b physics at LHC

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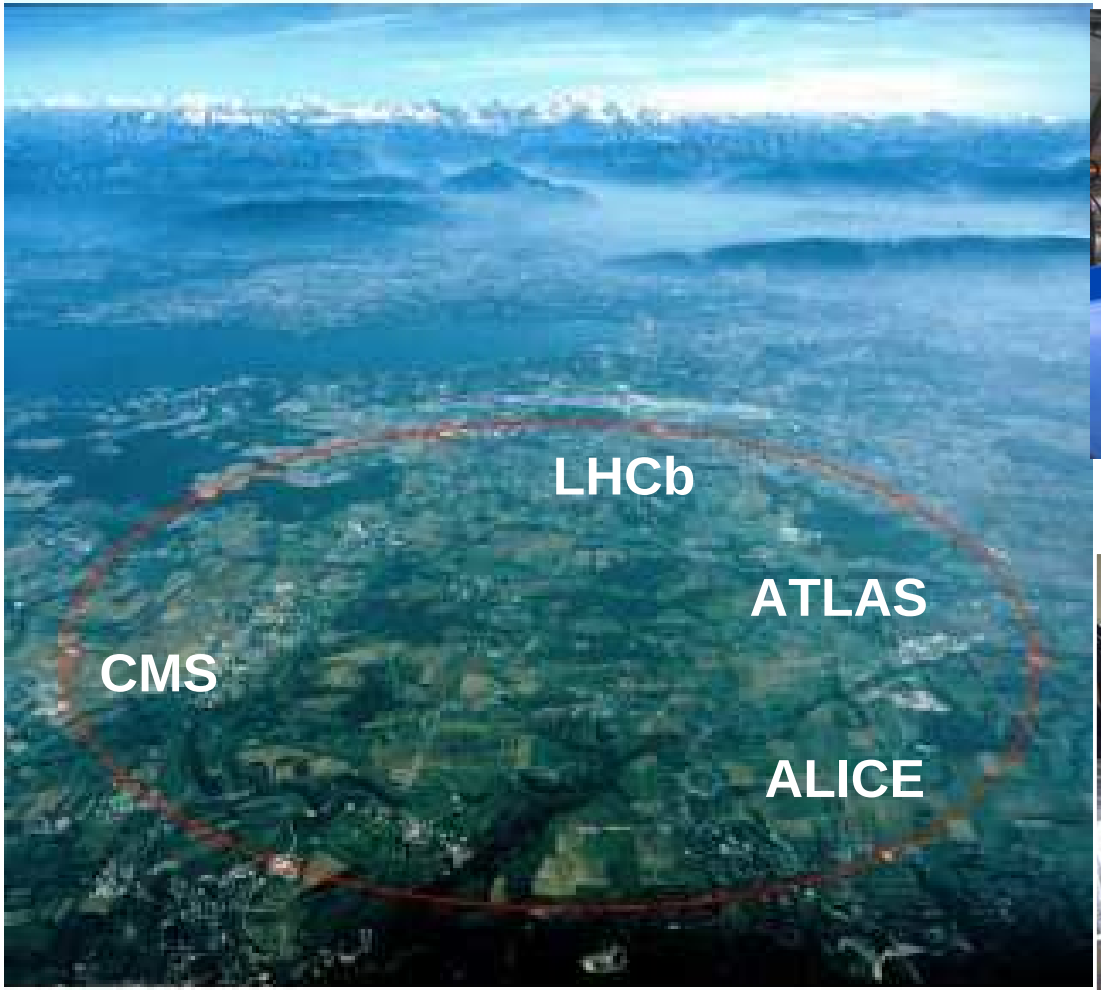
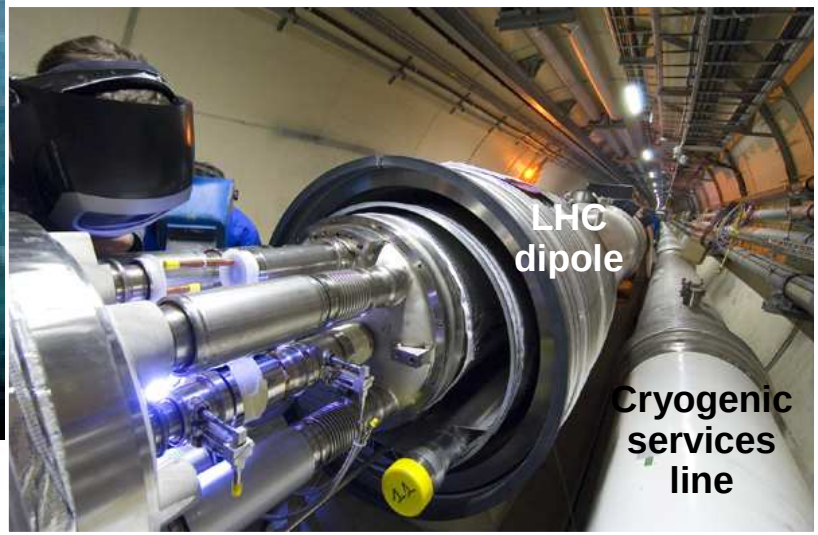
LAPP, Annecy, IN2P3, CNRS

