LHCb Muon System

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on behalf of LHCb Muon System:

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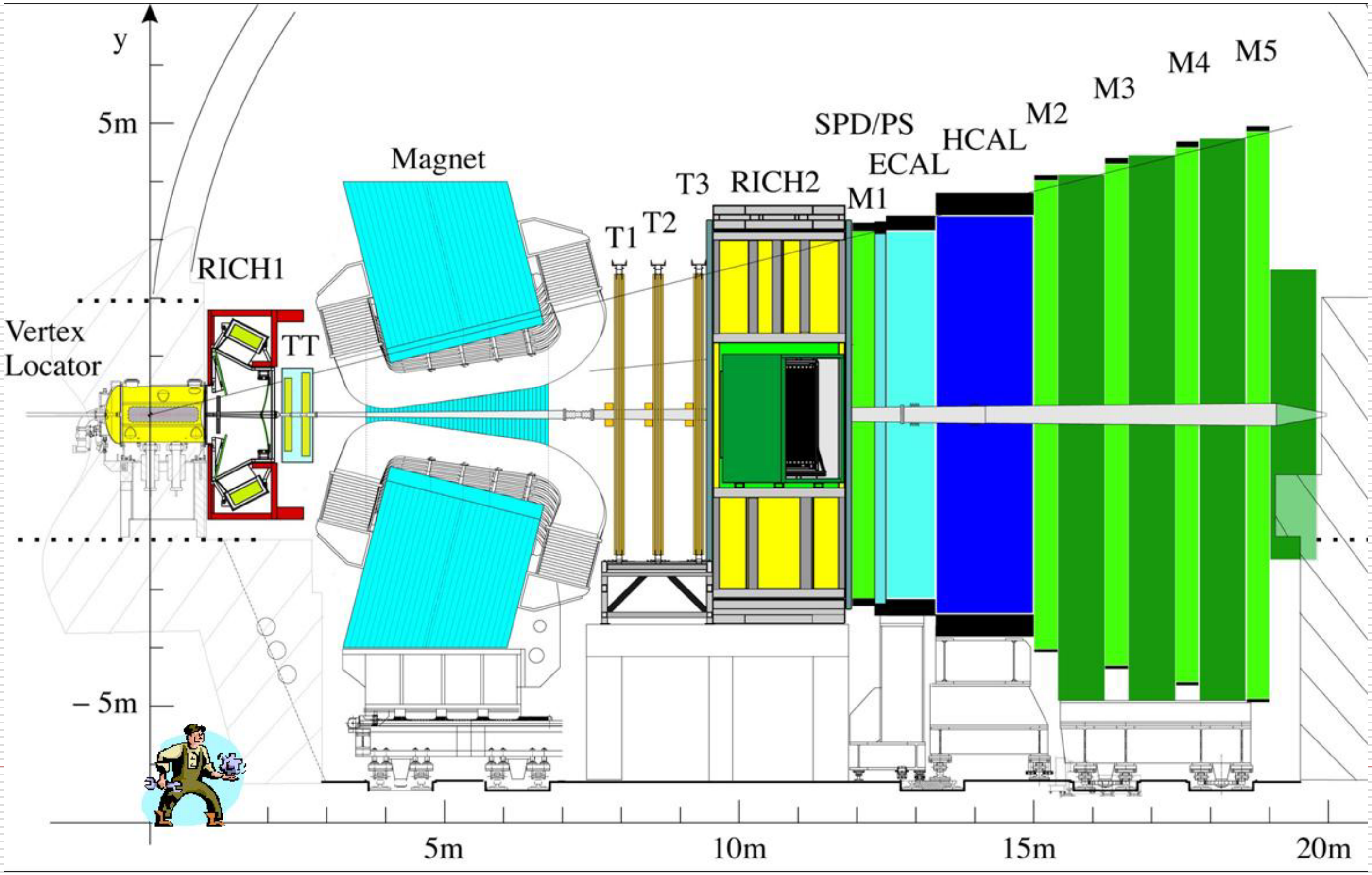
13/09/05

LHCB physics

- A beauty dedicated LHC experiment:
  - CP violations : measurements of α β γ
  - Unique access to Bs: measurements of Δm and $\Delta\Gamma$ and mixing angle
  - Rare decays
  - Unique access to all beauty hadrons ex. Λ_b , B_c
- Indirect search for new physics, complementary to direct observation possible in Atlas or CMS

LHCb: a dedicated b experiment

Beauty production peaks in forward- backward directions: a fixed target like detector layout



