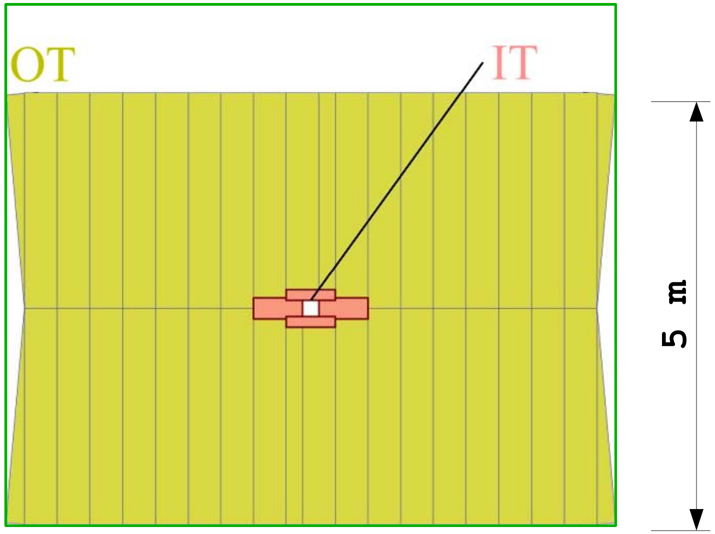


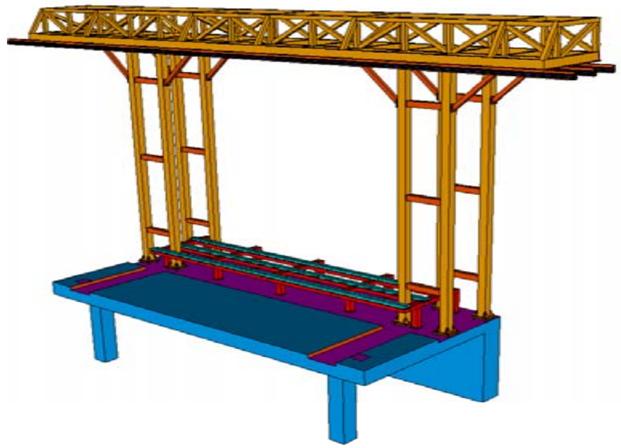


Microstrips silicon detector:

- Same sensors as Trigger Tracker
- Four layers (0°, +5°, -5°, 0°)
- Strip length 11, 22 cm
- Radiation ≤ 9×10^{12} n_{eq}/cm^2 over 10 years
- Cooled -5 °C

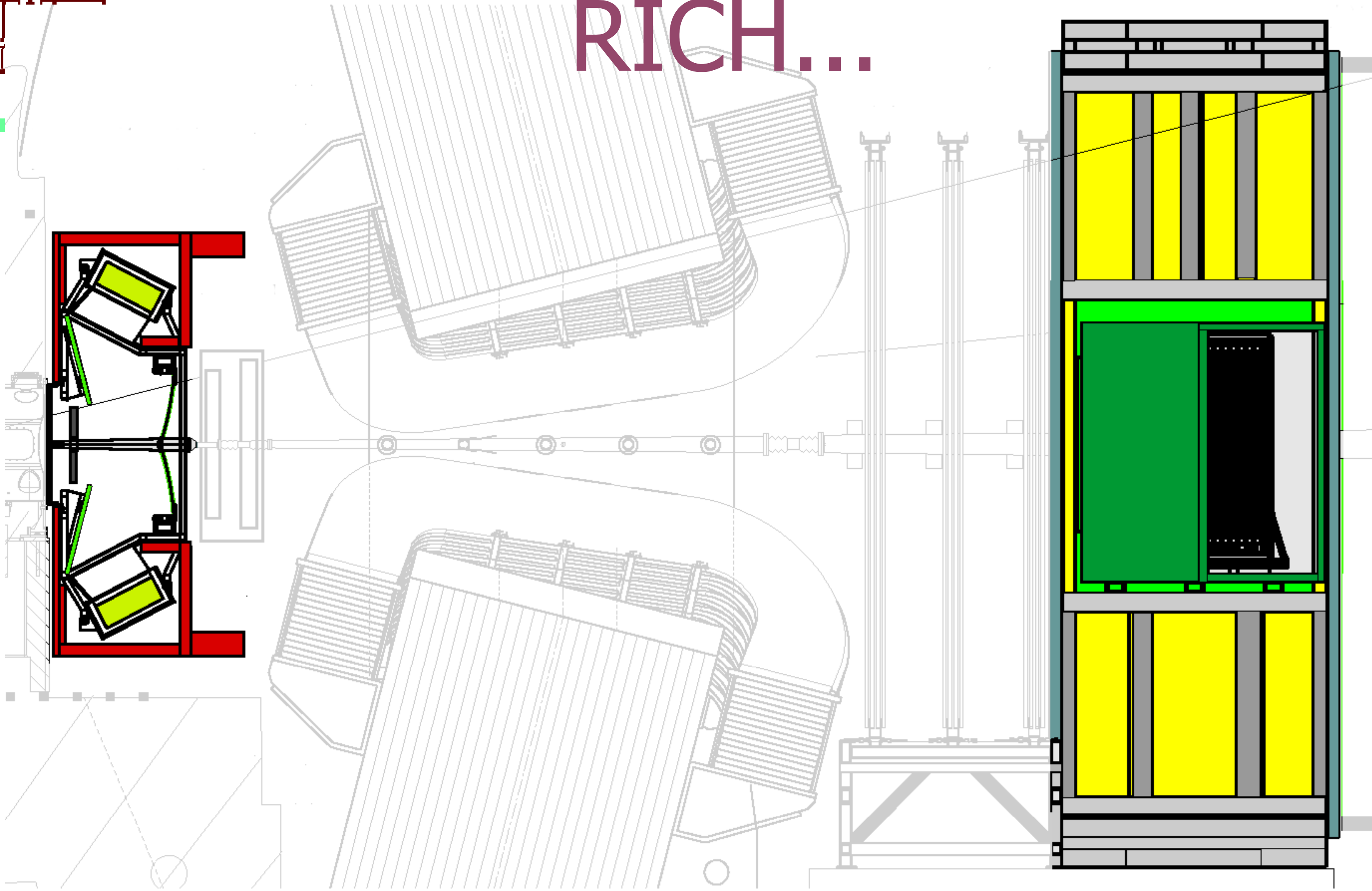
T station: outer tracker part





- Straw tubes:
  - Four double layers (0°,+5°,-5°,0°)
  - Staw length 5 m read on both sides
  - $Ar/CF_4/CO_2$

RICH…



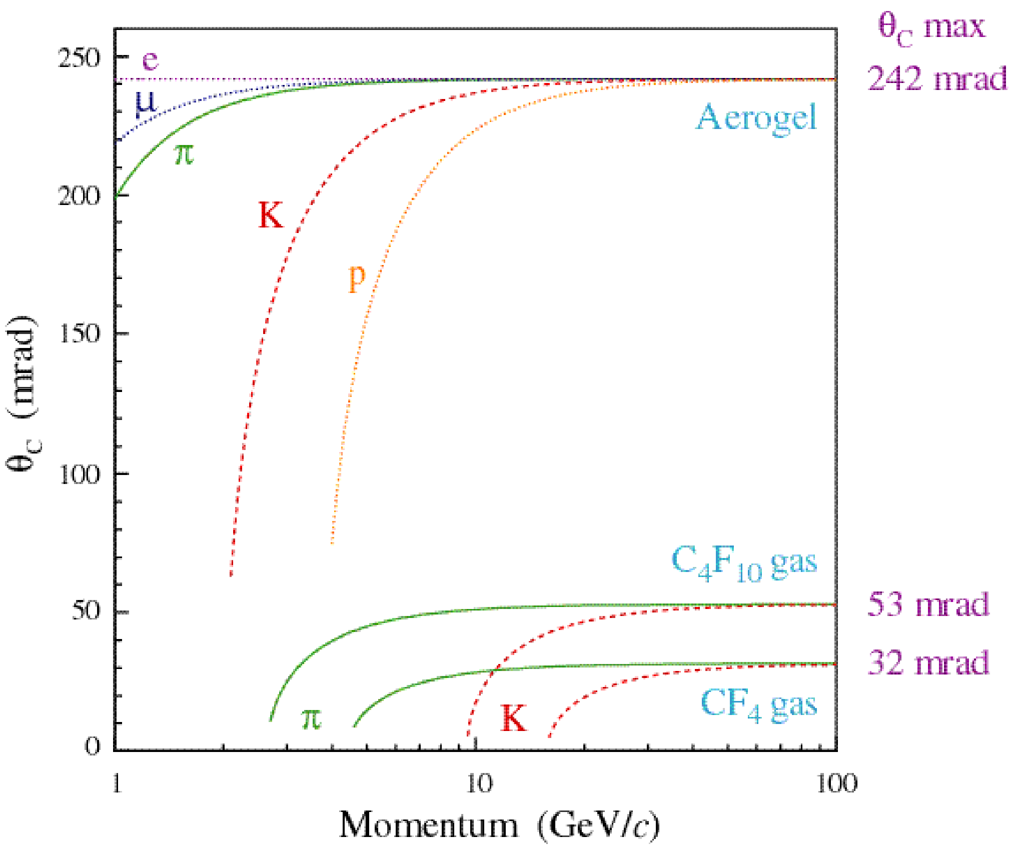
Key elements to identify pions and kaons in the momentum range $p \in [2, 100] \mathrm{GeV}/c$

Overview of the RICH

- RICH system divided in two detectors equipped with 3 radiators to cover the full acceptance and momentum range:

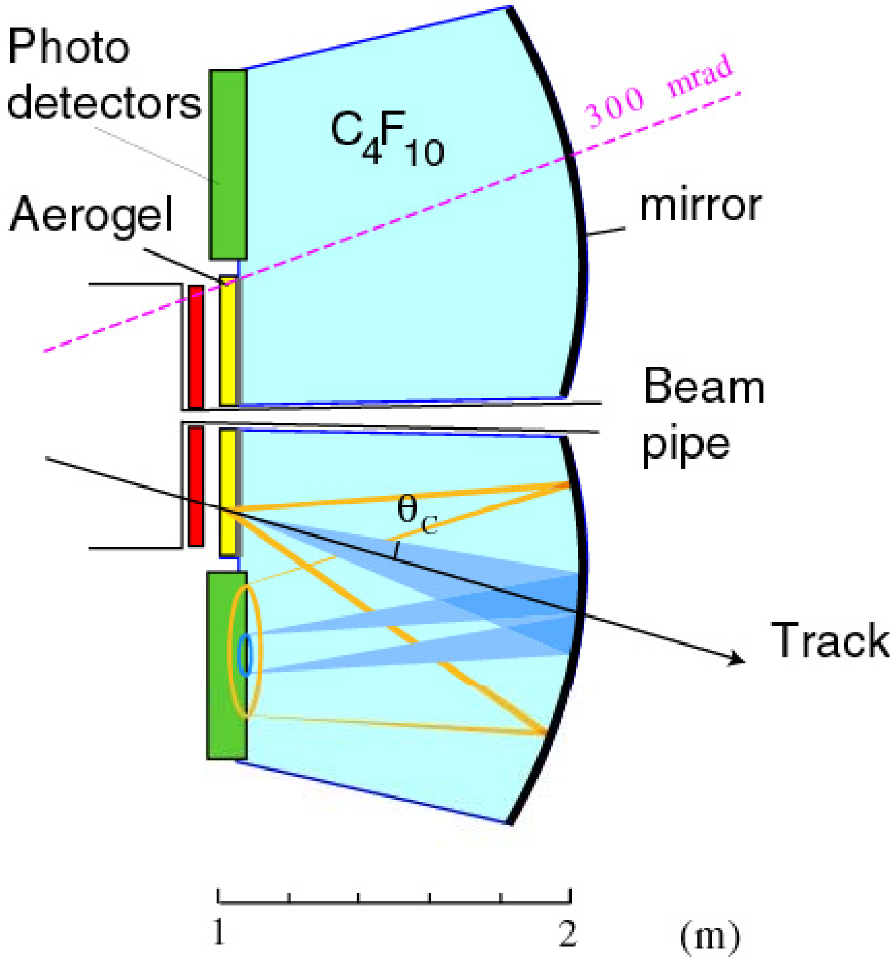
•from a few GeV (tagging kaons)

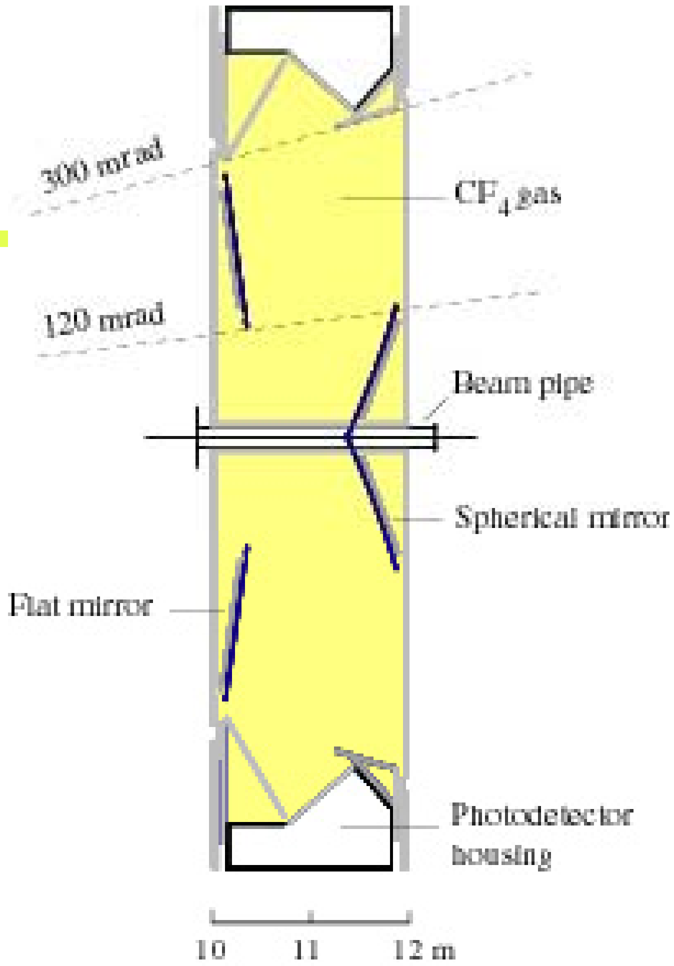
•up to 100 GeV: two body B decays



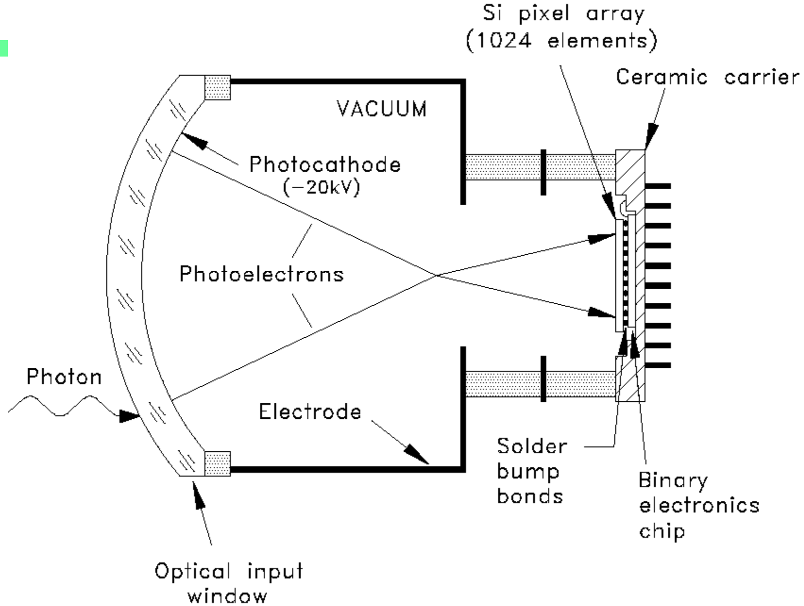
General rule: for 3σ separation, a RICH with a single radiator can cover a factor of 4-7 in momentum from threshold to the max. p. Larger region → more radiators!