Cracow Epiphany Conf. on LHC Physics
4-6 Styczeń (January) 2008, Kraków, Polska

LHC



Sector 81



LHC

October 21st, 2008, LHC official inauguration

may be …. beautiful

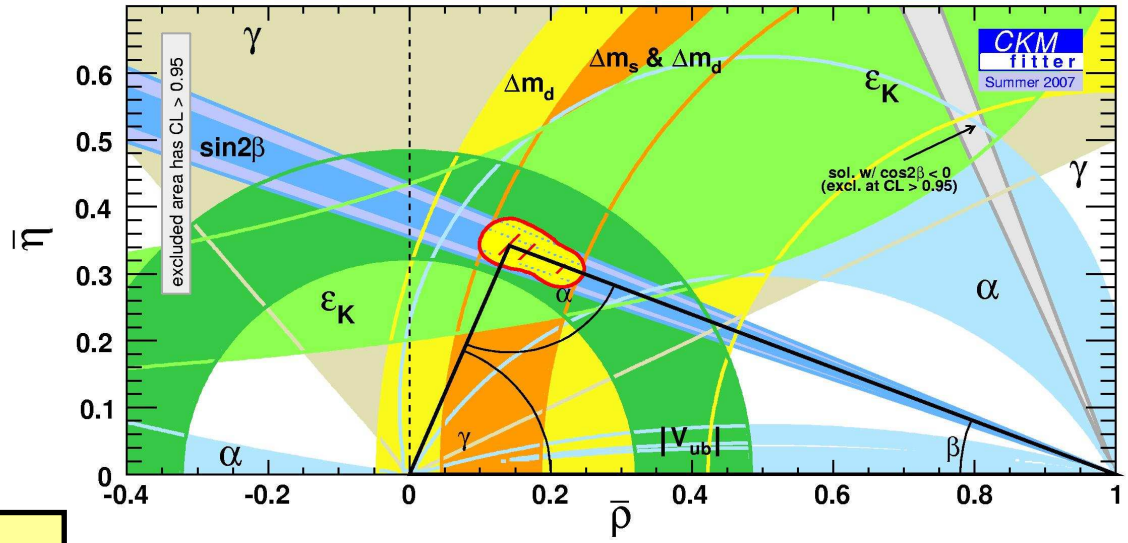
Physics at LHC

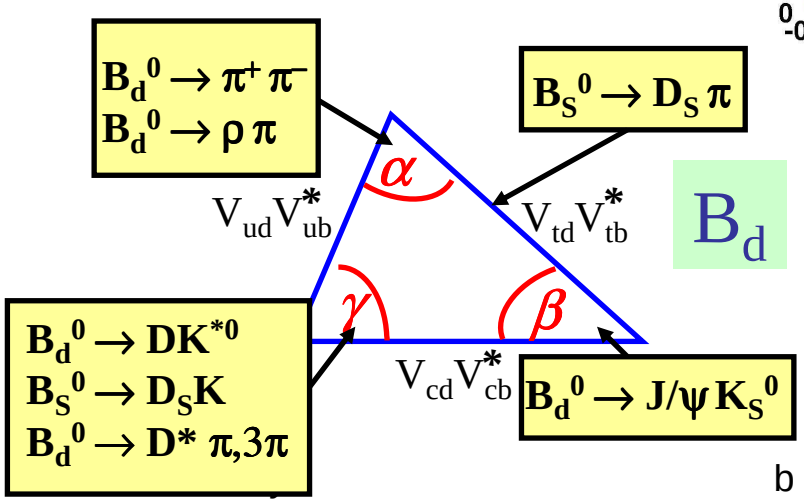
Excellent results from BABAR, BELLE, CDF and D0
The measurements of CKM parameters give coherent results