Muons in LHCb: usage

- Trigger:
  - Muons are ~ 200 KHz out of the 1MHz first level trigger rate
  - Inclusive muon selections fill 75% of stored data
- Offline
  - Decay channels mu:
    - Bs→J/Ψ ϕ
    - Bs→ J/Ψ η
    - Bs→$\mu\mu$ (Bd→$\mu\mu$ + D0→$\mu\mu$)
    - B→K* $\mu\mu$
    - ….
  - tagging

Muon system design

Design driven by first level (harware) trigger (L0)

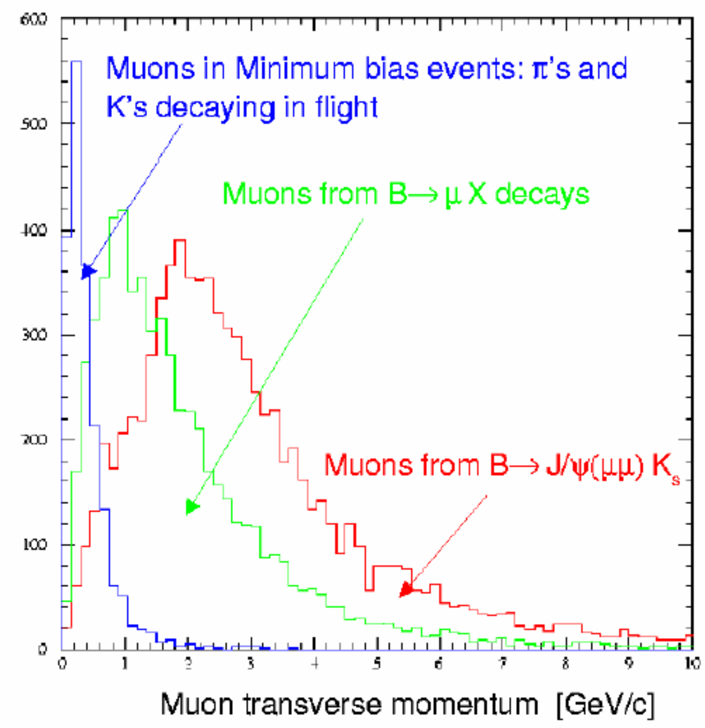
- A rejection factor of mb of ~1/100
- Medium Pt > 1GeV/c

→ Good momentum resolution is required

  - No B field in the detector

  → a station in front of the calorimeter

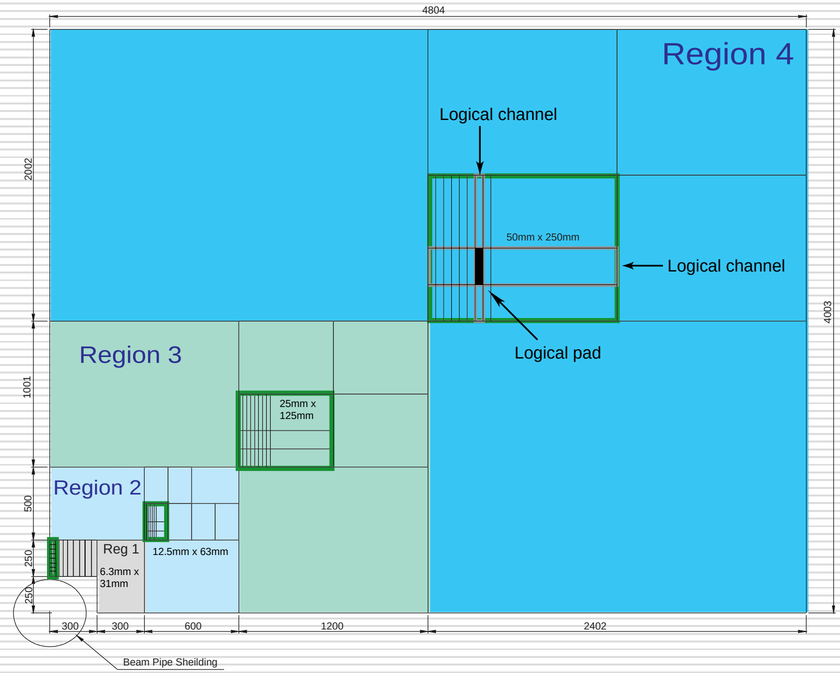
- Trigger requires 5 hits out of 5 inside BX
  →high efficiency in 25ns