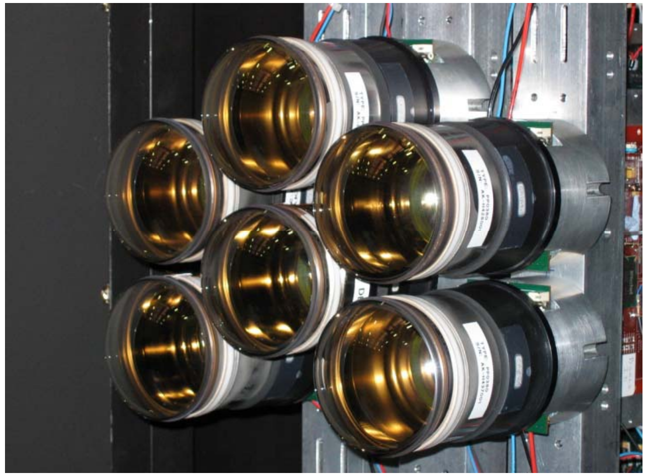
RICH with three radiators

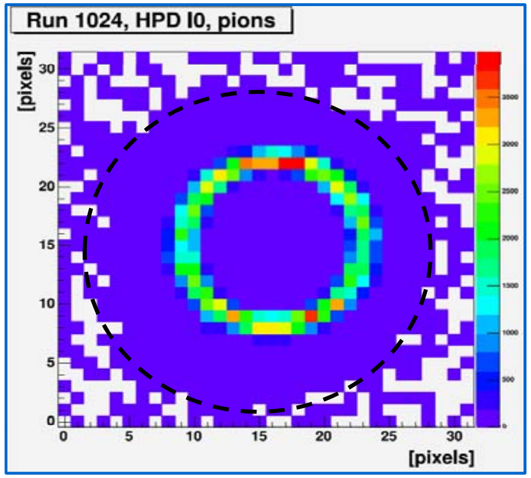




Photon detector HPD



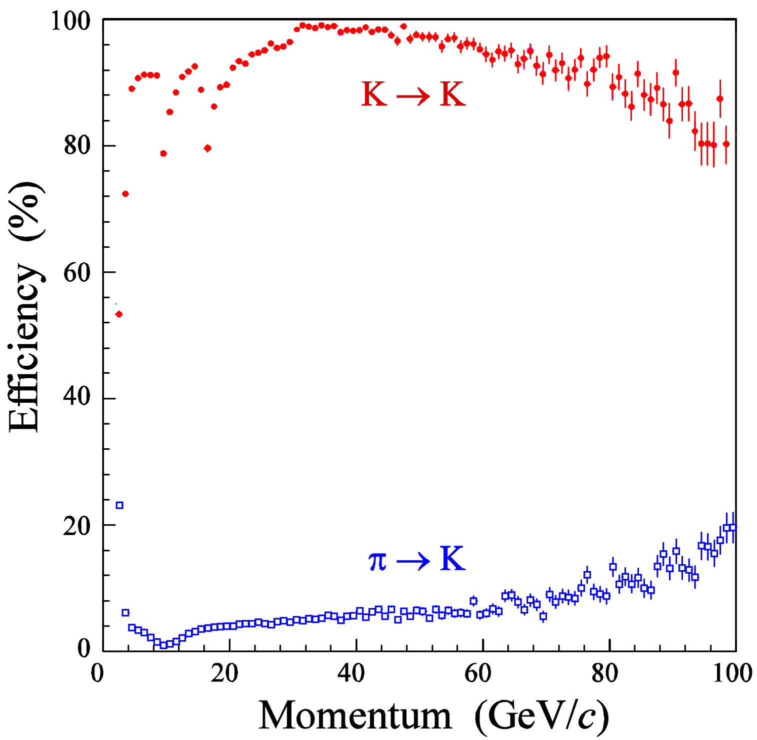


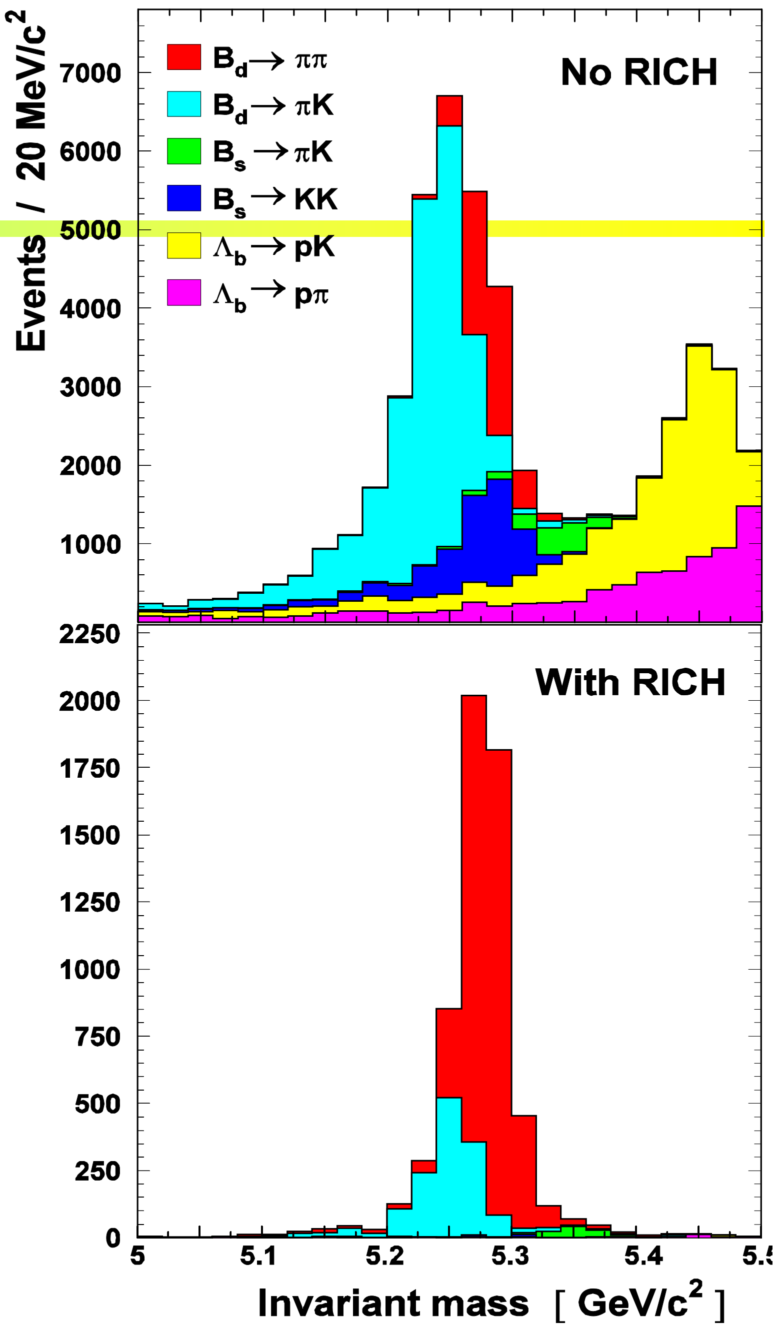


- Novel photodetector:
  - 32×32 pixel sensor array (500×500 μm²)
  - 20 kV operation voltage
  - Demagnification factor ~5

Particle Identification

Kaon identification efficiency:

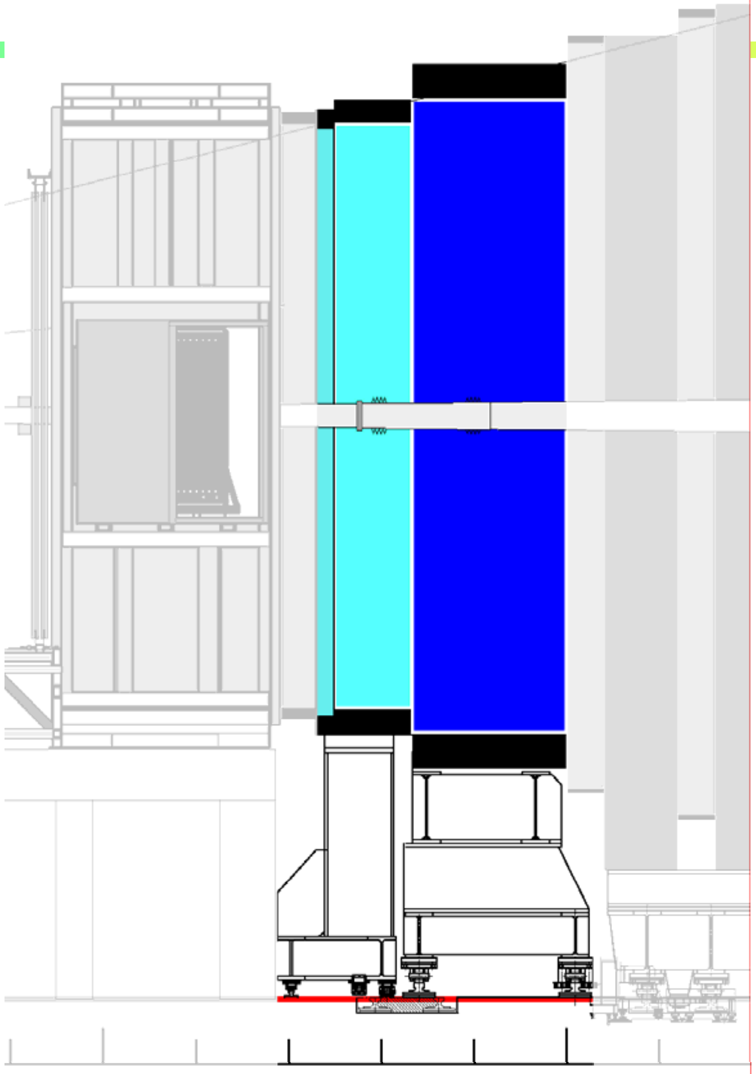




<K Efficiency>: 88%

<π misidentification> 3%

Calorimeters...



Key element to identify γ, π^0 and to measure their energy.

Used in L0 trigger.

Overview of the Calorimeters

- System subdivided in 3 parts:

  Scintillating Pad Detector (SPD) and Preshower:

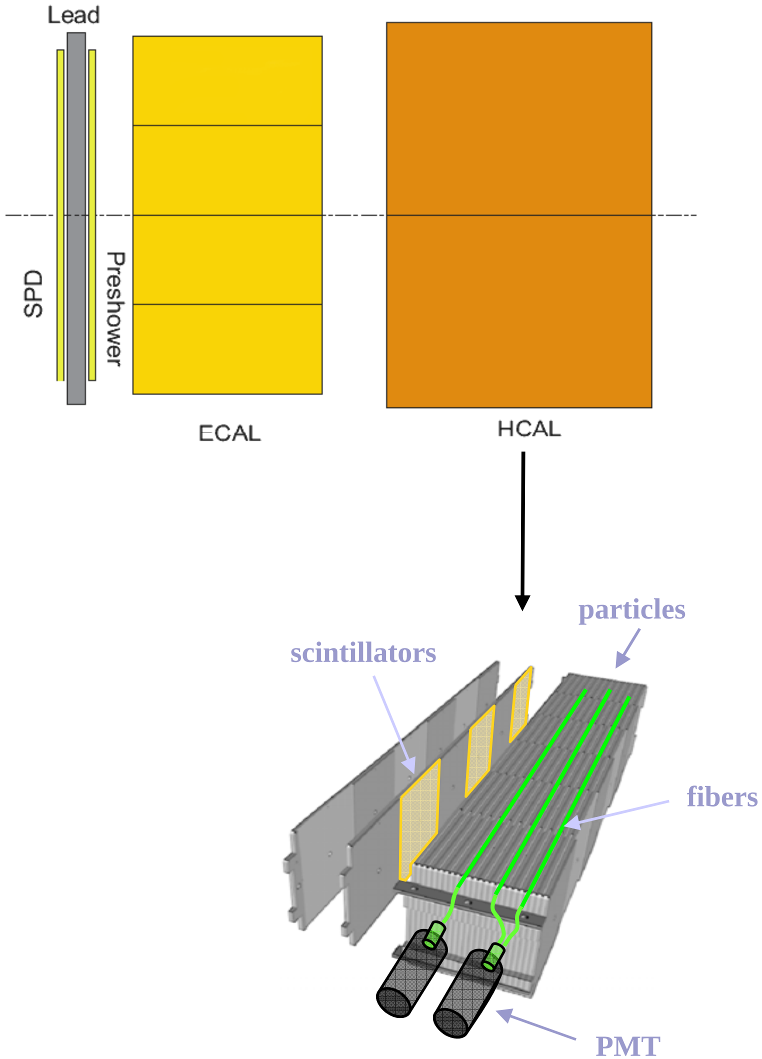
  - Two layers of scintillator pads separated by a 1.5cm lead converter

  Electromagnetic Calorimeter (ECAL):

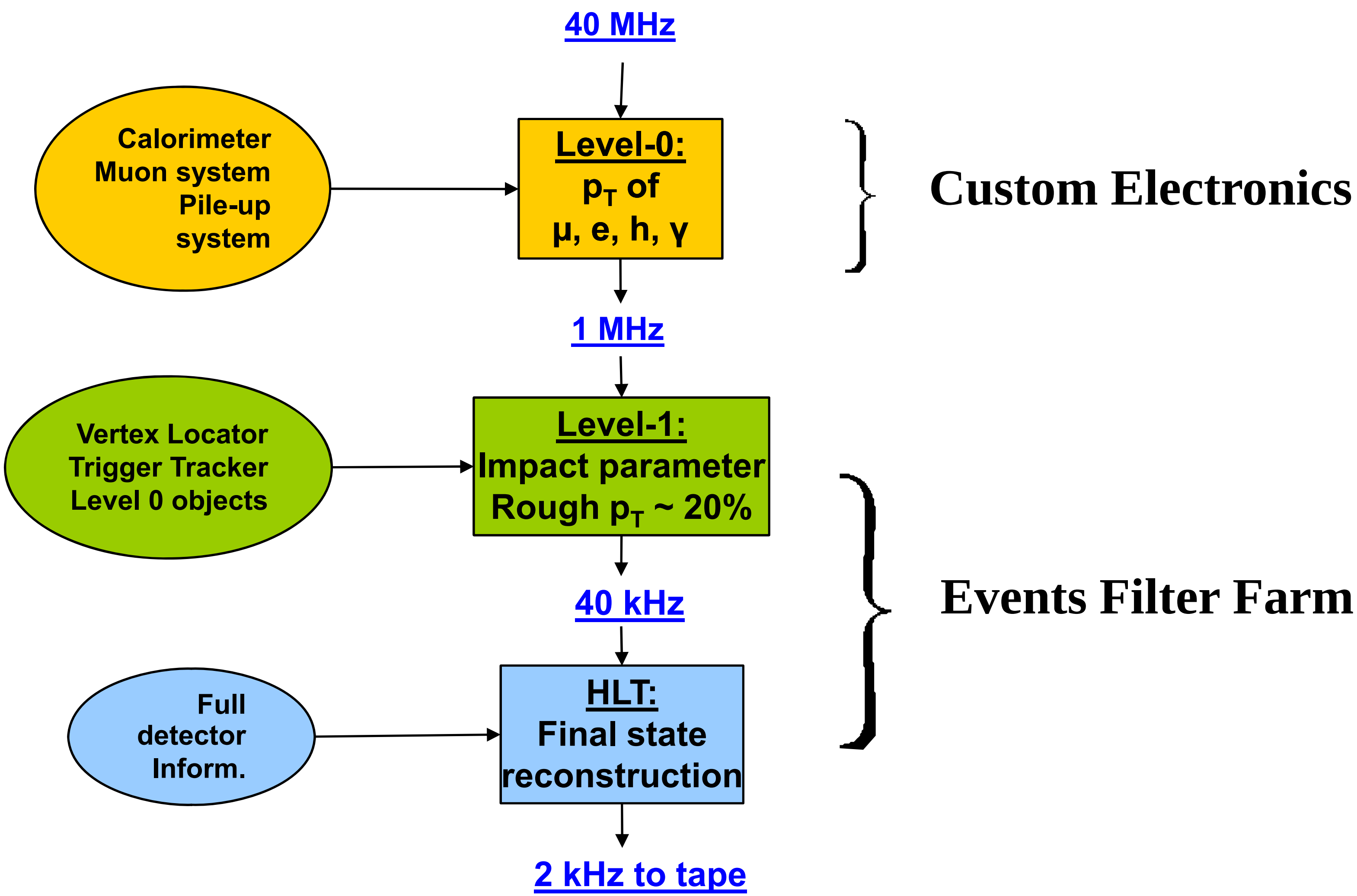
  - Shashlik types,
  - Lead+ scintillator tiles
  - 25 X_0