$$\beta = 21.5^{\circ}{}^{+1.0}_{-1.0}$$

$$\alpha = 87.5^{\circ}{}^{+6.2}_{-5.3}$$

$$\gamma = 76.8^{\circ}{}^{+30.4}_{-31.5}$$





B_d

No indication for New Physics

Physics at LHC

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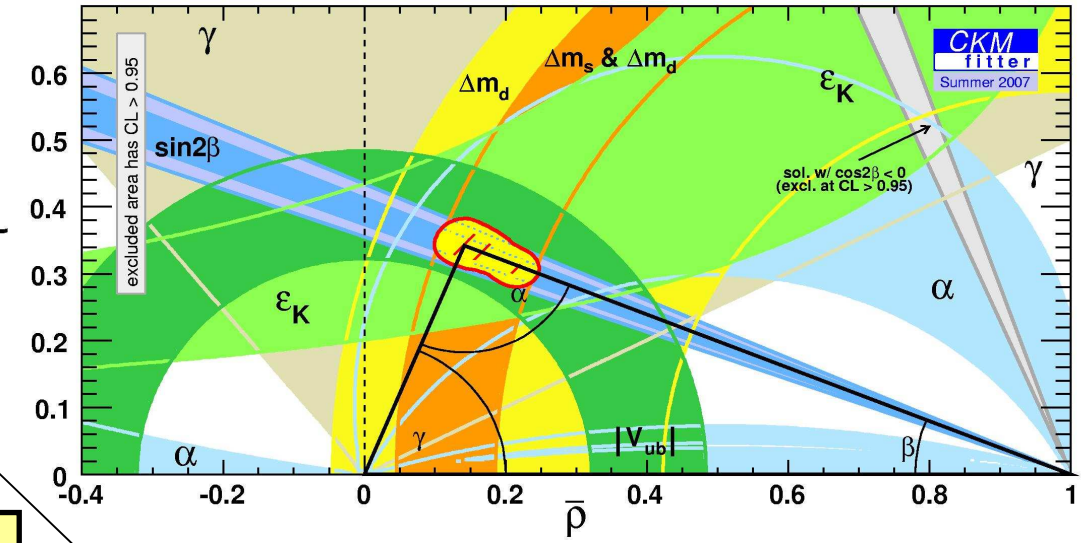
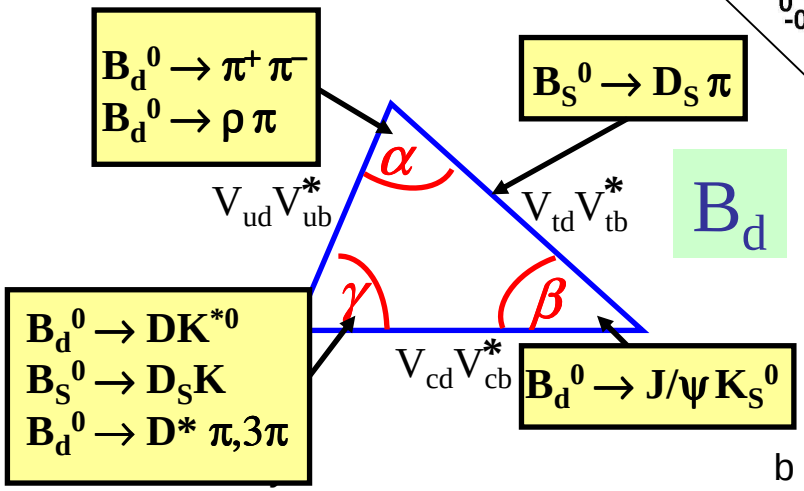
$\gamma = 76.8^{\circ}{}^{+30.4}_{-31.5}$

$26.6^{\circ}{}^{+1.0}_{-3.8}$

$102^{\circ}{}^{+2.9}_{-12.6}$

$67.6^{\circ}{}^{+2.7}_{-4.8}$





"SM" predictions

Physics at LHC

Theorists expected effects of New Physics in heavy flavour measurements
→ strong constraints on New Physics models