Logical Layout

Optimized granularity ~ MCS contribution to $\sigma(1/P_T)$

- High correlation angle momentum
  - Better granularity at high η
- 4 concentric regions
  - Channel linear dimensions double from an inner to an outer region
  - 20 different channels sizes



min 6.3x31 mm
max 250x 310 mm

Adopted technology

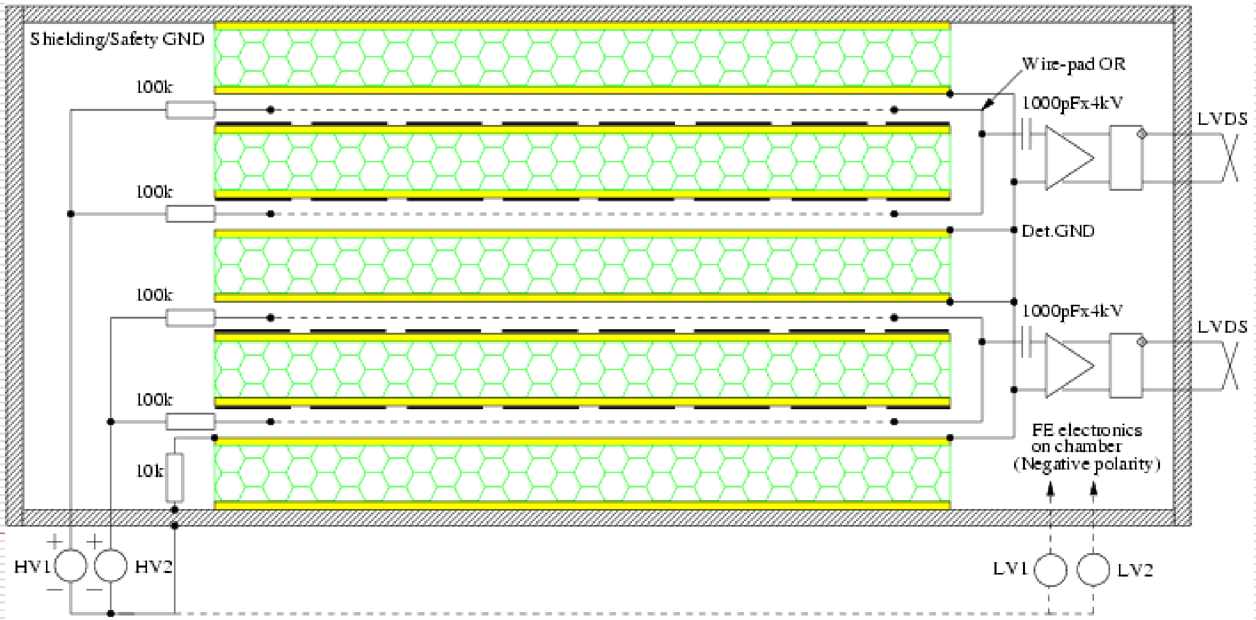
- Multi Wire Proportional chambers with 4 ORed gas gaps (2 gaps in M1 to reduce X_0)→ high efficiency
  - + GEM chambers 1% area **(see next talk)**
- 1 Front End per 2 gaps (1 in M1)→ rate capability and robustness

5 mm gas gap

2 mm wire pitch

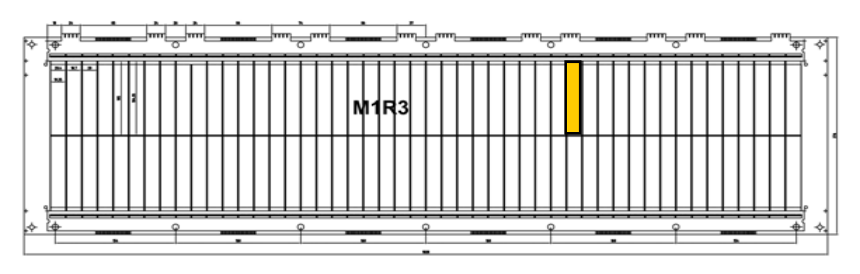
Ar /CO_2 /CF_4=

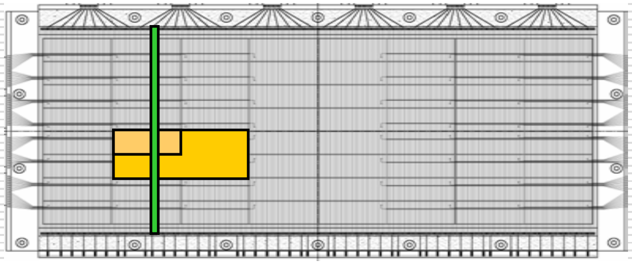
40/ 55/ 5



Layout

- Large variation in channel dimensions and occupancy in the 5x4 regions + technology and cost constraints → the desired layout is obtained by
  - Chambers with cathode, wire, combined readout
  - Pads and strips
  - Strips reduce from 55k → 26k trigger channels

