The LHCb RICH Detectors

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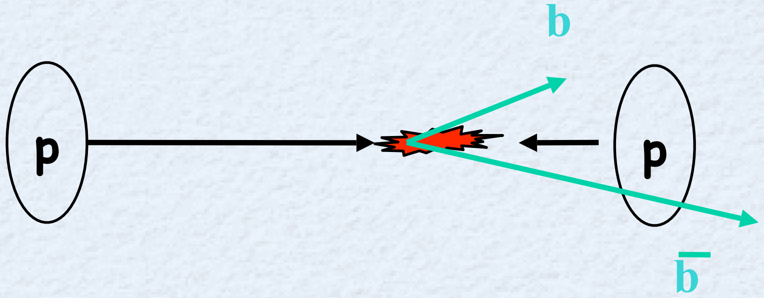
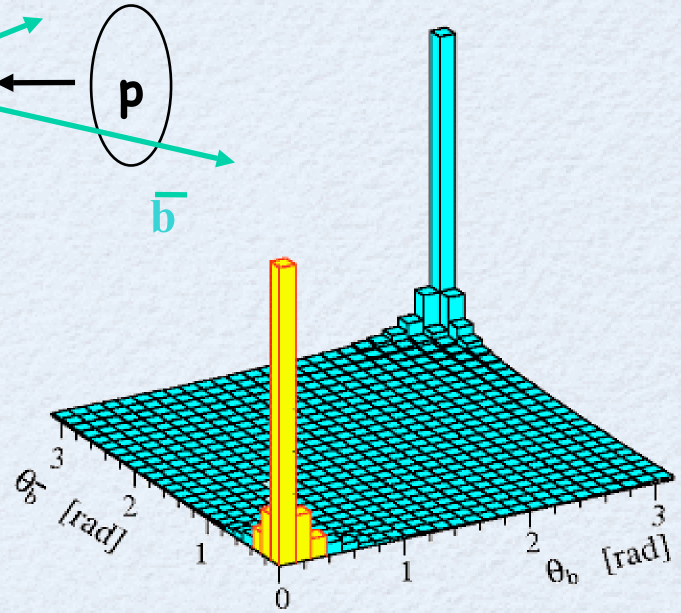
B Physics at LHCb

- LHCb dedicated to heavy flavour physics
  - Precision measurements of charm/beauty sector
  - Search for New Physics in CP violation, rare decays,...

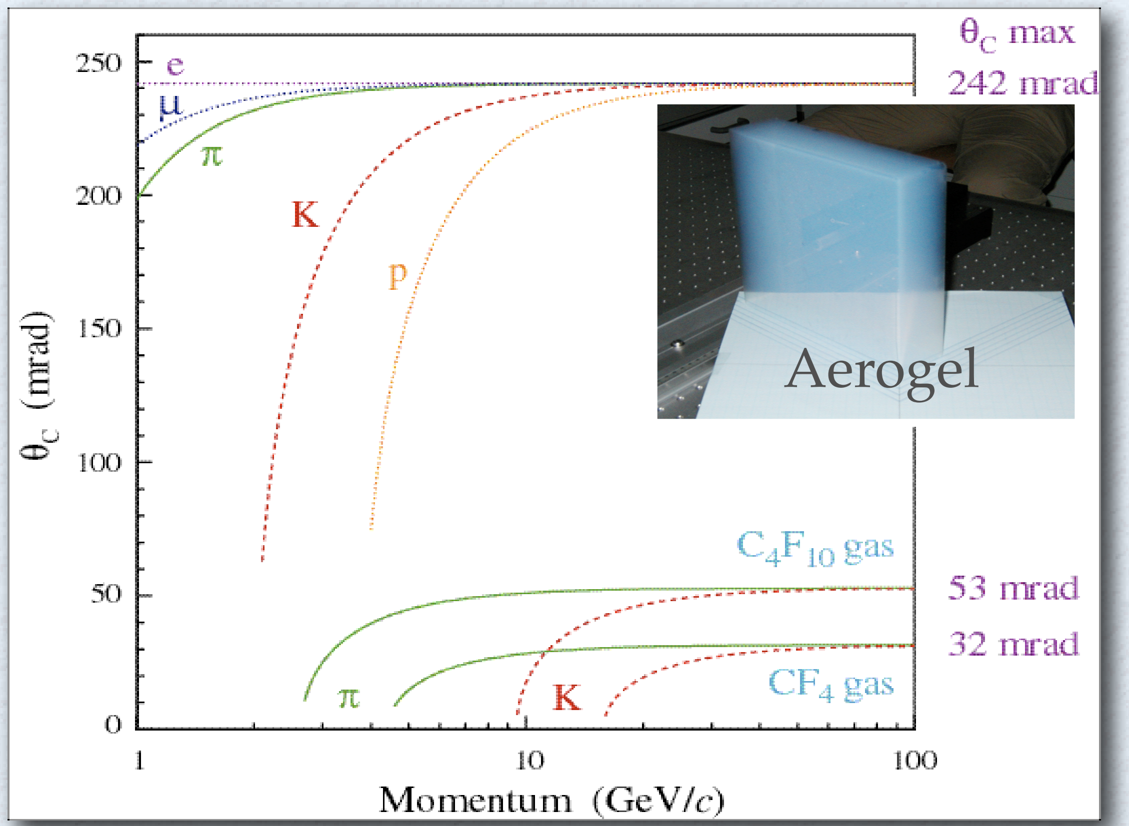


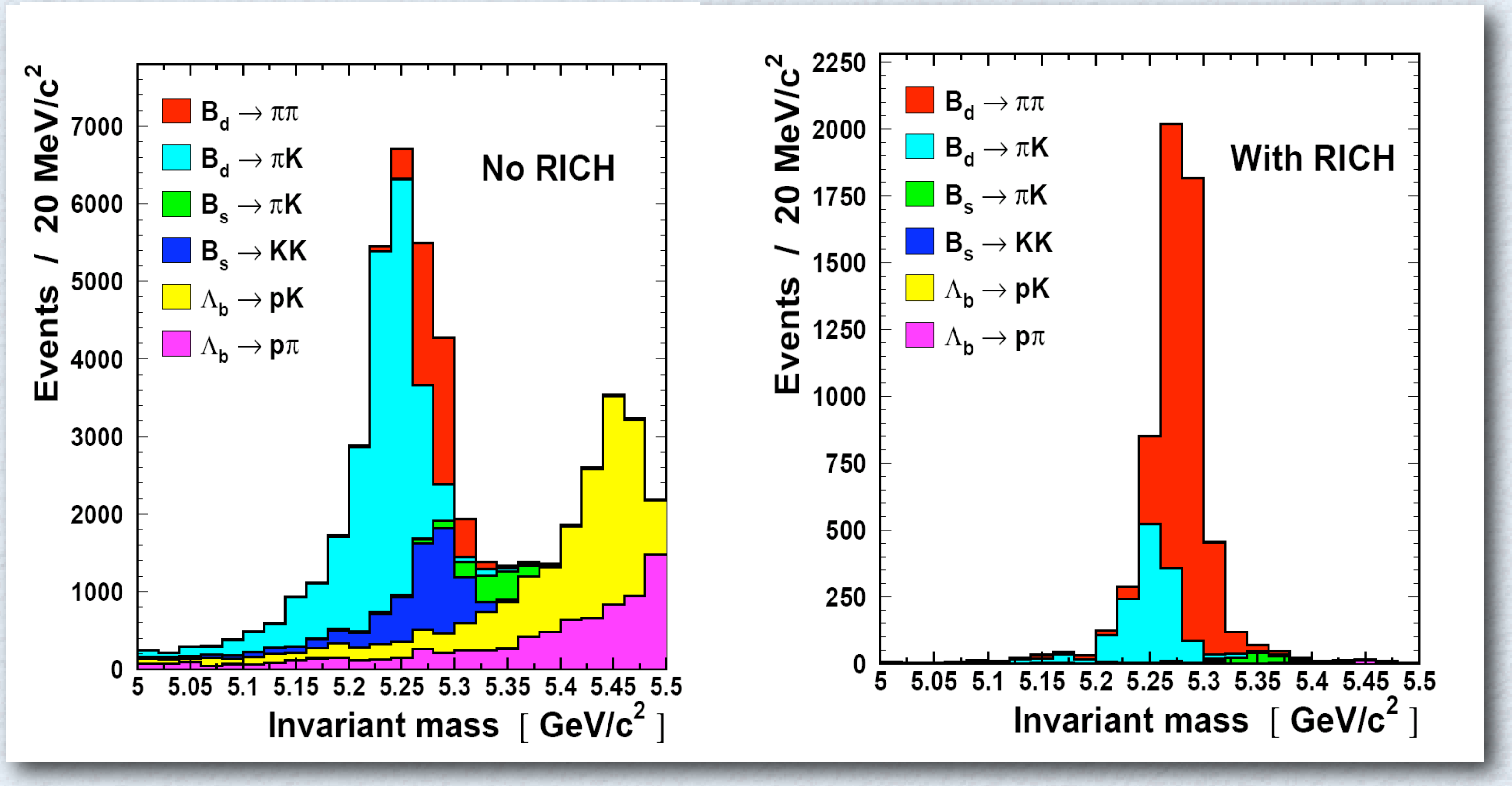
- $b\bar{b}$ production:
  - Correlated production
    ➥ single arm spectrometer
  - Large forward cross section (~230 μb)
  - All B species produced



Particle ID

- Excellent PID required for ambitious physics programme:
  - μ, e, γ : muon chambers and calorimeter
  - π / p / K : Ring Imaging Cherenkov Detectors
    - Cherenkov angle ($\cos\theta_c = 1/\beta n$) and momentum → PID
    - tune radiator materials to cover wide momentum range