$\beta = 21.5^{\circ}{}^{+1.0}_{-1.0}$

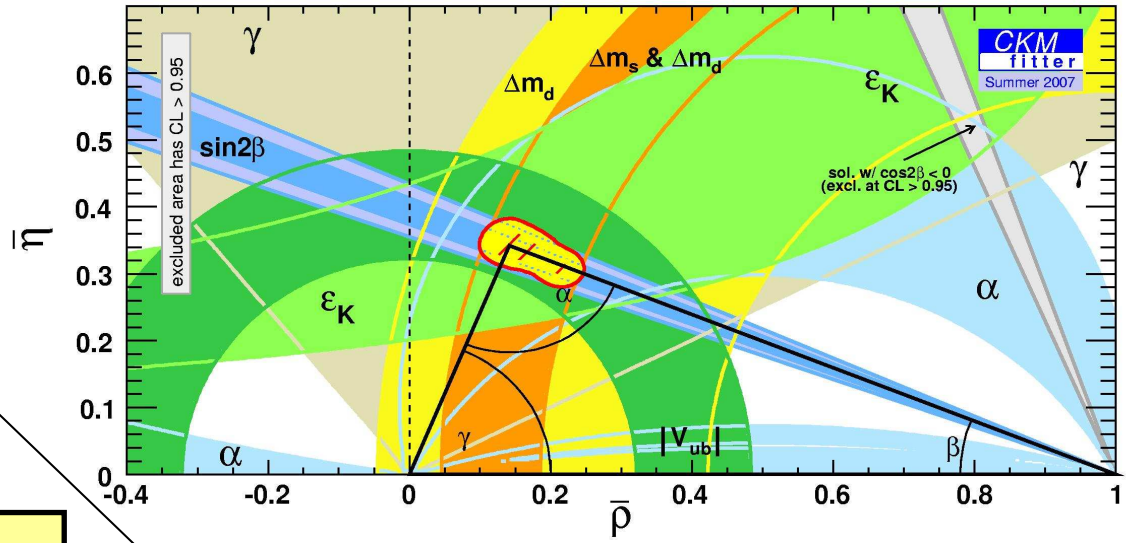
$\alpha = 87.5^{\circ}{}^{+6.2}_{-5.3}$

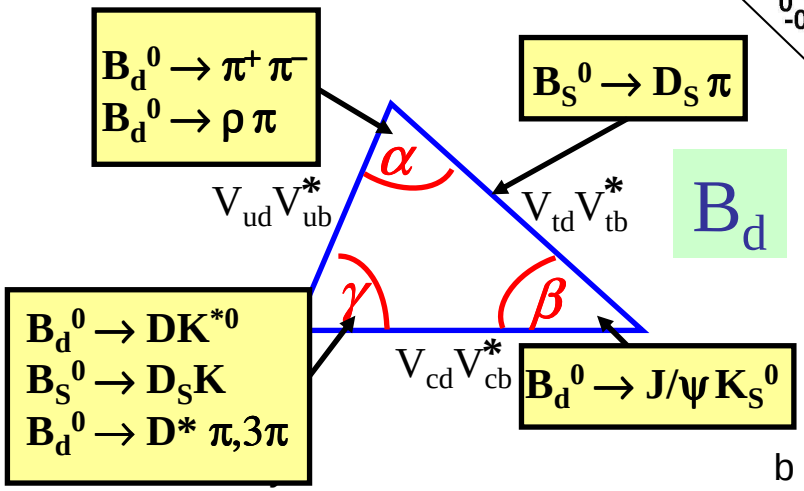
$\gamma = 76.8^{\circ}{}^{+30.4}_{-31.5}$