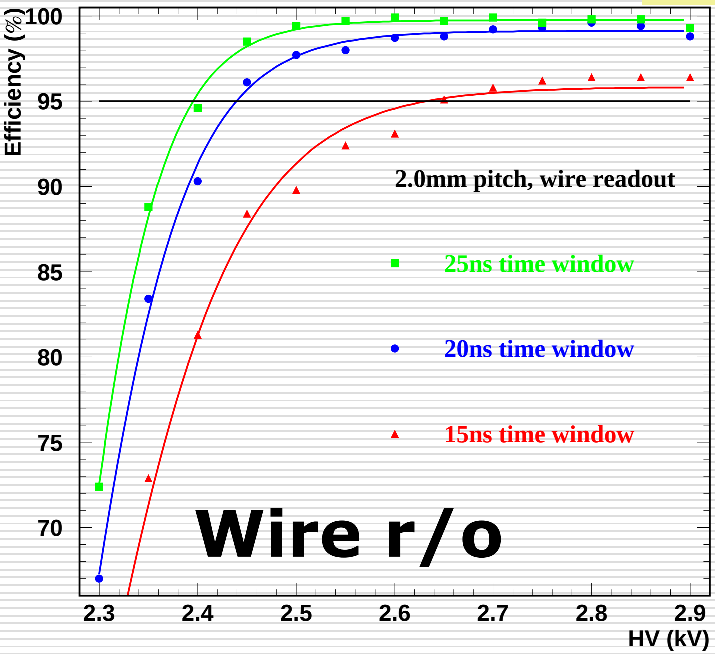


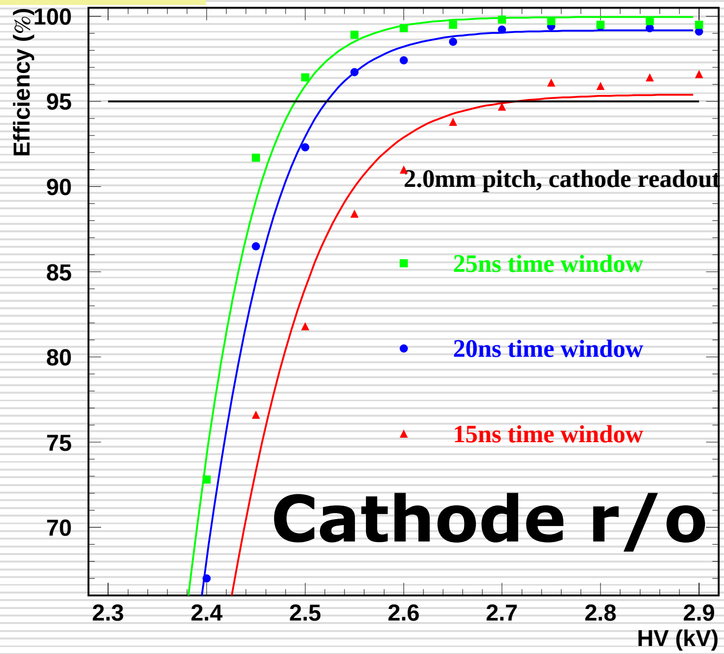


- To minimize capacitance and deadtime, pads smaller than required by granularity are connected to a FE → 120k ORed FE channels