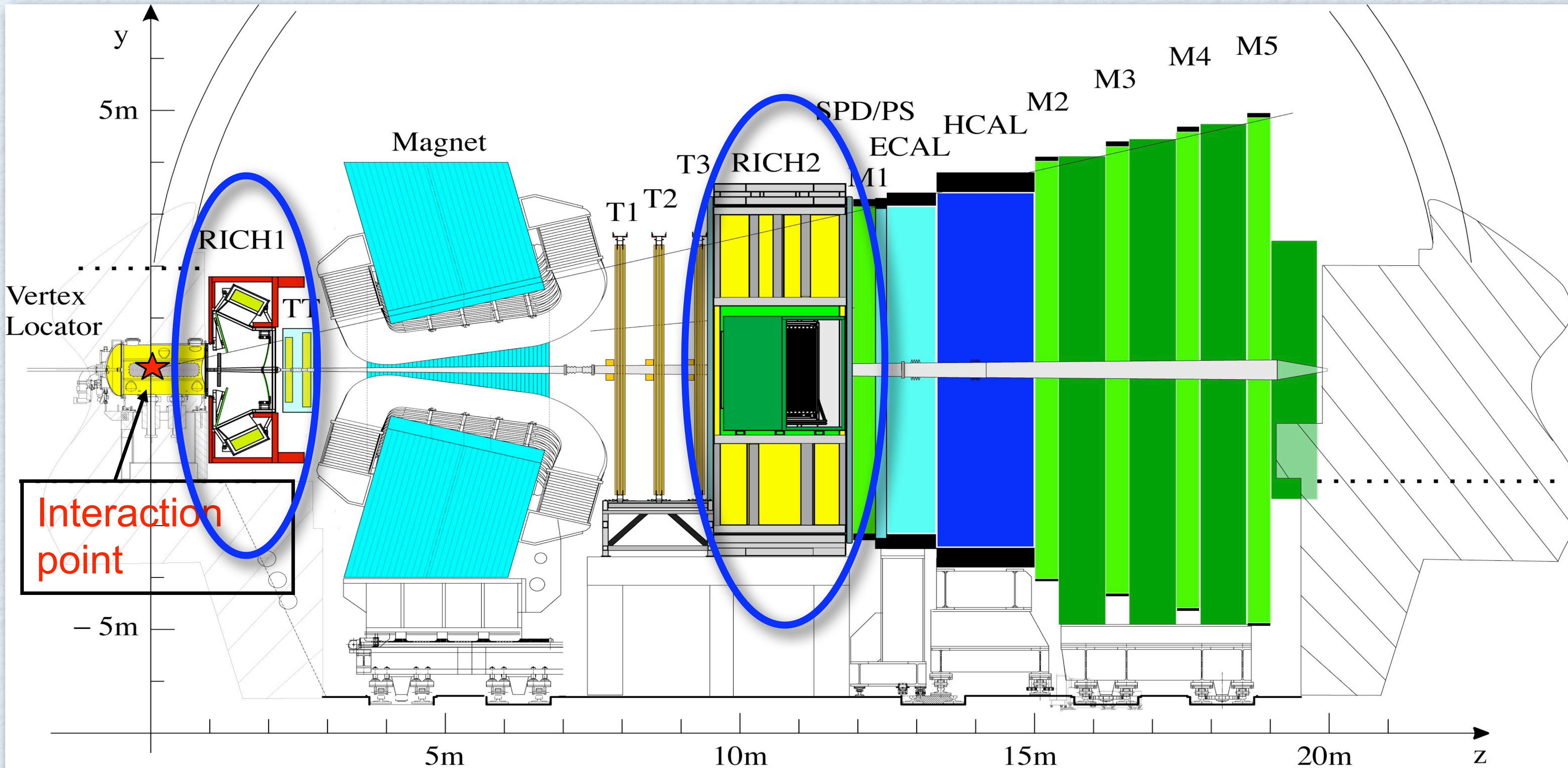


- Silica Aerogel (2-10 GeV/c)
- C_4F_{10} (10-60 GeV/c)
- CF_4 (16-100 GeV/c)

e. g. charmless B decays

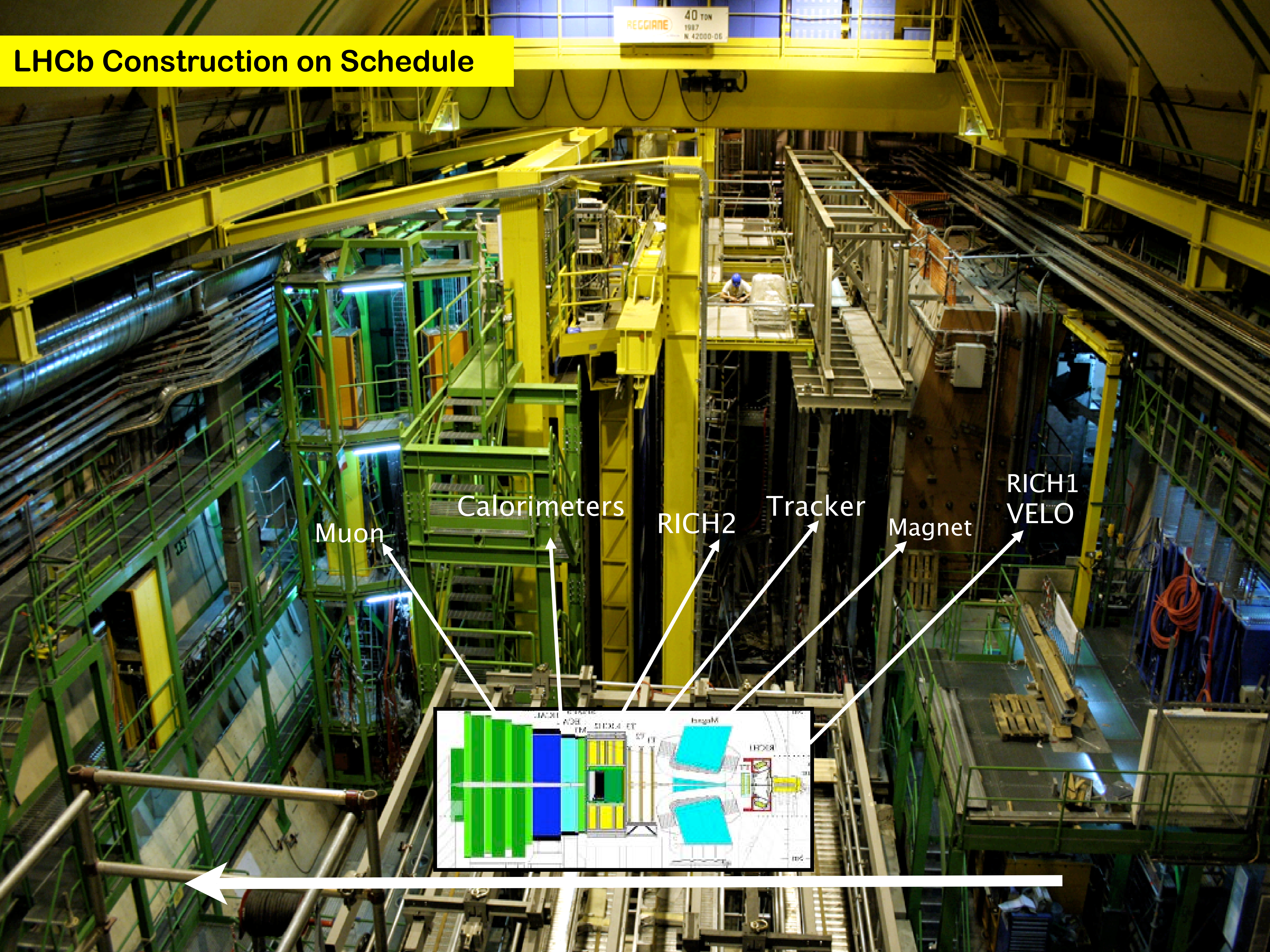
The LHCb Experiment

Design of LHCb optimised for forward *b* production



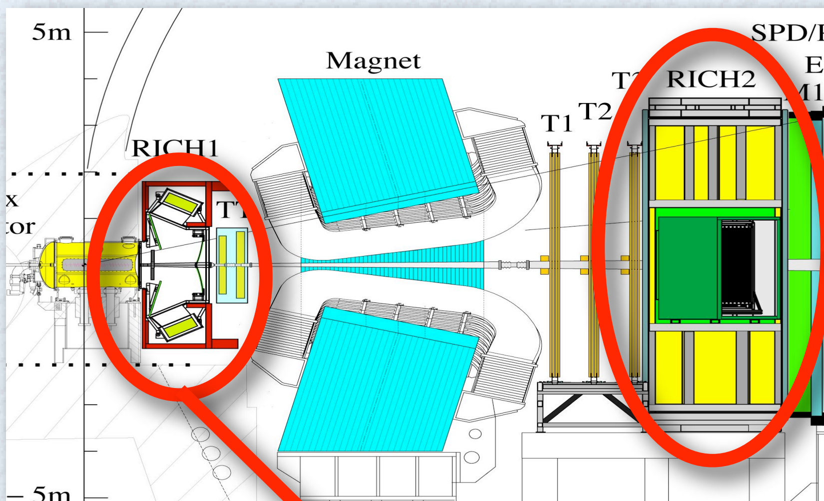
B hadrons (but also: beam remnant, etc)