$^{+}_{-}0.5^{\circ}$

$^{+}_{-}10^{\circ}$

$^{+}_{-}5^{\circ}$

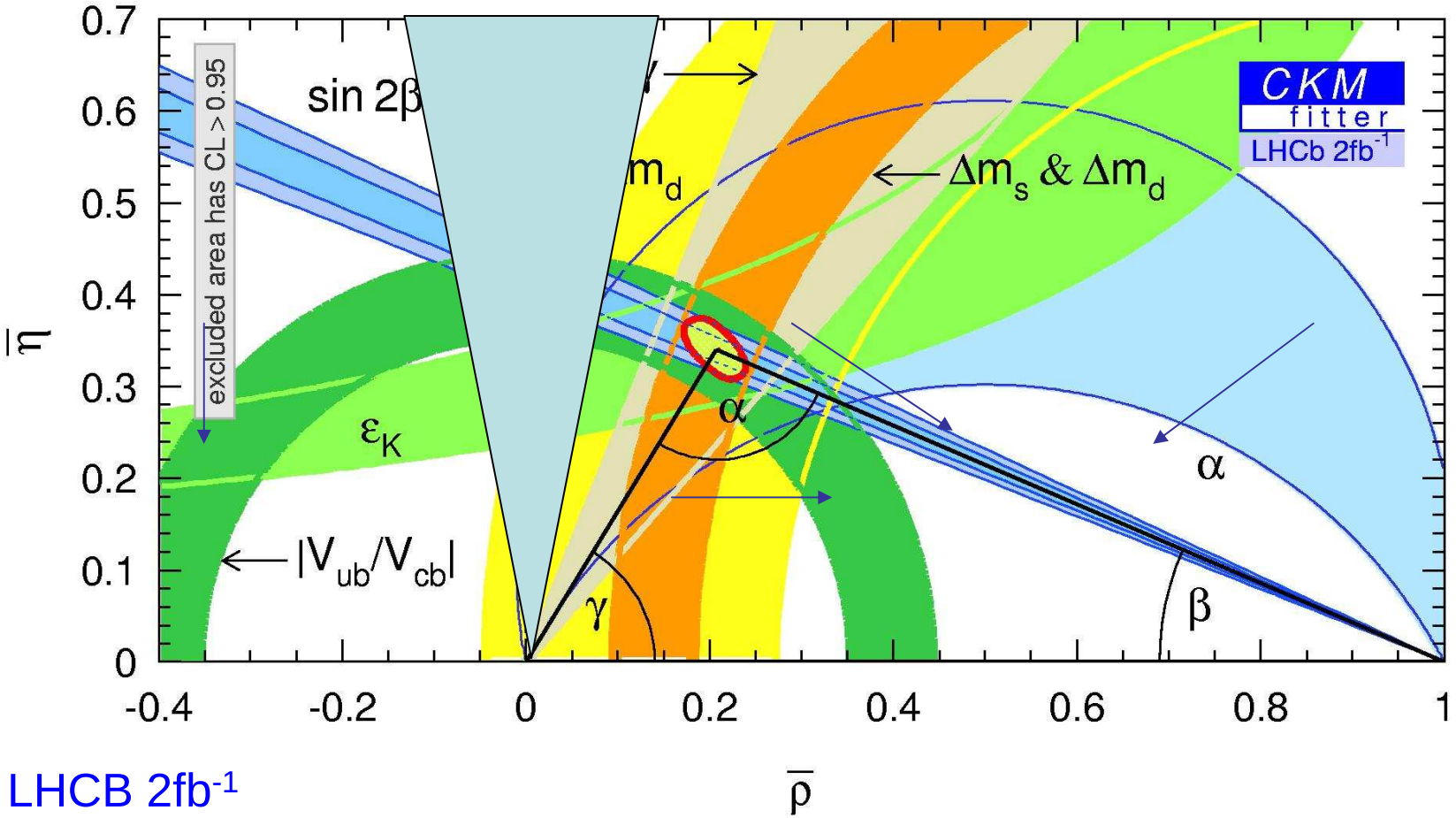




B_d

LHCb 2fb^{-1} (nominal one year)
More constraints on
New Physics

Measurement of γ at LHCb



LHCB $2fb^{-1}$

$\sigma(\beta) \approx 0.5,\ \sigma(\gamma) \approx 5°,\ \sigma(\alpha) \approx 10°,\ \sigma(\phi_s) \approx 2°,\ \sigma_{stat}(\Delta m_s) \sim 0.01\ ps^{-1}$

Rare decays

…….where standard model contributions are suppressed enough to allow potential small NP effects to emerge:

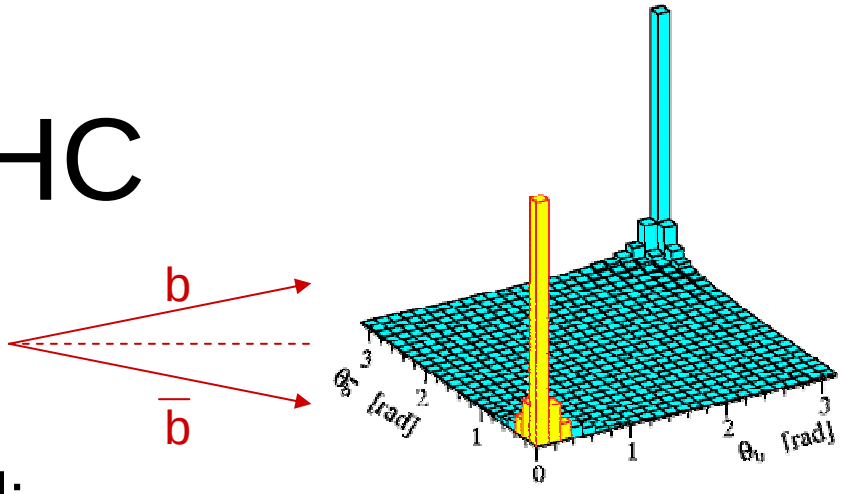
- Very rare leptonic decays: eg. $B_s \rightarrow \mu\mu$
- Rare semi-leptonic decays: $b \rightarrow s\ell\ell$