MWPC performance

efficiency



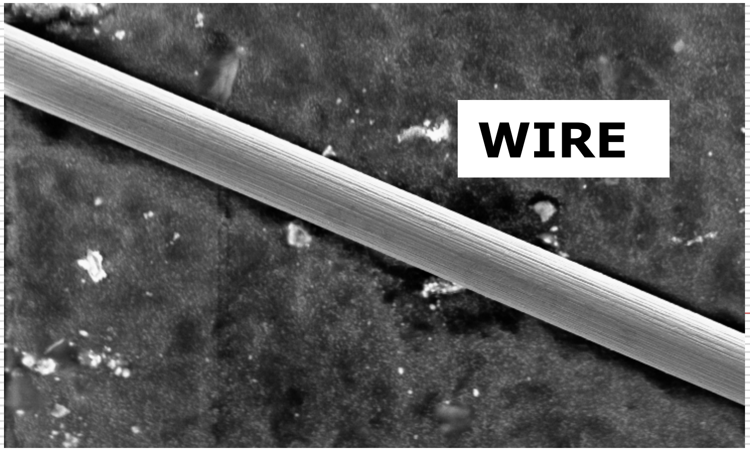


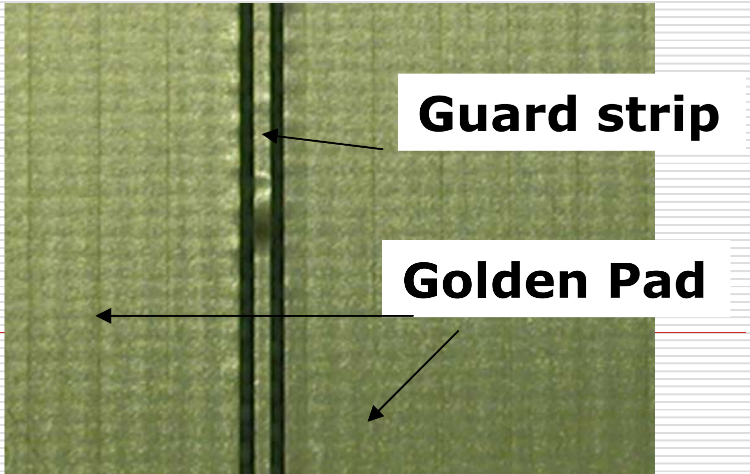
- Time resolution RMS < 4 ns
- XTalk ~ 10%

Rates

- Large radiation dose in the inner regions of station M1 and M2
  - Rate =80(M1R2), 35(M1R3,M2R1), < 15 (rest) kHz/cm2
  - Integrated Q= 0.9(M1R1), 0.5(M2R1), < 0.3 (rest) C/cm

    10 years of running + safety factor 2 (M1) 3(M2-M5) $L=2*10^{32}$
- 5 years of running of M1R2 (> 8 per M2R1 and >10 for the rest) have been tested and chamber performance is ok, wire ok - some etching on cathode and panel due to CF4 → CF4 content ↘ 5%