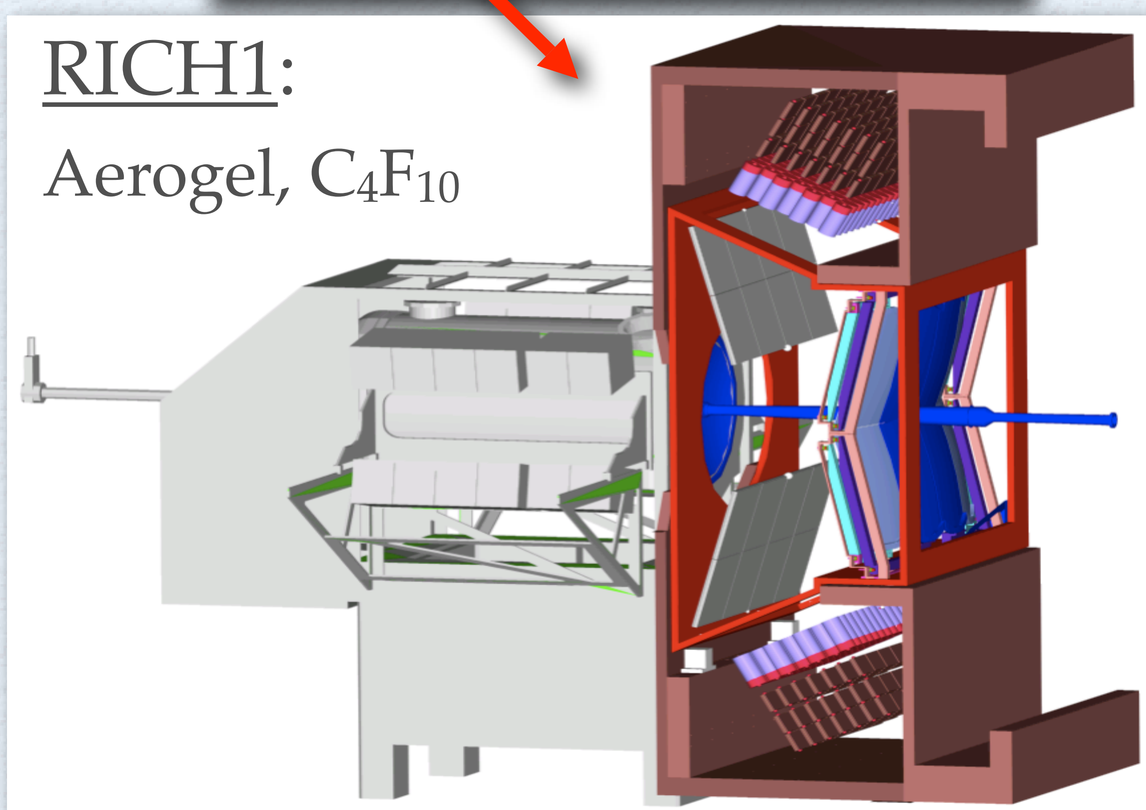
LHCb Construction on Schedule



RICH DETECTORS

- RICH1: π/K separation until 10 GeV/c and 60 GeV/c
- RICH2: π/K separation until 100 GeV/c





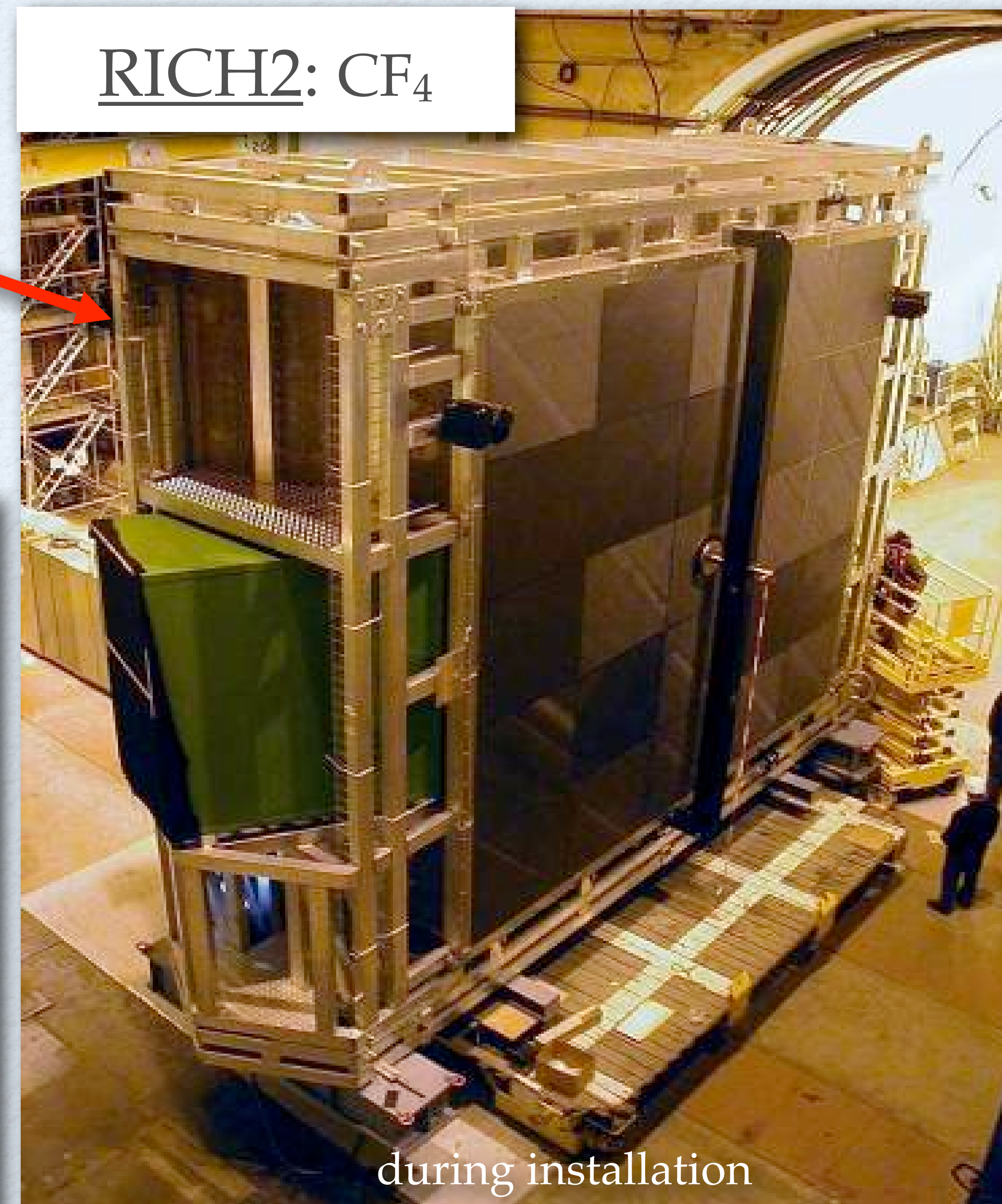
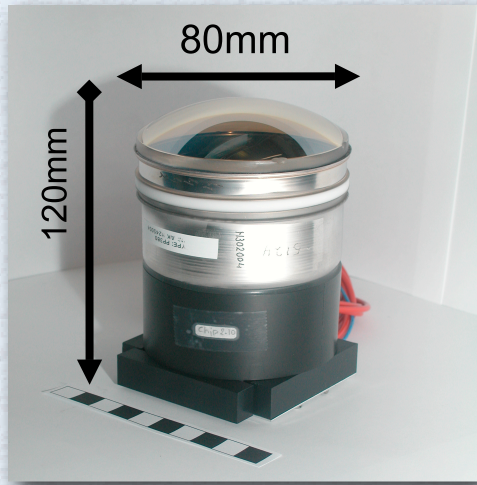
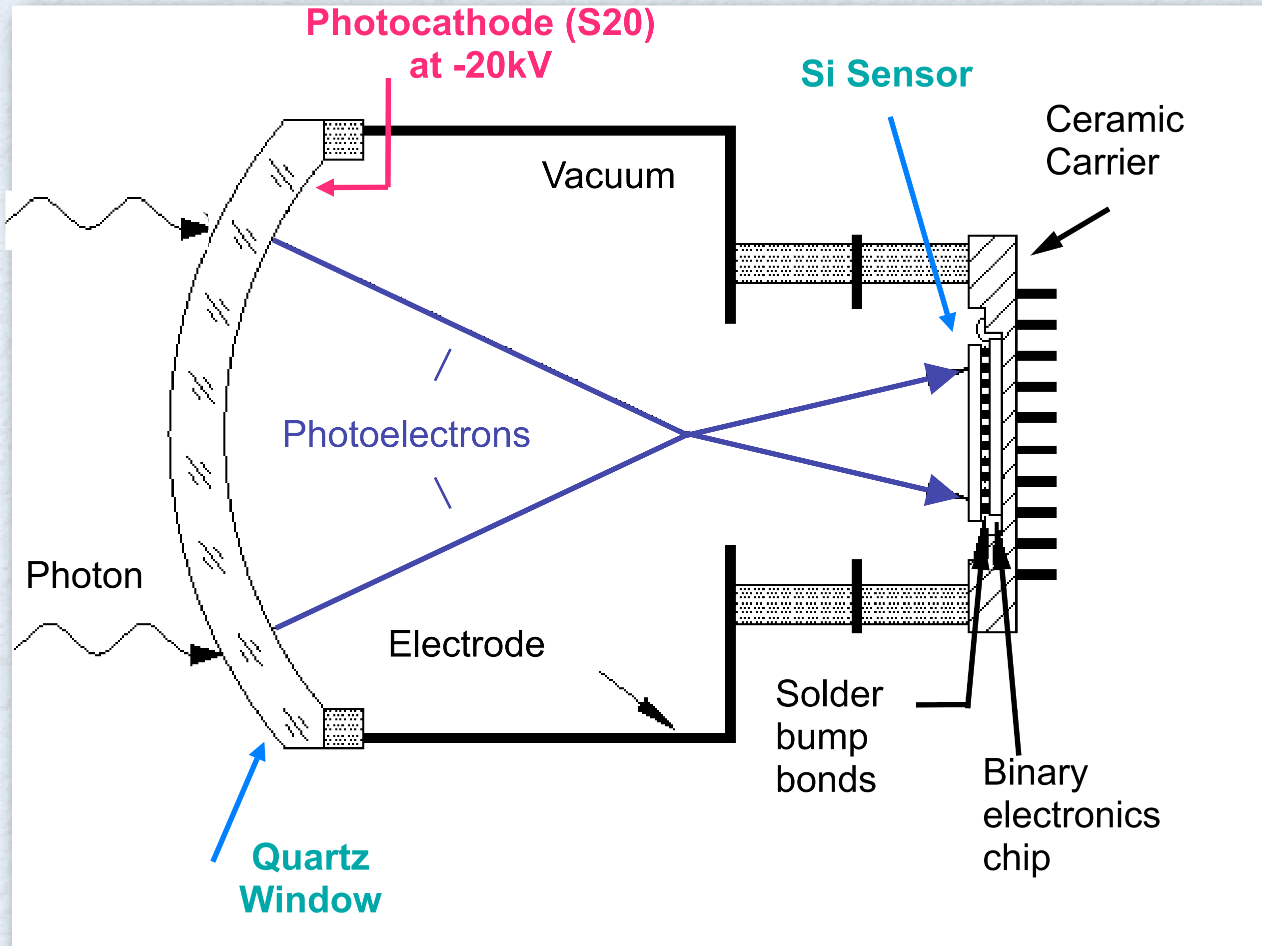