- Hadronic calorimeter (HCAL):
  - Iron + scintillator tiles
  - 5.6 λ_I

- A total of 19k channels readout by Wave Length Shifter fibres connected to PMs or MaPMTs.

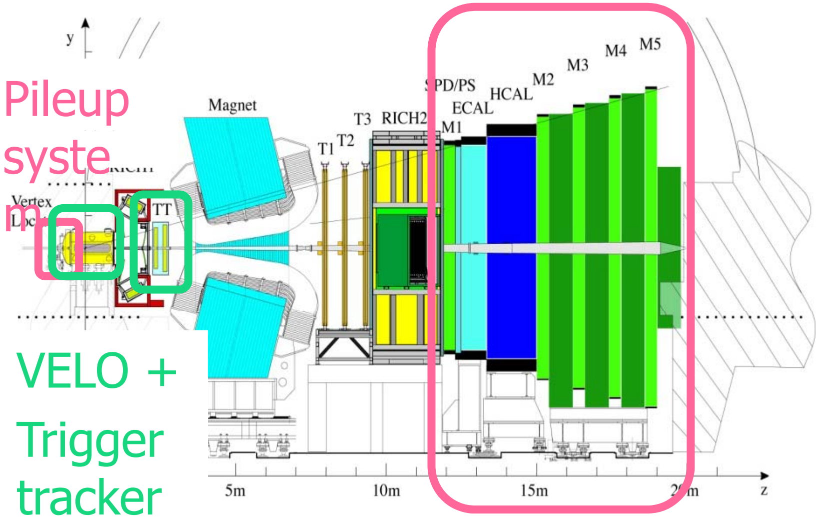


Triggers...



40 MHz
Calorimeter
Muon system
Pile-up
system
Level-0:
p_T of
μ, e, h, γ
Custom Electronics
1 MHz
Vertex Locator
Trigger Tracker
Level 0 objects
Level-1:
Impact parameter
Rough p_T ~ 20%
40 kHz
Events Filter Farm
Full
detector
Inform.
HLT:
Final state
reconstruction
2 kHz to tape

Trigger overview



Pileup system

VELO + Trigger tracker

Calorimeters + Muon system

10 MHz

L0: hight p_T + not too busy
- Fully synchr. (40 MHz), 4μs latency
- On custom boards

1 MHz

L1: IP + high p_T
- Ave. latency: 1 ms (max 50 ms)
- Buffer: 58254 events

40 KHz

HLT + reconstruction
- Full detector: ~ 40 kb / evt

~ 200 Hz

Single PC farm
~1800 CPUs

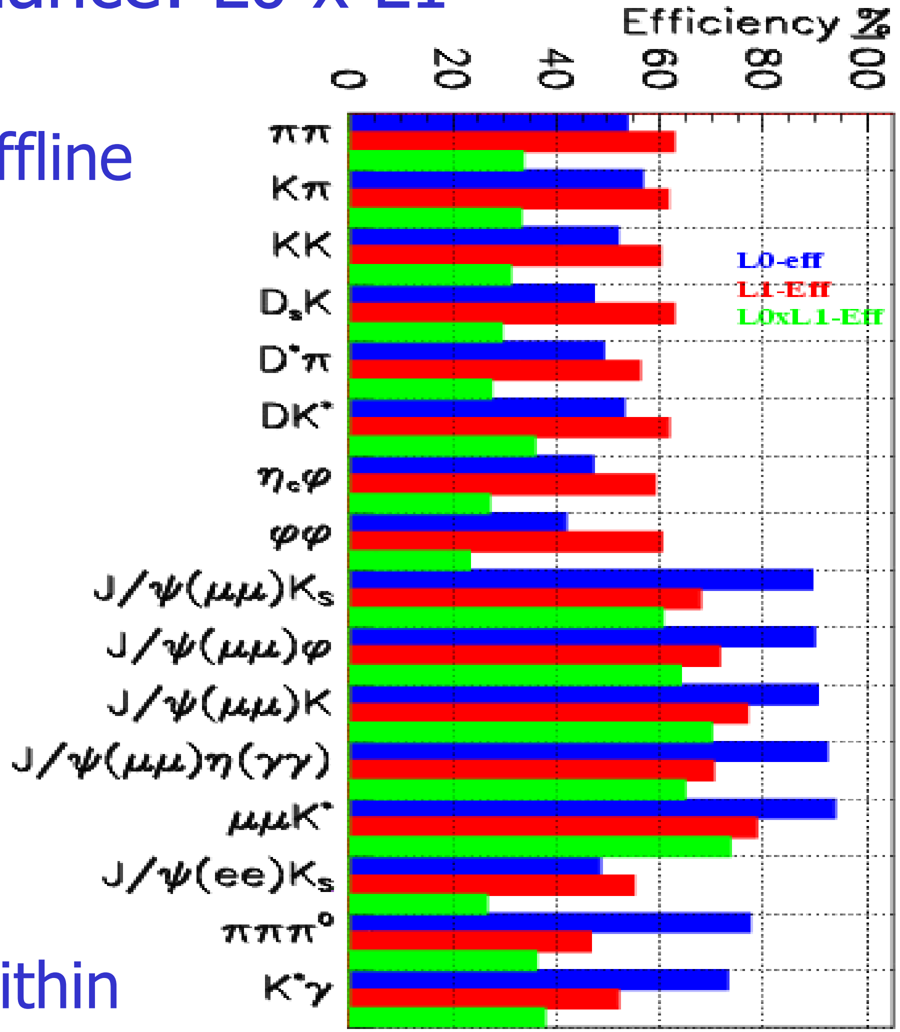
Level 0

- **Fast search for 'high' p_T particles** (calorimeters, muon syst)
  - Charged **hadrons**: HCAL (~ 3 GeV)
  - Electrons, photons, π^0: ECAL (~ 3 GeV)
  - Muons: muon system (~ 1 GeV)

- **Cut on global variables:**
  - Require minimum total E_T in HCAL (calorimeters)
    - Reduces background from halo-muons
  - Rejection of multiple primary vertices and busy events (Pileup system, SPD) :
    - fake B signatures (IP)
    - Busy events spend trigger resources without being more signal-like
      - Better throw them early and use bandwidth to relax other cuts

Performance: L0 x L1

- Efficiencies computed on offline selected events
- Overall L0xL1 efficiency:
  - **30% for**
    - **hadronic channels**
    - **e/γ/π⁰ channels**
  - **60-70% for di-muons**
- Software and hardware prototyped and working, within time budget
  - see Trigger TDR, Sept 2003