MWPC construction

- 1368 chambers → automatic tools

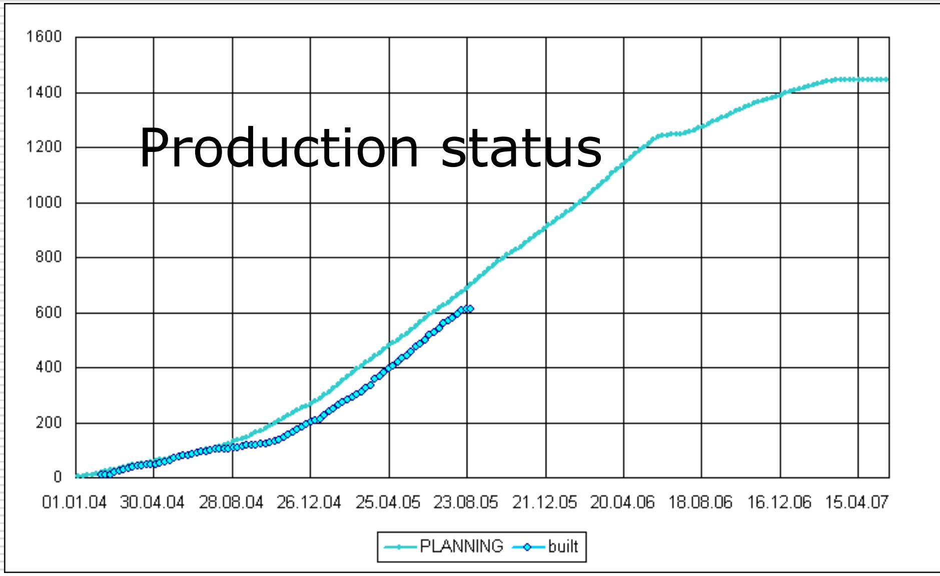
Ferrara wiring machine

CERN soldering machine

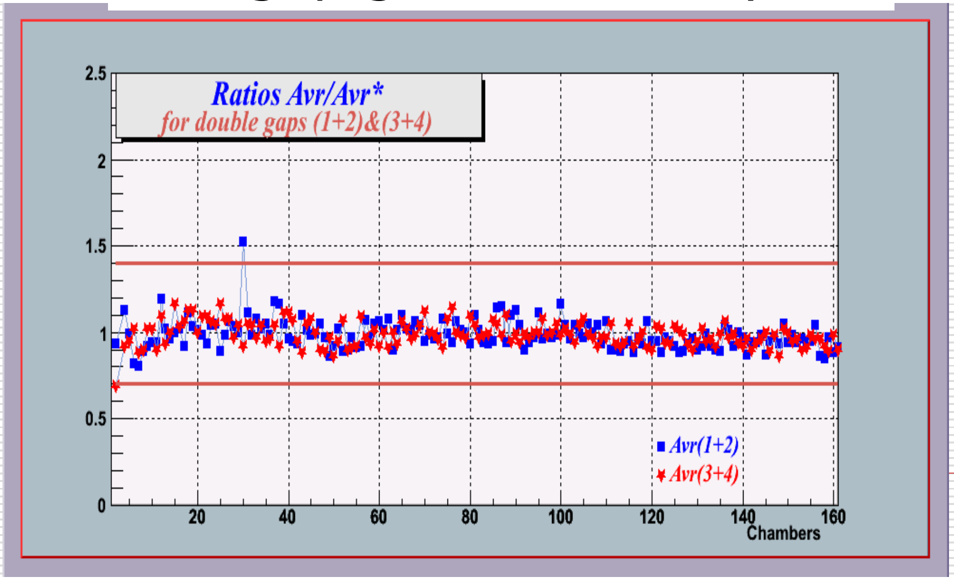
Many measurements tools exist: panel planarity, wire tension, wire pitch

Status of production

- ~ 45% of the chambers have been produced
- Chamber tests on 100% of production
  - gas tightness
  - HV
  - gain uniformity



Gas gap gain uniformity



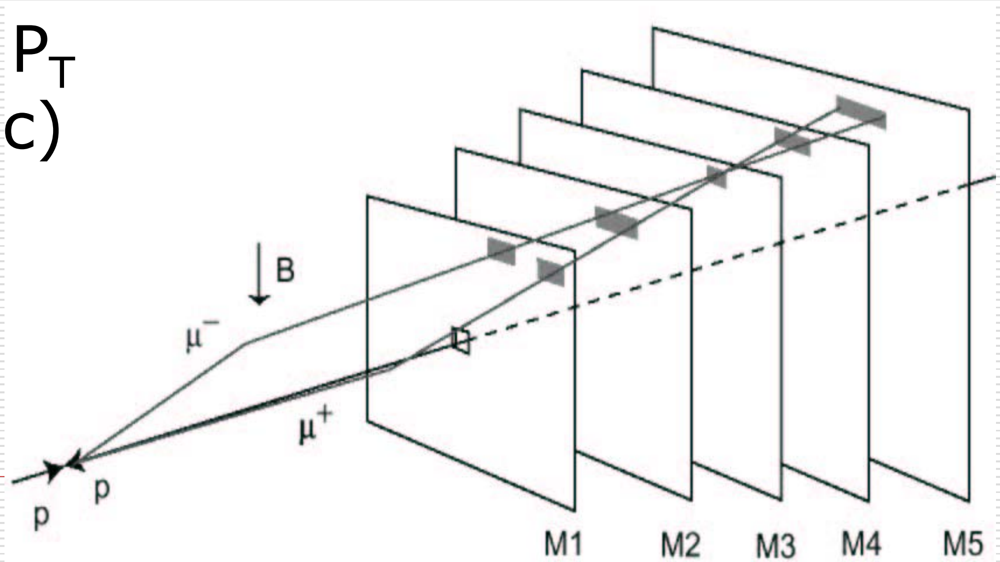
Electronic chain

- On detector boards:
  - CARIOCA : Custom front end chip (ASD+BLR) unipolar, peaking time 10 ns deadtime ~60ns (120k channels)
  - DIALOG : Custom chip OR FE's to achieve the required granularity introduce the delays per FE
- Off detector boards:
  - SYNC, a custom chip with TDC to allow the synchronization of the apparatus