Photo Detectors

custom Hybrid Photo Detector (HPD)

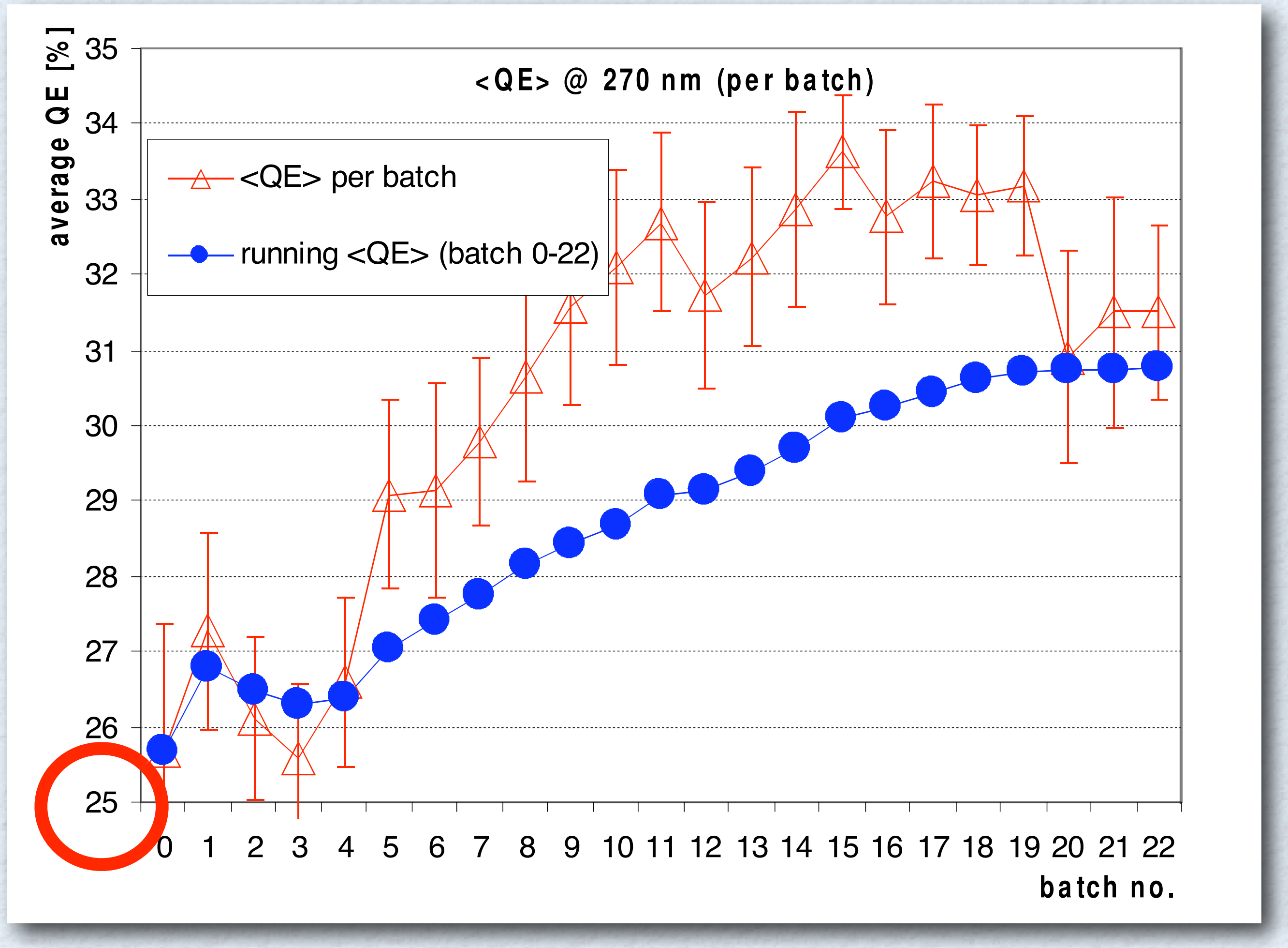
- 484 HPDs in both RICH detectors
- binary read out via Si pixel chip: 1024 channels
- 2.5 × 2.5 mm granularity at cathode window
- ~500’000 pixels over 2.9 m^2 active area
- single photon sensitivity between 200 - 600 nm