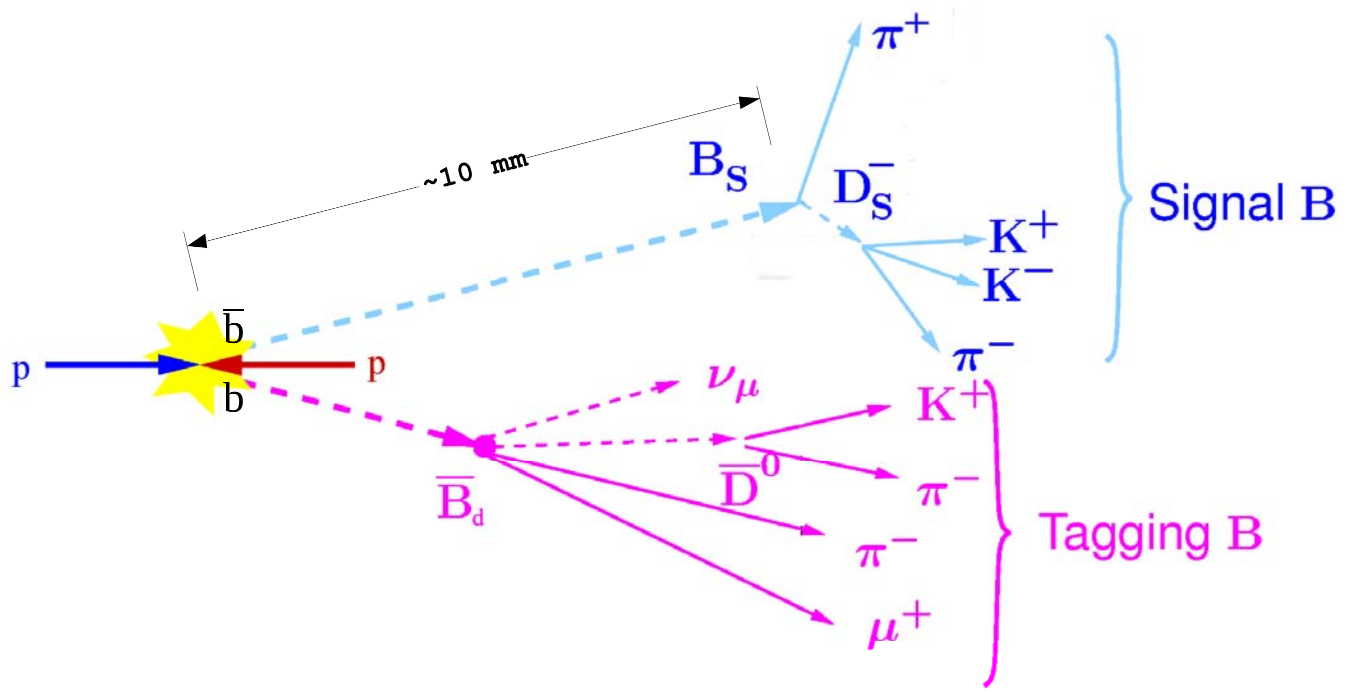


L0 efficiency
L1 efficiency
L0×L1 efficiency

LHCb physics program

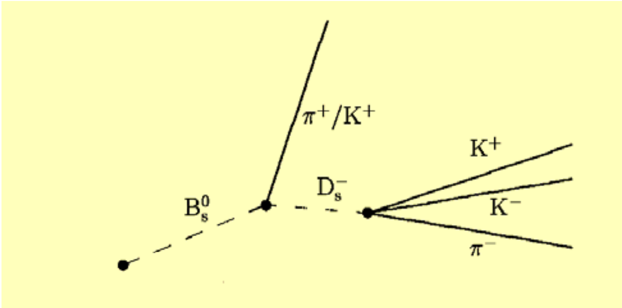
- B_s system parameters
- Angles of the unitarity triangle: precise measurements
- FCNC processes
- Measurement of angle γ (ϕ_3)

Time dependent asymmetry at LHCb

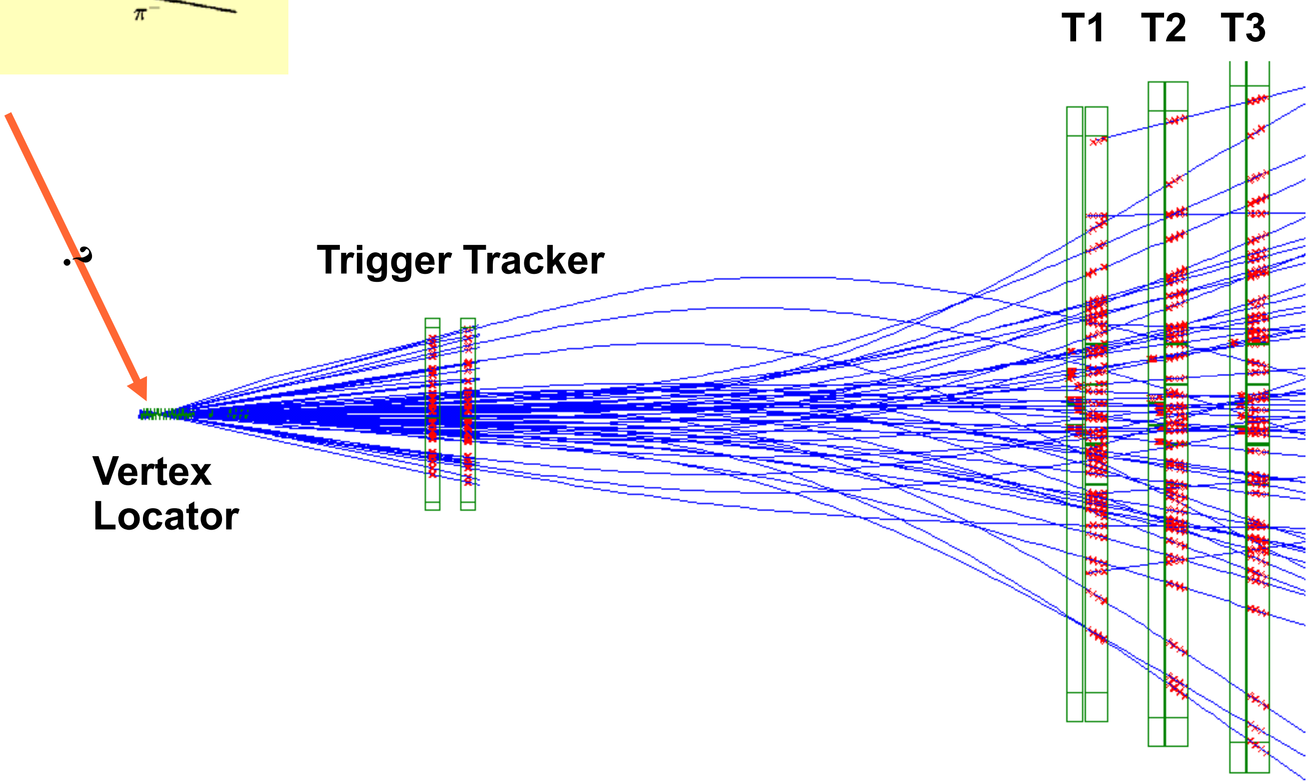


- The proper time of the signal B decay is measured via:
  - the position of the primary and secondary vertexes;
  - the momentum of the signal B state from its decay products.

Event selection: (1)



$$B_s \to D_s^{\pm} K^{\mp} \to \left(K^+ K^- \pi^{\pm}\right) K^{\mp}$$



Reconstructed event: ~72 tracks

Event selection: (2)

$$B_s \to D_s^{\pm} K^{\mp} \to \left(K^+ K^- \pi^{\pm}\right) K^{\mp}$$

1) Primary vertex.

2) D_s meson by using identified kaons and pions and a vertex constrained to the D_s mass.

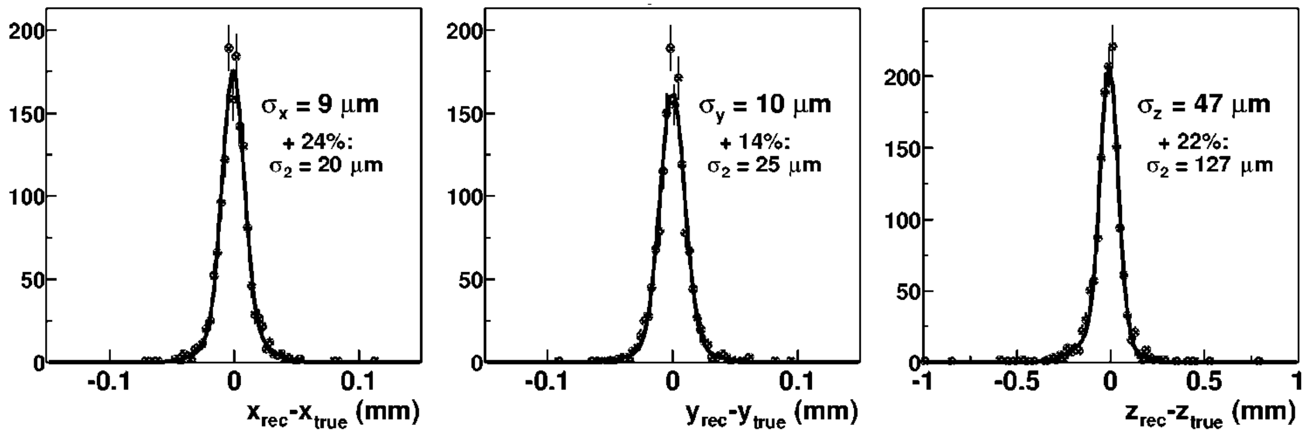
3) B_s meson by combining a D_s with a kaon forming a vertex (no mass constraint).

4) Select B_s with an impact parameter ~0 and an invariant mass in the window $m_{B_s} \pm 50\,\mathrm{MeV}/c^2$

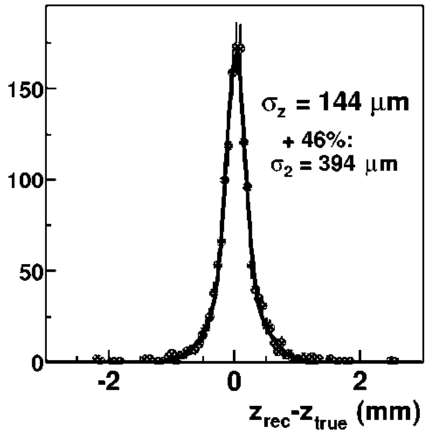
Resolution:

$$B_s \to D_s^{\pm} K^{\mp} \to \left(K^+ K^- \pi^{\pm}\right) K^{\mp}$$

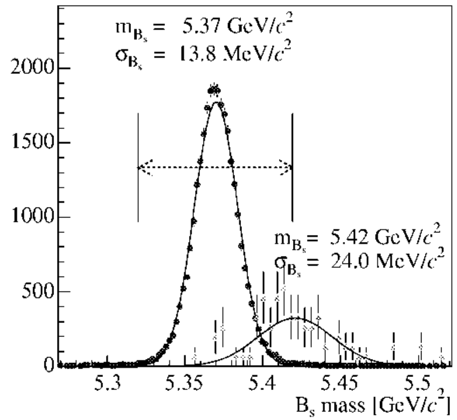
Primary vertex: 47μm



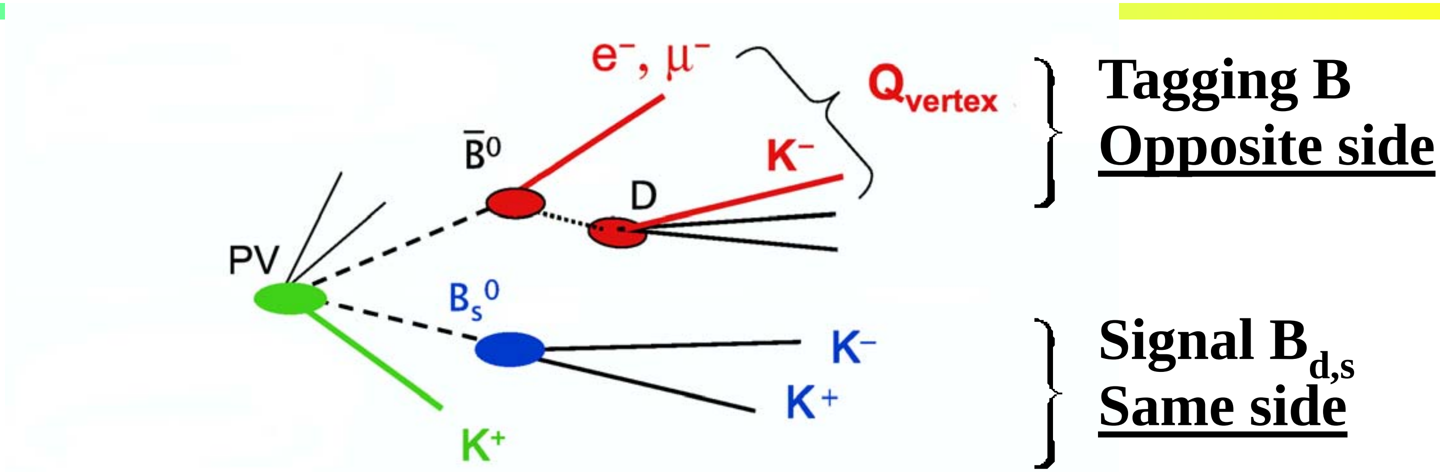
Bs vertex: 144μm



Bs mass: 14 MeV/c^2



Flavour Tagging



- Several algorithms to determine the flavour of the signal B meson at production:
  - Opposite side:
    - e, μ from semileptonic b decays;
    - $K^{\pm}$ from b decays chain;
    - Inclusive vertex charge.
  - Same side:
    - $K^{\pm}$ from fragmentation accompanying B_s meson.