L0 muon trigger

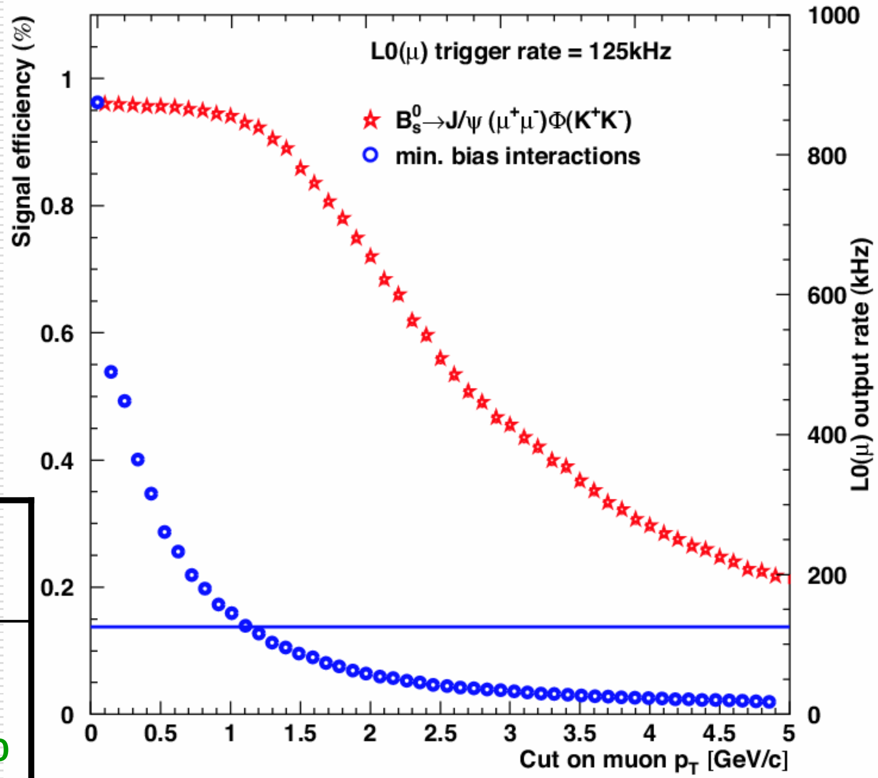
Completely hardware and fully synchronous

- Track search in M1-M5
  - Seed in M3
  - Hits in M4 and M5 define a μ track (20 λ_I)
  - M2 and M3 hits predict M1 hit position
  - M1 and M2 hits define μ direction after magnet
- B-kick to calculate P_T (P_T kick ~ 1.2 GeV/c)



L0 Muon performance

- P_T resolution ~20%
- High efficiency
- Very robust against high background level in the detector



100 kHz output rate	efficiency
Nominal condition	46% 82%
+ safety factors	41% 76%

$b \to \mu X$

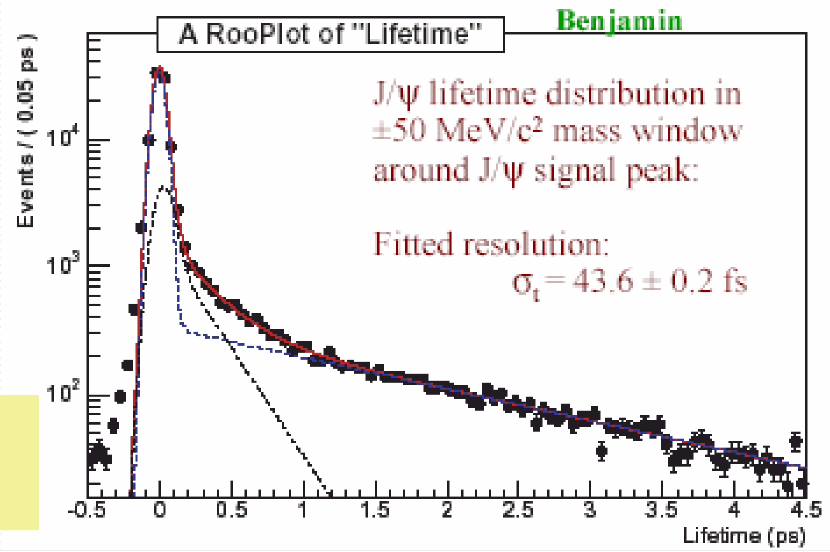
$B \to J\Psi\phi$

safety factor 2 in M1 and 3 in M2-M5

HLT muon streams

Lifetime unbiased dimuon stream (600Hz)

- High rate dimuon trigger will provide invaluable calibration tool
- Distinctive mass peaks: J/Ψ…, ϒ…, Z…
  - → can be used to fix mass scale
- Sample selected independent of lifetime dominated by prompt J/Ψ → allow study of IP and proper time res. in data
- Overlap with other triggers will allow proper time acceptance to be studied



True J/Ψ rate ~ 130 Hz
→10^9 events / year !