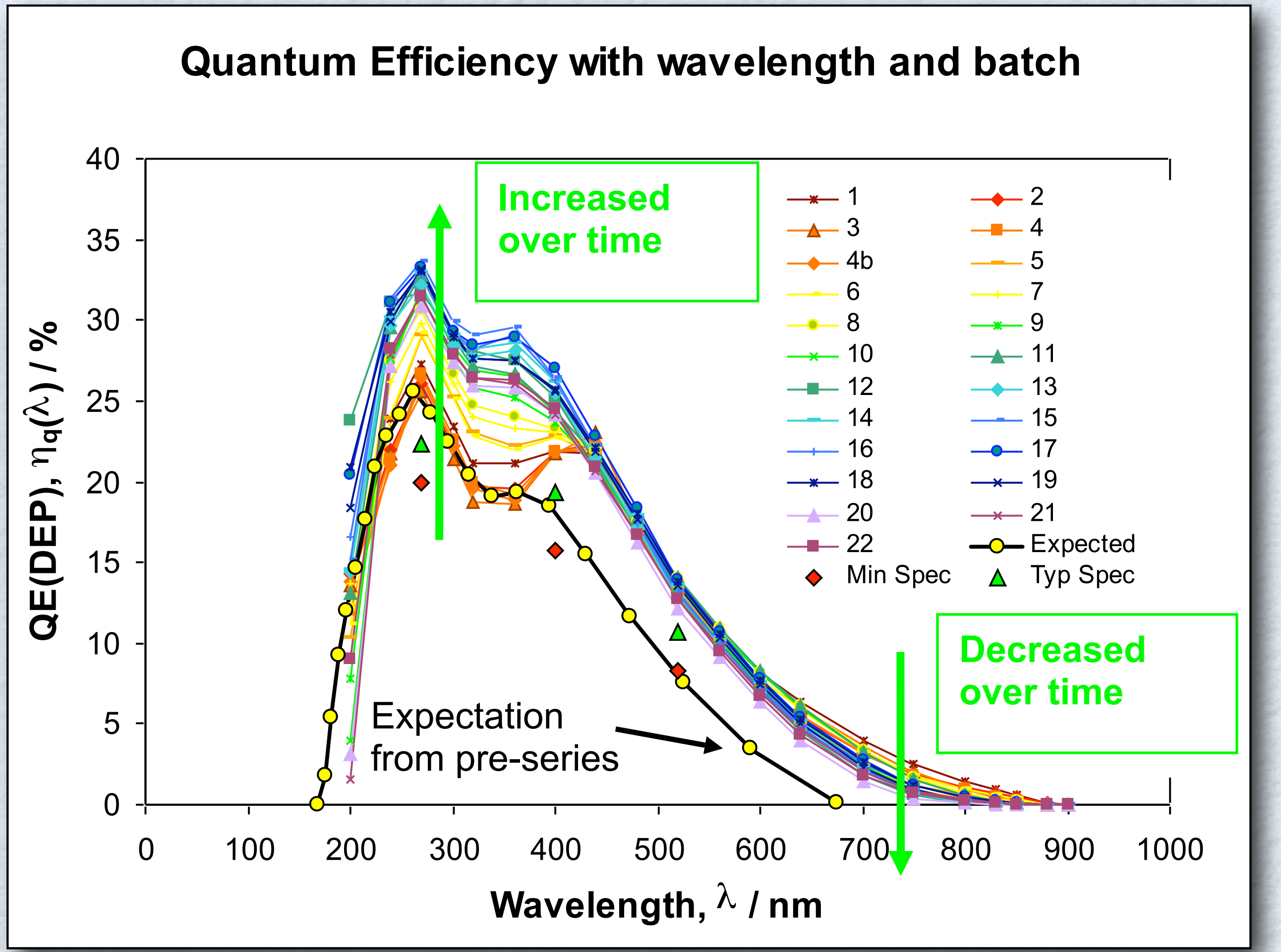




Quantum Efficiency

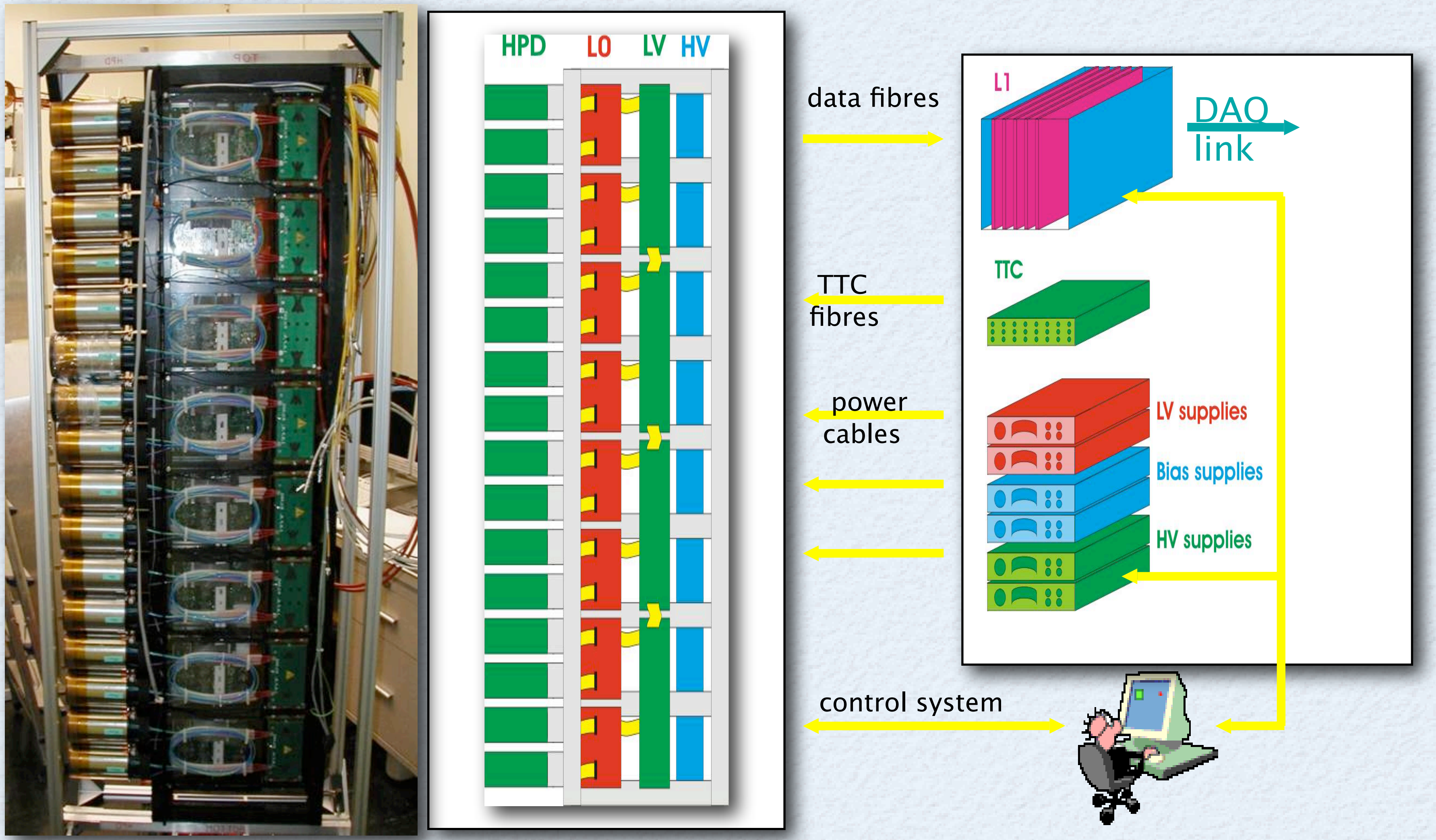
- Q.E. determines efficiency to convert photon to electron
- All HPD produced <u>exceed requirement</u>: Q.E. > 20.0%
- Significant learning-process at manufacturer (DEP):
  - ➡ 24% improvement in Q.E. with delivered HPD batches
  - ➡ optimise HPD placement w.r.t. anticipated hit occupancy





HPD INTEGRATION

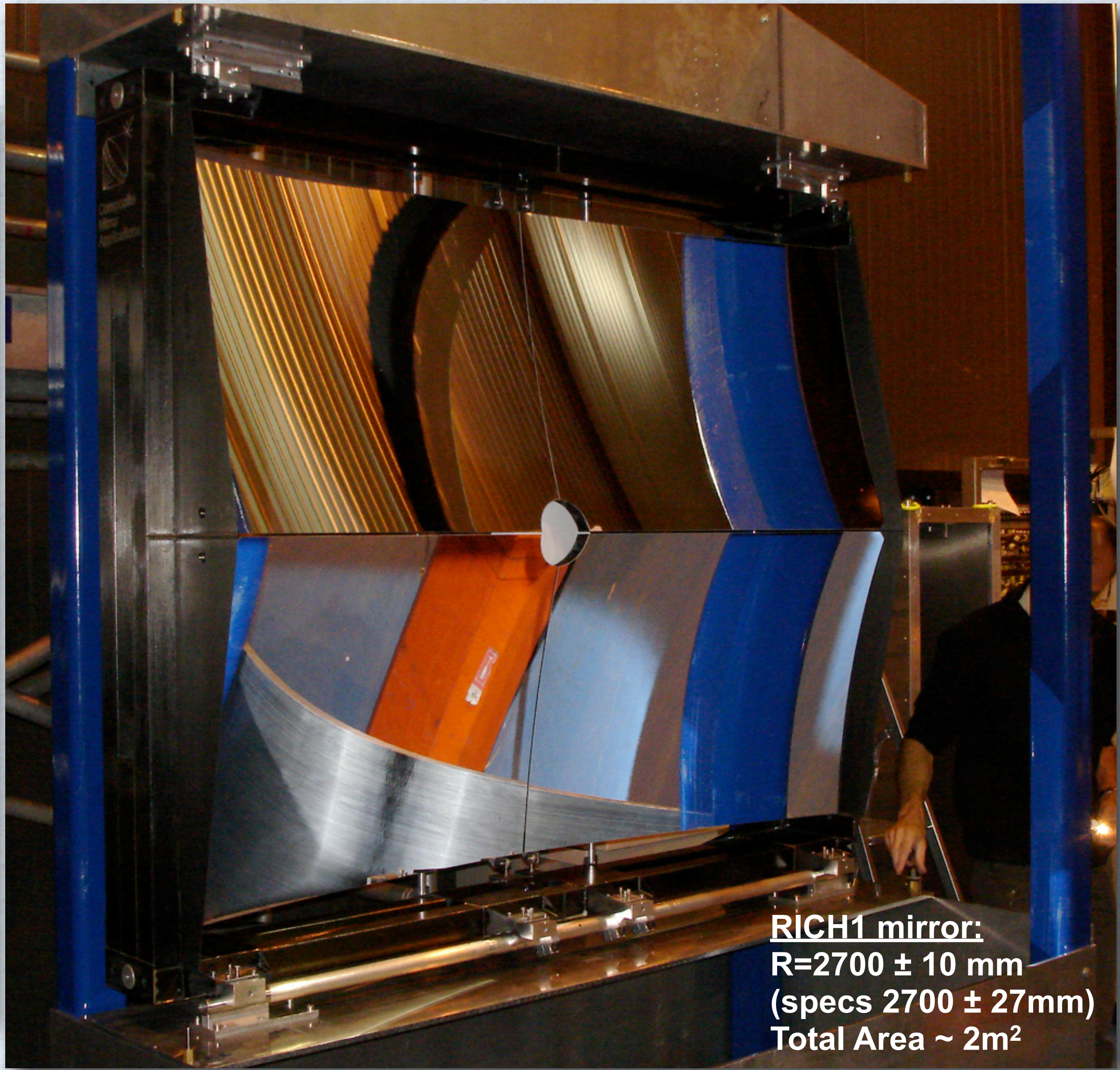
- 14 (16) HPDs + High Voltage (HV), electronics (L0, LV)
  → 1 "column" for RICH 1 (2)



- RICH2: fully installed, currently being commissioned
- RICH1: all columns with HPDs assembled, awaiting installation

RICH Mirrors

- HPDs mounted outside acceptance
  ➥ need mirrors to reflect Cherenkov light to HPDs
- Mirrors mounted inside acceptance
  ➥ reduce contribution to material budget: carbon fibre, support structure $< 6\text{kg}/\text{m}^2 = 1.5\%\ X_0$