Performance of Flavour Tagging

After passing trigger and offline cuts

Channel	$\varepsilon_{\rm tag}$ (%)	w (%)	$\varepsilon_{\rm eff}$ (%)
$B^0 \to \pi^+\pi^-$	41.8±0.7	34.9±1.1	3.8±0.5
$B^0 \to K^+\pi^-$	43.2±1.4	33.3±2.1	4.8±1.0
$B^0 \to J/\psi\,(\mu\mu)K^0_S$	45.1±1.3	36.7±1.9	3.2±0.8
$B^0 \to J/\psi\,(\mu\mu)K^{*0}$	41.9±0.5	34.3±0.7	4.1±0.3
$B^0_s \to K^+K^-$	49.8±0.5	33.0±0.8	5.8±0.5
$B^0_s \to \pi^+K^-$	49.5±1.8	30.4±2.6	7.6±1.7
$B^0_s \to D^-_s\pi^+$	54.6±1.2	30.0±1.6	8.7±1.2
$B^0_s \to D^{\mp}_s K^{\pm}$	54.2±0.6	33.4±0.8	6.0±0.5
$B^0_s \to J/\psi\,(\mu\mu)\phi$	50.4±0.3	33.4±0.4	5.5±0.3

- Effective tagging efficiencies vary between 3 and 9% depending on the final state.
- In real physics analysis, the wrong tag fraction will be measured using control channels with similar topology, e.g.

$$B_d \to J/\psi K^{*0} \text{ for } B_d \to J/\psi K_S$$

N.B. Effective tagging efficiencies is >20% at B factories, ~2% at CDF/D0

Events yield for rare decays

- For 2 fb^{-1} after trigger and offline selection:

Channel	B.R.	Yield	B/S (90%CL)
$B_d \to K^{*0}(K^+\pi^-)\gamma$	2.9×10^{-5}	3.5×10^{4}	<0.7
$B_s \to \varphi(K^+K^-)\gamma$	2.1×10^{-5}	9.3×10^{3}	<2.4
$B_d \to \omega(\pi^+\pi^-\pi^0)\gamma$		40	<3.5
$B_d \to K^{*0}(K^+\pi^-)\mu^+\mu^-$	8×10^{-7}	4.4×10^{3}	<2.0
$B_d \to \varphi(K^+K^-)K_S(\pi^+\pi^-)$	1.4×10^{-6}	0.8×10^{3}	<0.2
$B_s \to \varphi(K^+K^-)\varphi(K^+K^-)$	1.3×10^{-6}	1.2×10^{3}	<1.1
$B_s \to \mu^+\mu^-$	3.5×10^{-9}	17	<5.7

- Promising physics potential to study numerous loop-induced rare decays.
  Still room to adjust trigger in order to increase the rate for channels of topical interest

LHCb key measurements

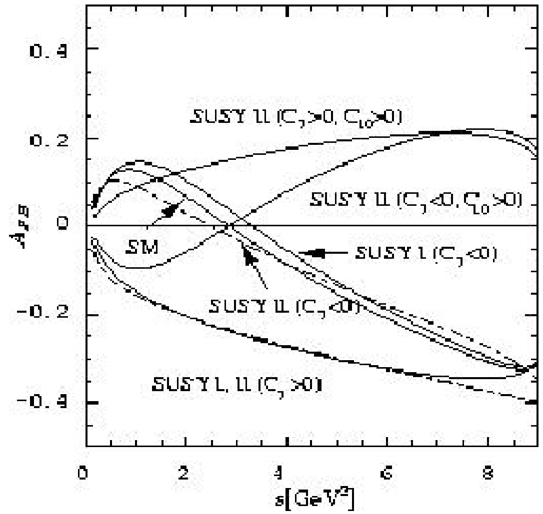
(to search for NP in CP violation and Rare Decays)

Key Measurements	Accuracy in 1 nominal year ($2\ fb^{-1}$)
❑ In CP – violation	
✓ β_s	**0.03**
✓ γ in trees	$4.5°$
✓ γ in loops	$7°$
❑ In Rare Decays	
✓ $B_s \rightarrow \mu\mu$	**3σ measurement down to SM prediction**
✓ $B \rightarrow K^*\mu\mu$	$\sigma(s0) = 0.5\ GeV^2$
✓ Polarization of photon in radiative penguin decays	$\sigma(H_R/H_L) = 0.1$ (in $B_s \rightarrow \phi\gamma$) $\sigma(H_R/H_L) = 0.1$ (in $B_d \rightarrow K^* e^+ e^-$)

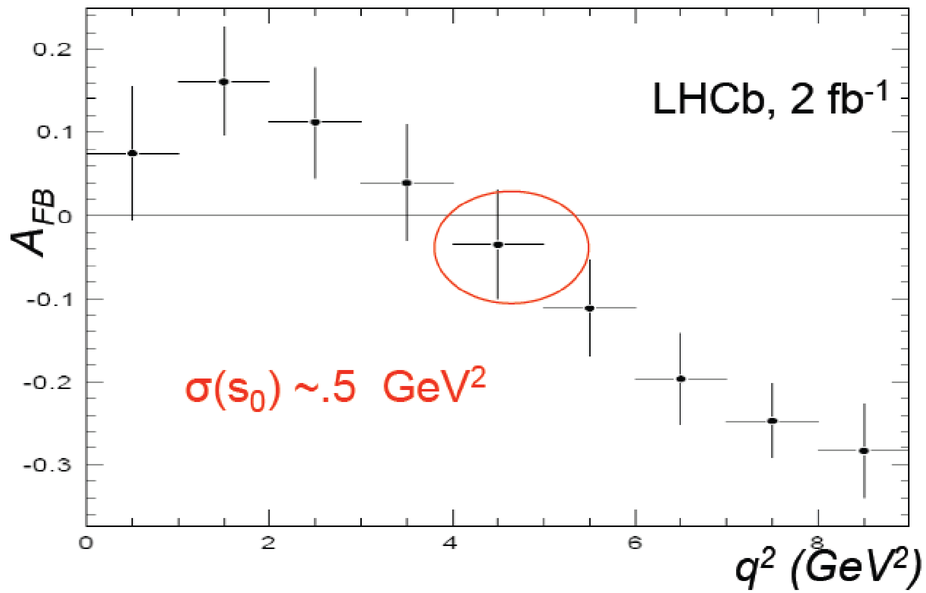
Measurements highlighted in red will become competitive first

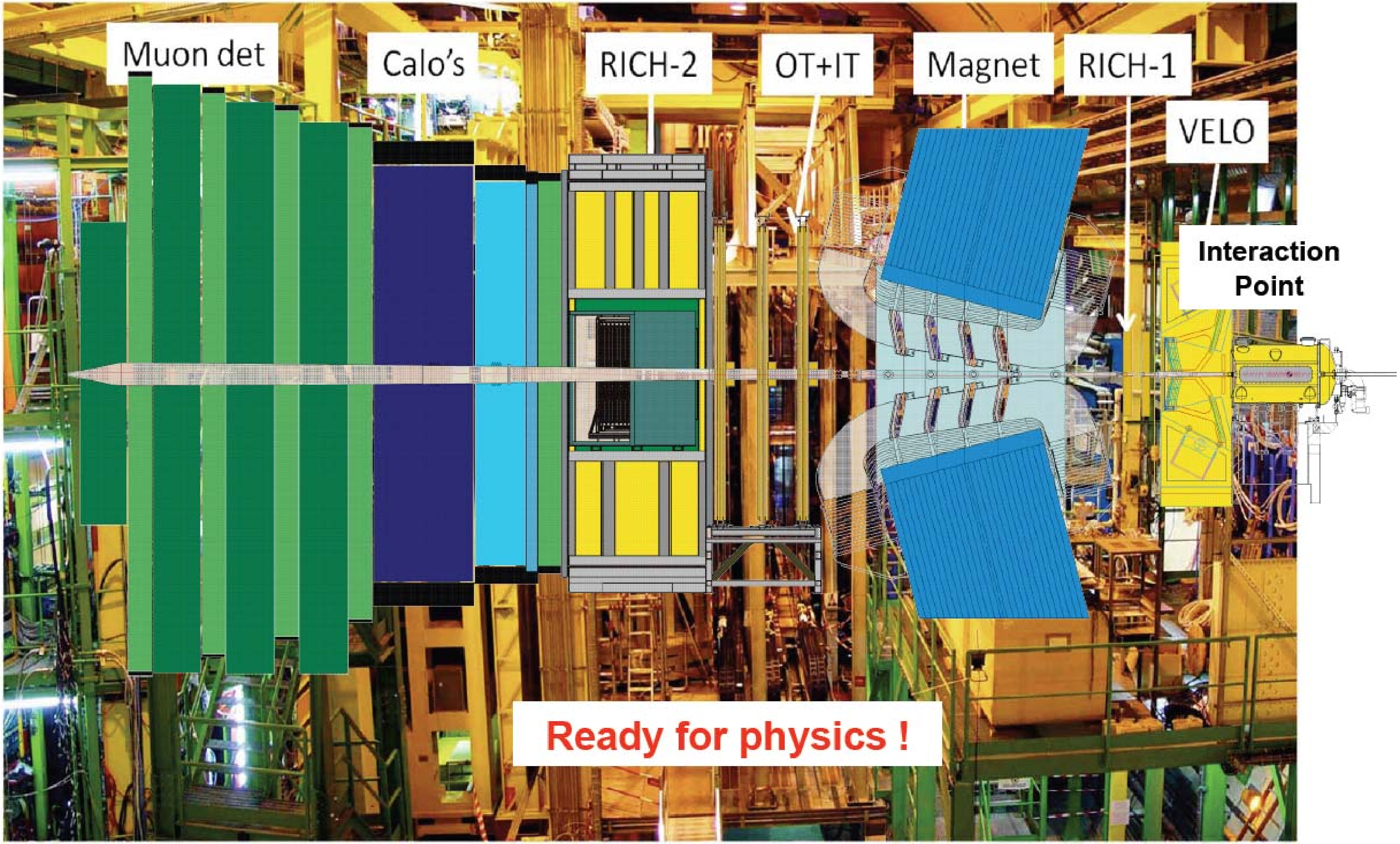
$A_{FB}(s)$ $\quad B^0 \to K^{*0}\mu^+\mu^-$