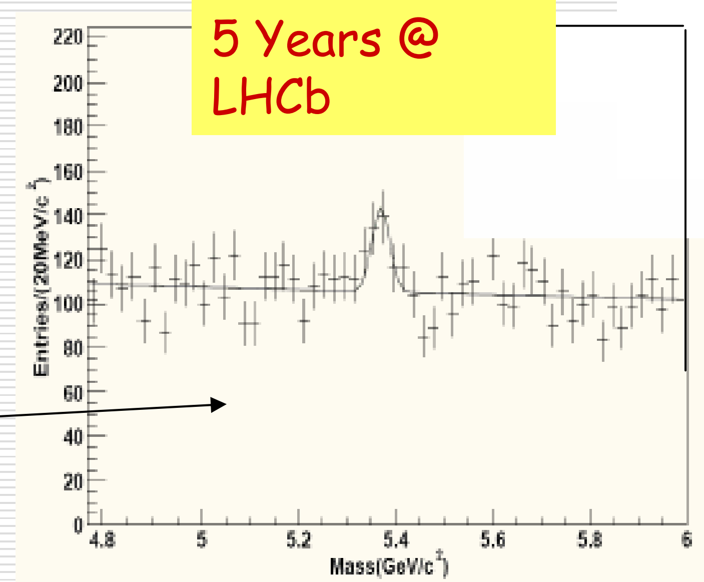
HLT muon streams

Inclusive single muon (900Hz)

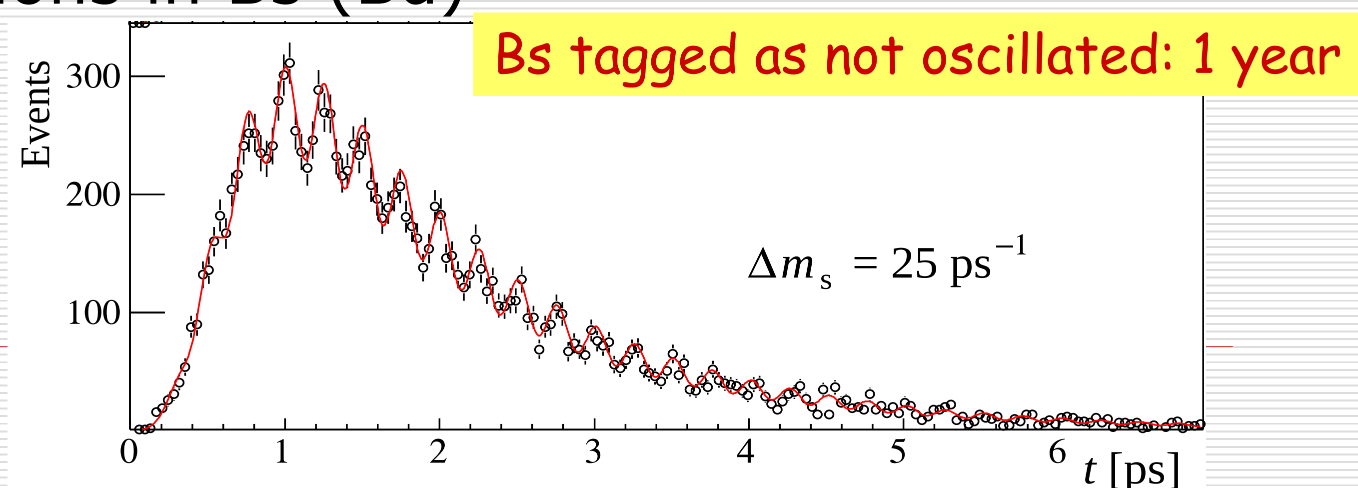
- providing unbiased selection of ‘other B’ in event, invaluable for studying biases in exclusive trigger selection
- useful for ‘data-mining’
- Straightforward & robust trigger; a reassuring lifeboat for early operation
- High beauty purity: 550 Hz of true $b \rightarrow \mu$ events in the 900 Hz
- $\sim 10^9$ perfectly tagged B decays / year !
- Add ~ 10% of effective statistics with respect to exclusive selection
- Useful to recover decay modes difficult to trigger exclusively (e.g. Bs->Ks Ks)

Offline performance

- Bs->J/Ψ φ + Bs->J/Ψ η
  - Mixing angle of Bs : σ~0.05 (1y)
  - ΔΓ/Γ : σ~ 0.03 (1y)
- Bs->μμ:



- ~1/7 (1/5) of the effective tagging power is due to muons in Bs (Bd)



Conclusions

- The designed detector has
  - Good time resolution, high efficiency, robustness, high rate capability, aging resistance
- Construction well advanced