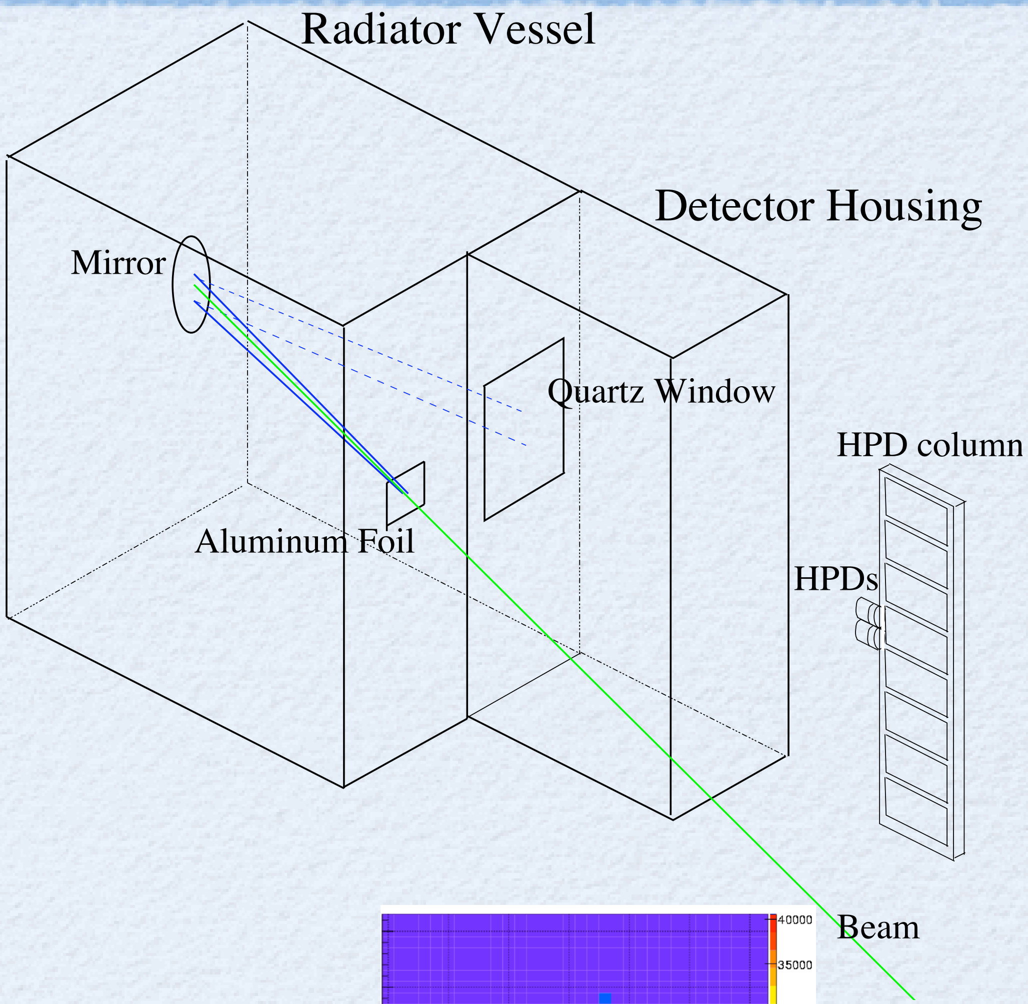


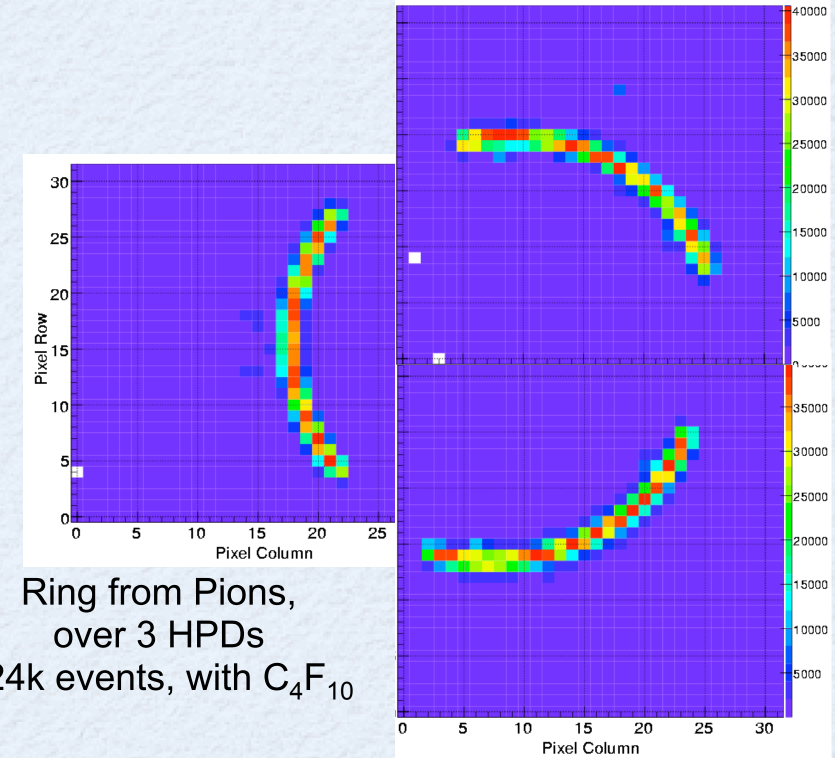
Beam Tests

- Performance of components monitored in multiple beam tests
- Sep. 2006: beam test using CERN's SPS:
  - multiple aspects of RICH operations tested
  - N_2 and C_4F_{10} used as radiators
  - HPDs / DAQ electronics from final production
  - data recorded using LHCb online environment
  - analysis in progress using full LHCb reconstruction and analysis software

➥ performance of components meets or exceeds expectations

➥ important milestone: test all aspects from DAQ to analysis prior to LHC start



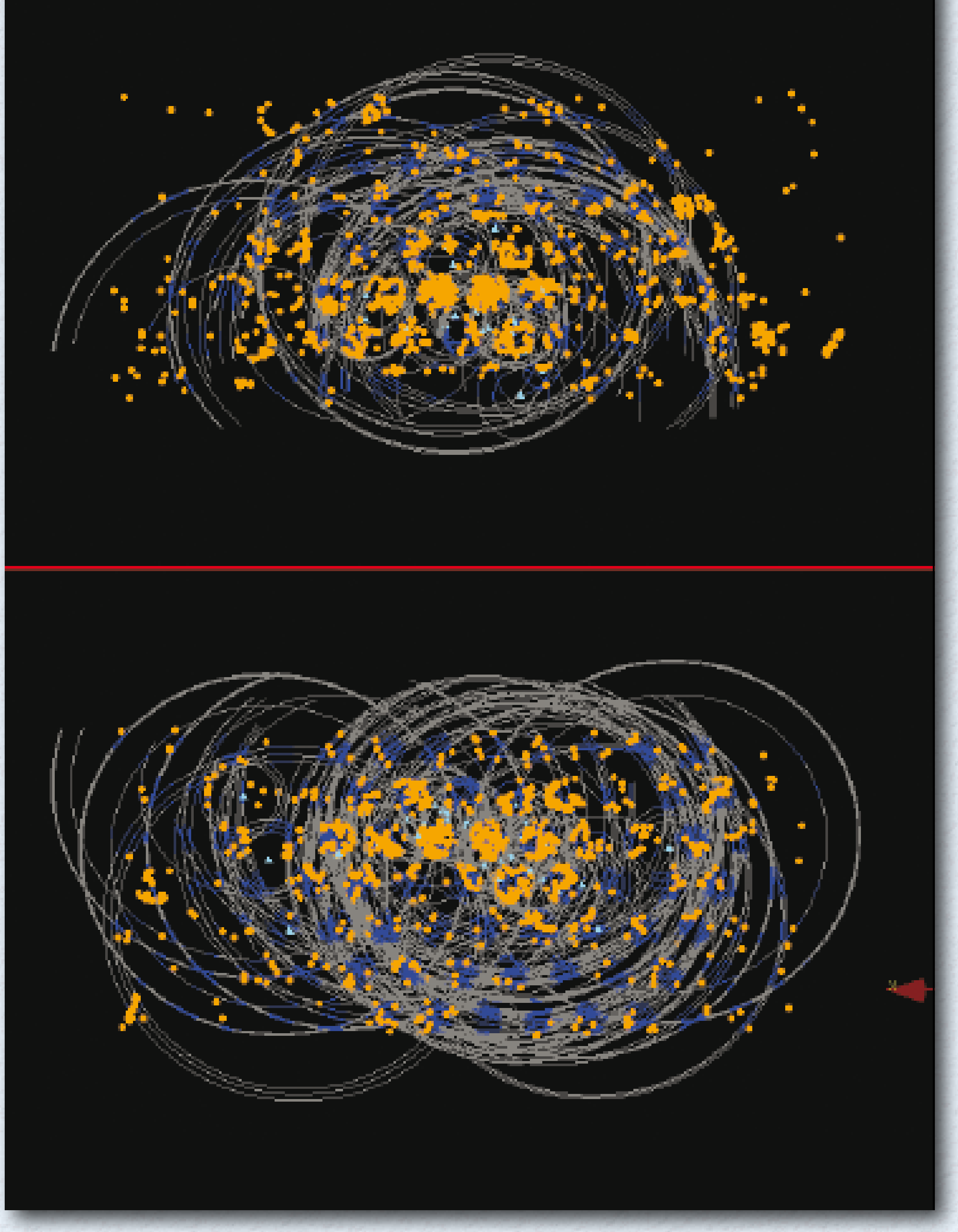


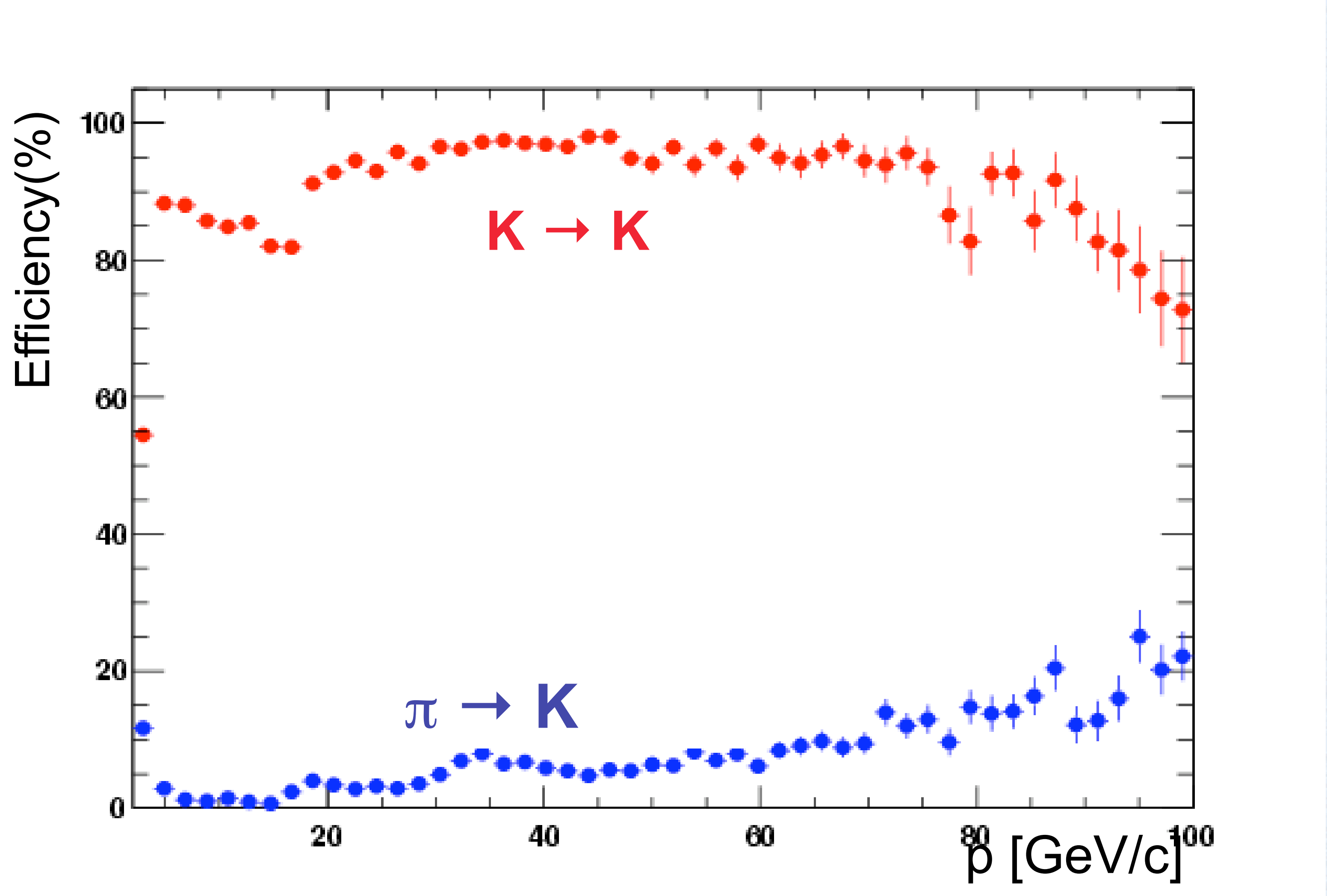
Ring from Pions, over 3 HPDs 124k events, with C_4F_{10}