- Forward-backward asymmetry in the μμ rest frame $A_{FB}(s)$ is a sensitive probe of new physics



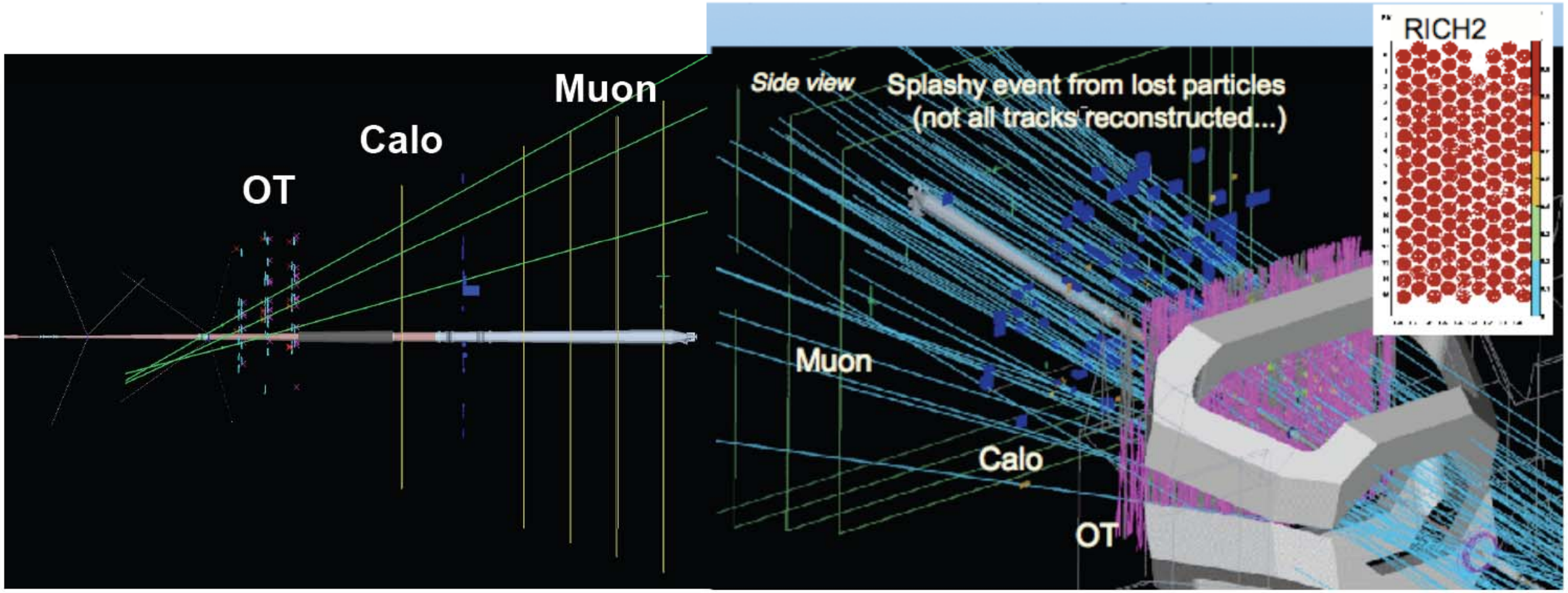
- Sensitivity at 2 fb^{-1}: zero point location to +-0.5 GeV^2




Muon det
Calo's
RICH-2
OT+IT
Magnet
RICH-1
VELO
Interaction Point
Ready for physics !

Events registered on September 10, 2008 for a LHC operation (media day)

- *Beam 1 was circulated during few hours (correct direction for LHCb)*
- *Readout of consecutive triggers, 8 events every 25 ns*
- *Two types of events have been observed: a'la beam gas events or beam halo muons and splashy events hitting on collimator*
- ***LHCb made very successful start !!!***



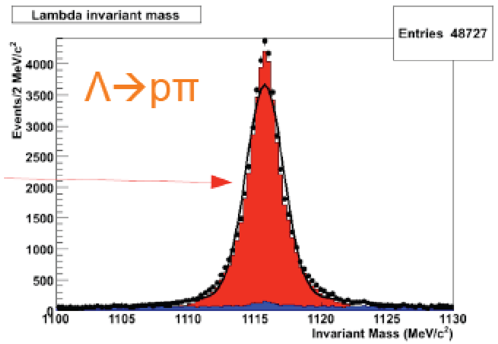
Physics goals of 2010

Early measurements

- Calibration signals and minimum bias physics: 10^8 events

Key channels available in min bias data with simple trigger:

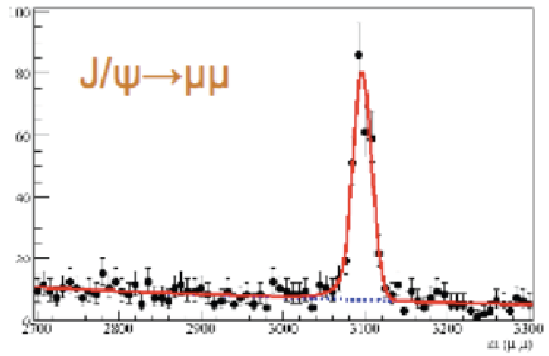
- *$K_s \rightarrow \pi\pi$*
- *$\Lambda \rightarrow p\pi$*



95% purities achievable using kinematical & vertex cuts alone

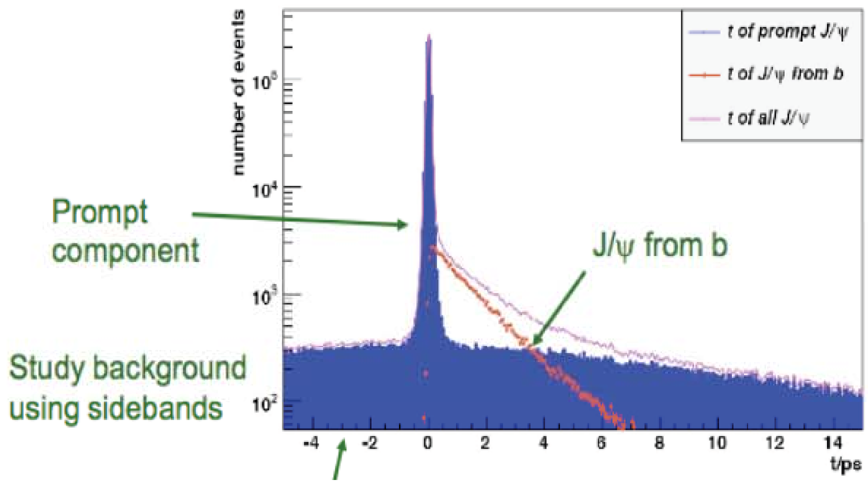
~ 40 mins @ 10^{31}
With 2 kHz random trigger

- *J/ψ trigger on single muon with p_t cut (600k ev./pb^{-1})*
  → one muon unbiased for PID studies and momentum calibration



- J/ψ physics & production cross-sections: ~ 1-5 pb^{-1}

Measure diff. cross-section for prompt J/ψ and bb production cross-section (from secondary J/ψ) in region inaccessible to other experiments



Physics goals of 2010

❑ Analysis commissioning in hadronic modes

Channel	Yield / 10 pb^{-1}
$B^0 \rightarrow K\pi$	340
$B \rightarrow D(K\pi)X$	31k
$B^+ \rightarrow D(K\pi)\pi^+$	1900
$B^+ \rightarrow D(K\pi)K^+$	160
$B_s \rightarrow D_s\pi^+$	320

Detailed studies of $D \rightarrow hh$ (rehearsal for $B \rightarrow hh$)
- *Separate $K\pi$, KK, $\pi\pi$ and DCS $K\pi$*
- *Vertex and mass resolutions*
- *Lifetimes*

Accumulate samples of $B \rightarrow D(K\pi)\pi$ ("ADS" control mode)
- *Study background environment*
- *Look for any evidence of B^+ / B^- asymmetries*

❑ Charm physics: 20 pb^{-1} and upward

(Exciting possibilities even with low luminosity)

An example: flavour tagged $D^0 \rightarrow KK$ events for measuring y_{CP}

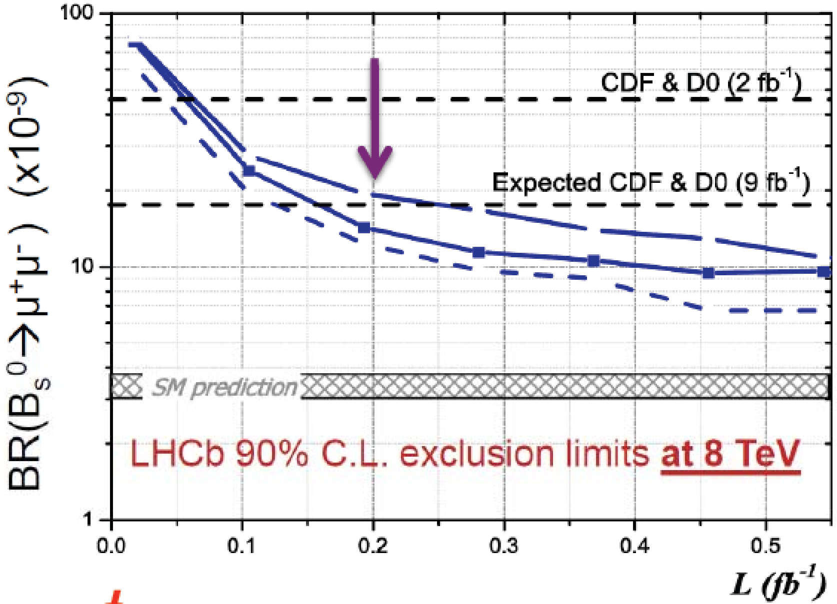
$$y = \tau(D^0 \rightarrow K\pi) / \tau(D^0 \rightarrow KK) - 1$$

and corresponding CP asymmetry

LHCb can collect ~ 10^5 flavour tagged KK events with 20 pb^{-1} (same statistics as BELLE with 540 fb^{-1}). Similar data sets for many related channels: $D^0 \rightarrow \pi\pi$, $KK\pi\pi$, $K_S\pi\pi$, K_SKK, $D^+ \rightarrow KK\pi$ …