EXPECTED PERFORMANCE

RICH1

typical event, full detector simulation





Performance estimated from realistic simulation:

K → K: 84.4% effficiency

π → K : 4.5% misID rate

SUMMARY

- LHCb focus:
  precision measurements in heavy flavour physics
- RICH detectors incorporate multiple novel technologies:
  - HPD with Si pixel read-out
  - carbon-fibre mirrors, etc.
- High Pion/Kaon separation over wide momentum range
- RICH detectors currently in final phase of assembly/installation (RICH1) and commissioning (RICH2)
- Excellent quality of all components verified in multiple beam tests

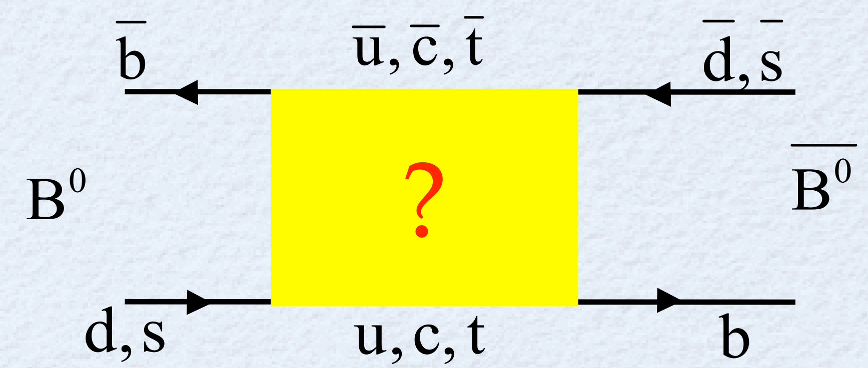
➥ LHCb RICH (almost) ready for data - taking !

BACKUP

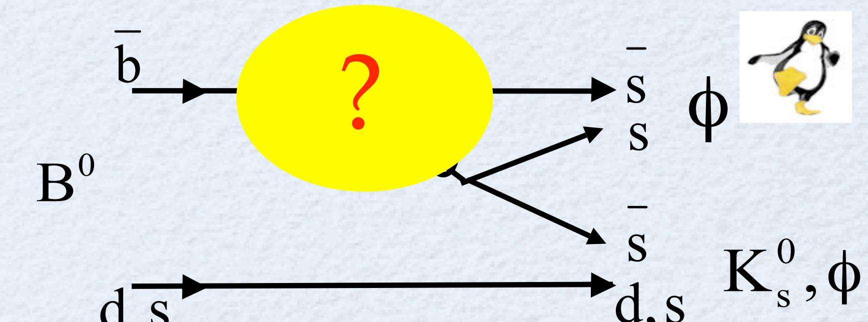
additional material

New Physics

- Standard Model very successful - but not "ultimate theory"
  - SM low energy effective theory, more fundamental theory expected at ~TeV range
  - E.g. CP violation not enough to explain matter/antimatter asymmetry
- New Physics
  - Introduces new particles, dynamics and/or symmetries
    ➡ appear as virtual particles in loops
  - B physics complements direct searches
  - Understand flavour structure of NP



Box diagram



Penguin diagram

Search for NP

- Precision measurements of $B_{(s)}$ mixing
  Δm_s, $\Delta\Gamma_s$, ϕ_s

$B_s \rightarrow D_s\pi$
$B_s \rightarrow J/\psi\ \phi$
$B_s \rightarrow \phi\ \phi$
...

- Radiative and (very) rare B decays
  ➥ enhanced rate w.r.t. SM expectation

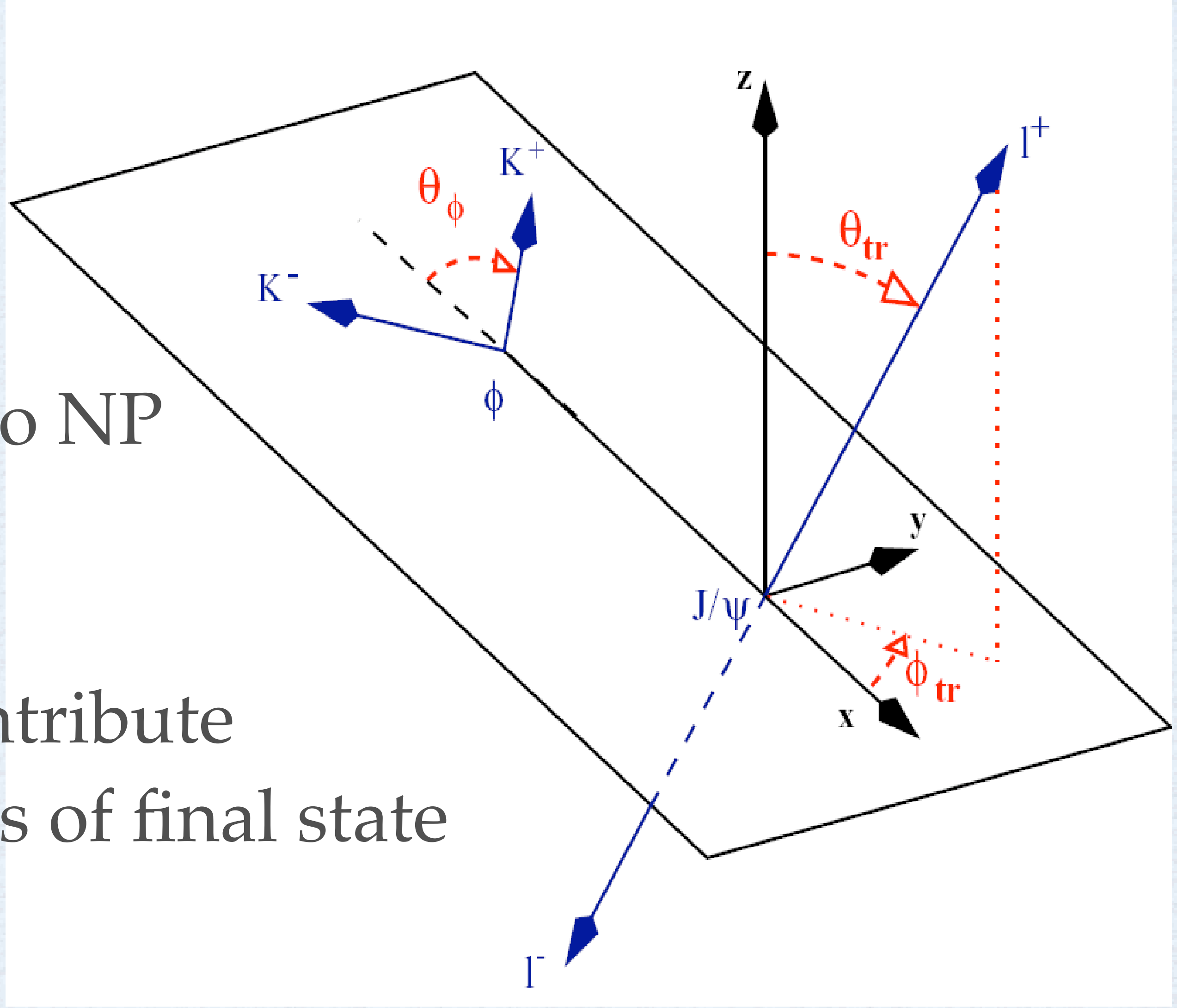
$B_d \rightarrow K^*\mu\mu$
$B_{(d,s)} \rightarrow \mu\mu$
...

- Precise determination of γ, sin(2β)
  - compare measurements from pure tree-level with processes sensitive to NP

<u>sin(2β):</u>
$B_d \rightarrow J/\psi\ K_s$ vs. $B_s \rightarrow \phi\ K_s$
...
<u>γ:</u>
$B \rightarrow DK$ vs. $B \rightarrow \pi\pi/KK$
...

- Over-constrain unitarity triangle/CKM matrix

ϕ_s FROM $B_s \to J/\psi\phi$



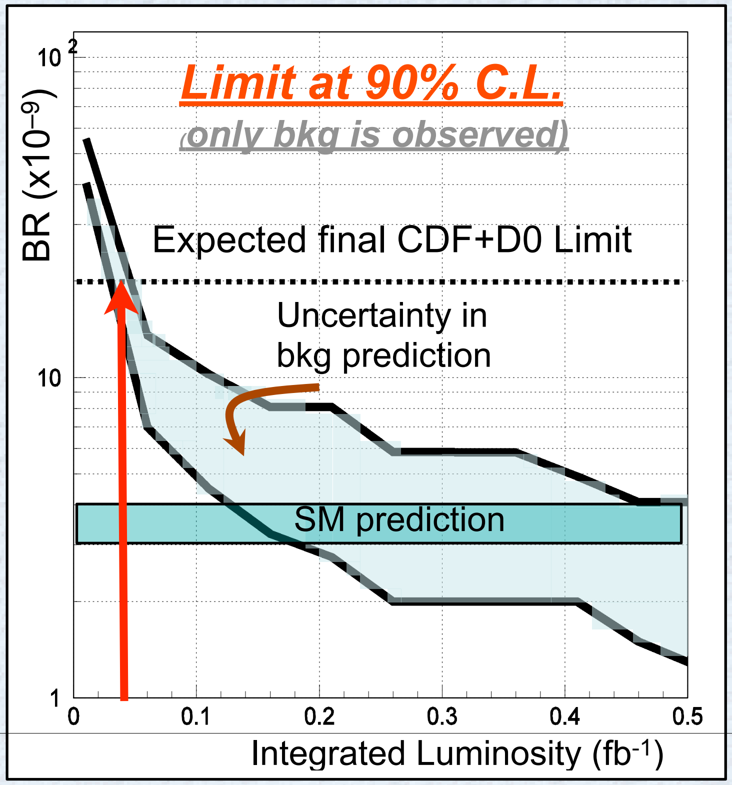
- Measure B_s mixing phase ϕ_s
  ➡ analogue to $B \to J/\psi K_s$
- In SM: $\phi_s \approx -2\lambda^2\eta \sim 0.04 \to$ sensitive to NP
- $B_s \to J/\psi\phi$ not a pure CP Eigenstate
  - 2 CP even, 1 CP odd amplitude contribute
  - need angular (transversity) analysis of final state
- <u>Expected sensitivity:</u>
  - 125k $B_s \to J/\psi\phi$/year
  - $\sigma_{stat}(\sin\phi_s) \sim 0.023$, $\sigma_{stat}(\Delta\Gamma_s/\Gamma_s) \sim 0.01$/(year, 2 fb^{-1})
  - Include pure CP modes, for 10 fb^{-1}: $\sigma_{stat}(\phi_s) \sim 0.01$

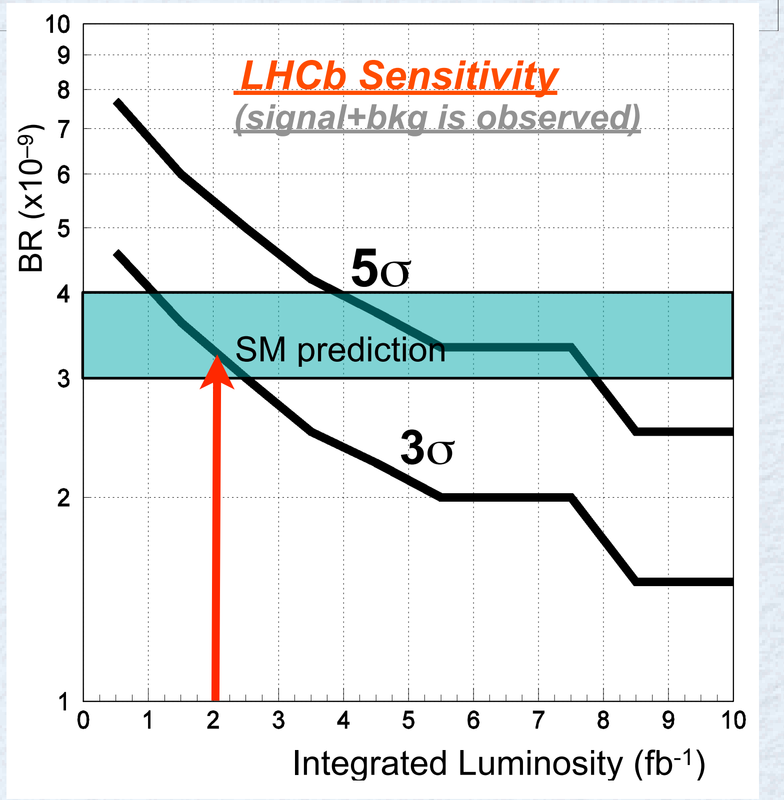
NP via $B \to \mu\mu$

- Very rare loop decay
- Sensitive to NP
- SM: BR ~$3.5 * 10^{-9}$

➡ any observation at Tevatron ⇒ NP

- May be strongly enhanced by SUSY
- Main issue: background rejection
- Sensitivity:
  - 0.05 fb^{-1}: overtake CDF/D0
  - 0.5 fb^{-1}: exclude BR down to SM
  - 2 fb^{-1}: 3σ for SM signal (1 nominal year)
  - 10 fb^{-1}: 5σ for SM signal

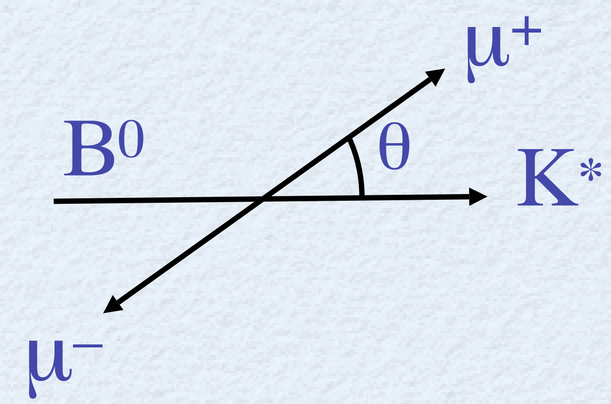


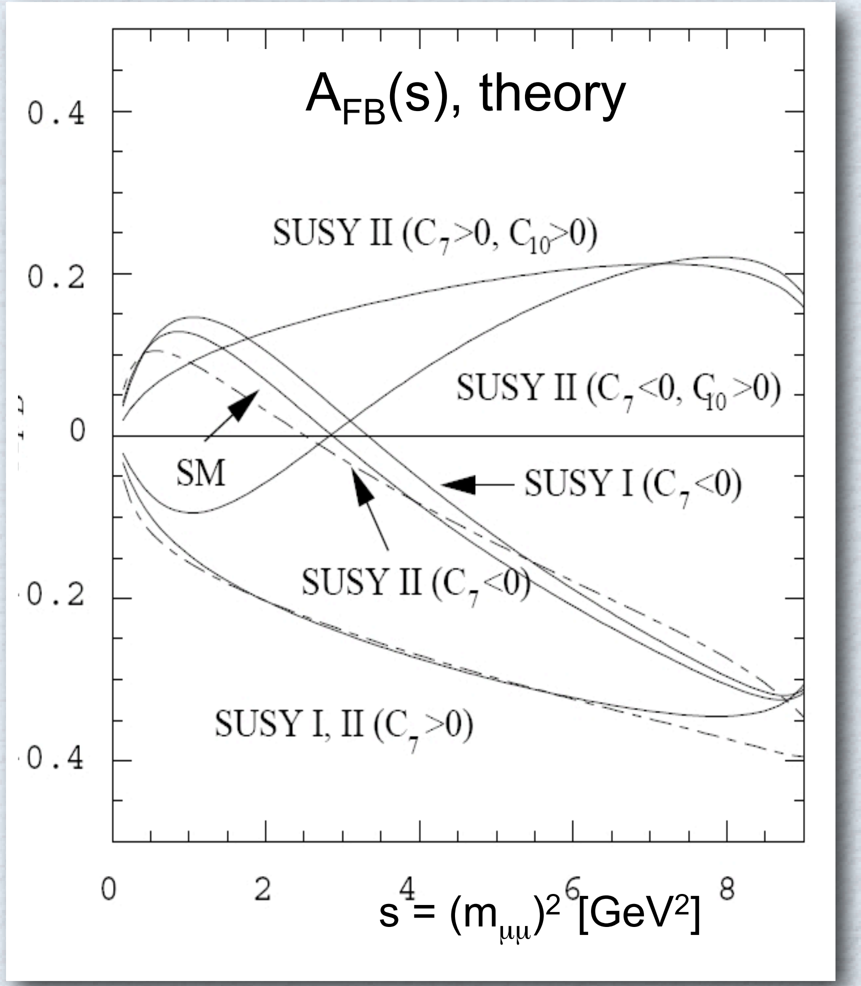


NP via $B_d \to K^*\mu\mu$

- A_{FB} in μμ rest-frame sensitive to NP
- BR ~$1.2*10^{-6}$

  ➡ expect 7.7k signal events/$2fb^{-1}$
- With $2fb^{-1}$: determine zero position in $A_{FB}(s)$ to ±0.5 GeV^2
- Determine ratio of Wilson coefficients C_7^{eff}/C_9^{eff} with 13% stat. error (SM)



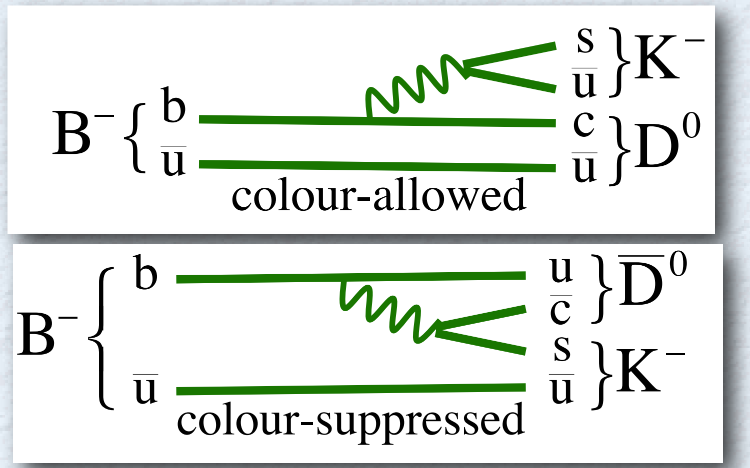


CKM angle γ

Many different channels to measure γ

- Tree-level processes:
  - $B^{\pm} \to K^{\pm} D^0$
    $D^0 \to K\pi, K3\pi, KK, \ldots$

    $\sigma(\gamma) \sim 5\text{-}10^{\circ}$ per $2 fb^{-1}$



weak phase difference: γ

  - $B_s \to D_s K$
  - $B_d \to D^{(*)}\pi$

    $\sigma(\gamma) \sim 14^{\circ}$ per $2 fb^{-1}$

  - …
- Penguin processes:
  - $B_d \to \pi\pi$, $B_s \to KK$

    $\sigma(\gamma) \sim 4^{\circ}$ per $2 fb^{-1}$

➥ needs excellent particle identification!

CHERENKOV RINGS