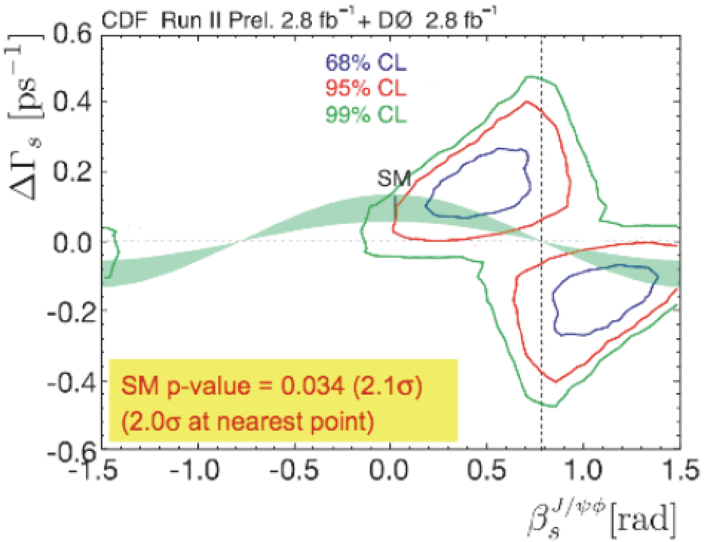
Prospects for most competitive measurements in 2010

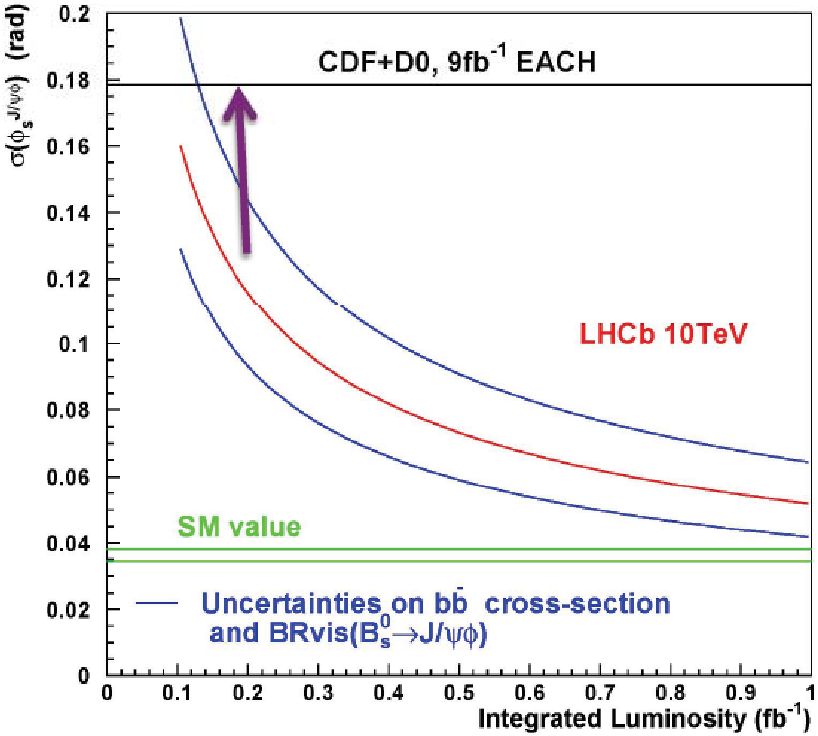
$B_s \rightarrow \mu\mu$



With data sample of ~200 pb^{-1} LHCb should be able to improve Tevatron sensitivity for $B_s \rightarrow \mu\mu$ and ϕ_s
(present 'central' value from Tevatron would be confirmed at 5σ level)

ϕ_s

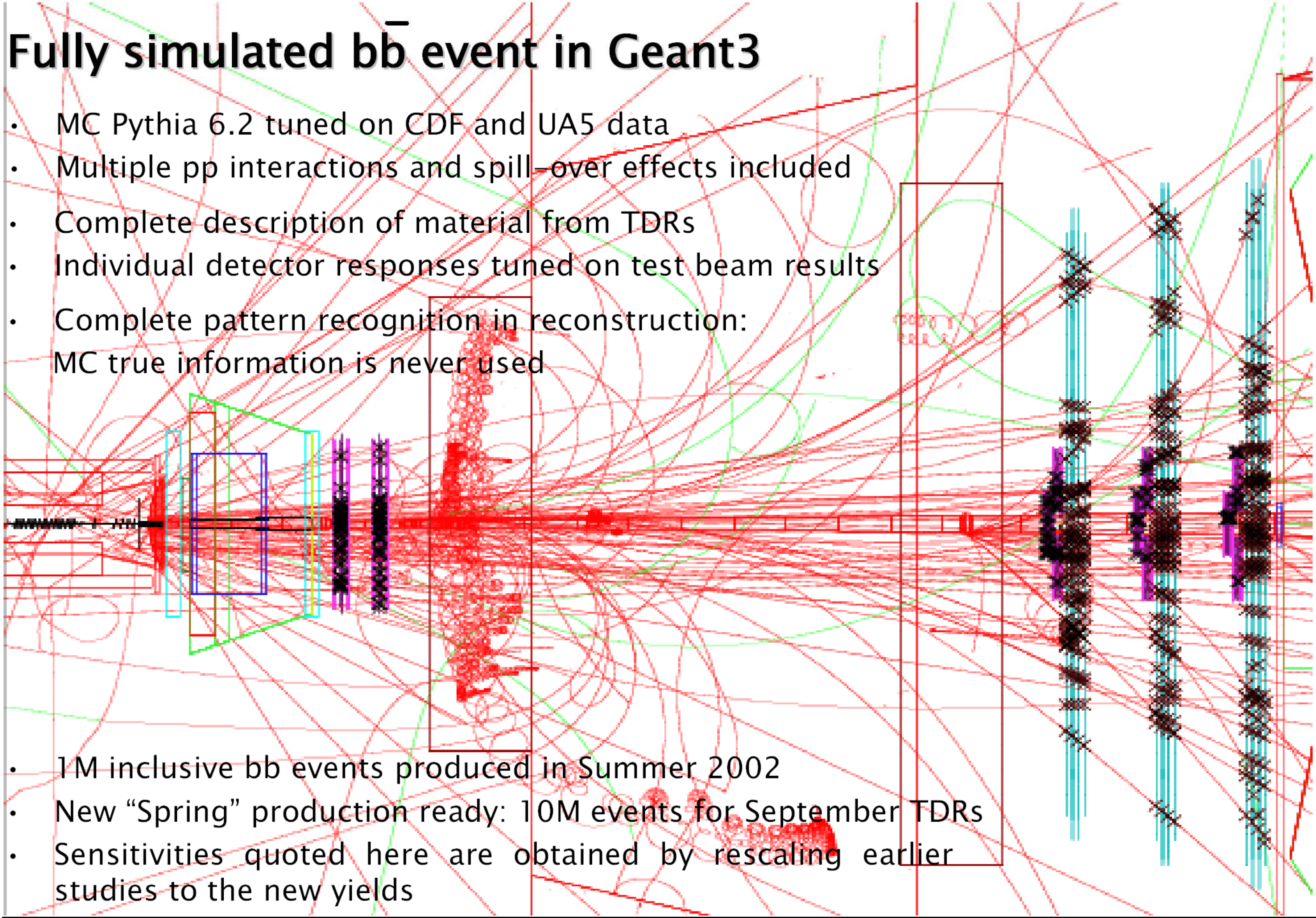




LHCb summary

- LHCb is ready for data taking
- First data will be used for calibration of the detector and trigger in particular. First exploration of low Pt physics at LHC energies. Some high class measurements in the charm sector may be possible
- With 150 – 200 pb-1 data sample LHCb will reach Tevatron sensitivity in a few golden channels in the beauty sector
- With 10 fb-1 LHCb has an excellent opportunity to both discover New Physics and to elucidate its nature. LHCb have an important role to complement physics programme of ATLAS and CMS
- Study of possible LHCb upgrade, in order to collect ~100 fb-1 and investigate further interactions of New Particles with flavours, is underway

Fully simulated $b\bar{b}$ event in Geant3



- MC Pythia 6.2 tuned on CDF and UA5 data
- Multiple pp interactions and spill–over effects included
- Complete description of material from TDRs
- Individual detector responses tuned on test beam results
- Complete pattern recognition in reconstruction:
  MC true information is never used

- 1M inclusive bb events produced in Summer 2002
- New “Spring” production ready: 10M events for September TDRs
- Sensitivities quoted here are obtained by rescaling earlier studies to the new yields

Backup slides

LHCb CP reach

	Channel	Yield	Precision*
β	$B_d \to J/\psi\, K_s$	119 k	$\sigma(\beta) \approx 0.6^o$
γ	$B_s \to D_s K$ $B_d \to \pi\pi,\ B_s \to KK$	8 k 27 k, 35 k	$\sigma(\gamma) \approx 10^o$ $\sigma(\gamma) \approx 3^o$
α	$B_d \to \pi^+\pi^-$	27 k	$\sigma(\alpha) \approx 5^o - 10^o$
$2\delta\gamma$	$B_s \to J/\psi\, \phi$	128 k	$\sigma(2\delta\gamma) \approx 2^o$
$\|V_{td}/V_{ts}\|$	$B_s \to D_s\pi$	72 k	Δm_s up to 58 ps^{-1}
rare decays	$B_d \to K^* \gamma$	20 k	

2003 status