  (eg. $B_d \rightarrow K^{0*}\mu\mu$, $B_u \rightarrow Kee/B_u \rightarrow K\mu\mu$)
- Radiative decays: $b \rightarrow s\gamma$

  (eg. $B_d \rightarrow K^*\gamma$, $B_s \rightarrow \phi\gamma$, $\Lambda_B \rightarrow \Lambda\gamma$, …)

… at LHC

correlated forward bb pair production

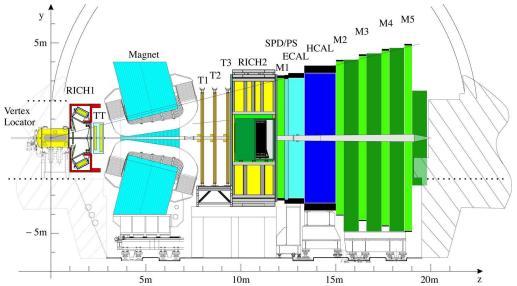


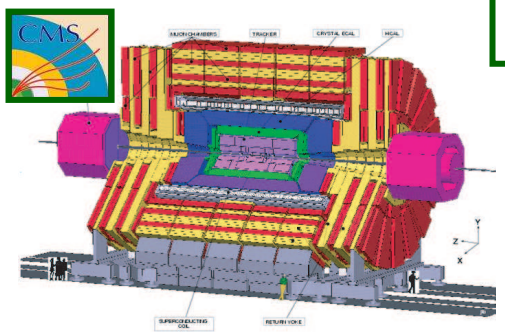
…different b hadrons are produced:

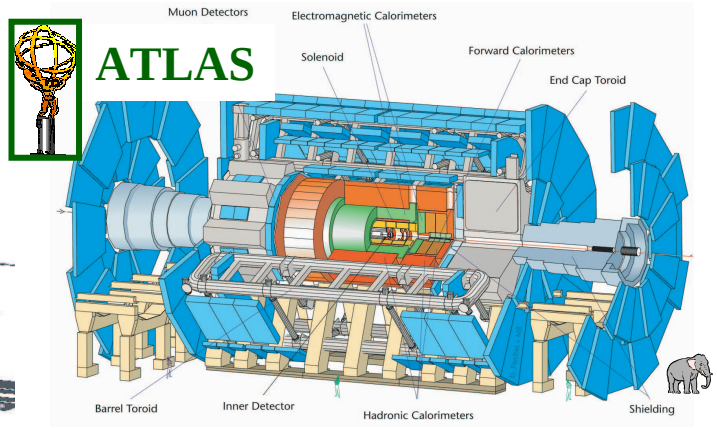
B_d, B_u, B_s, B_c, Λ_b , …

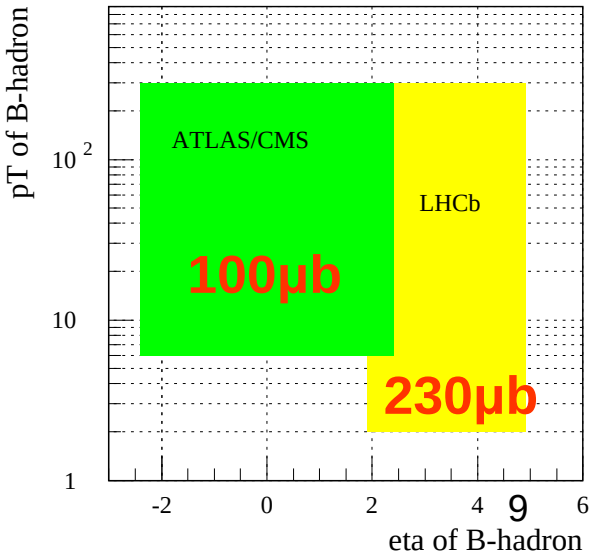
σ_{total} ~ 100 mb, $\sigma_{visible}$ ~ 65 mb, σ_{bb}~ 500 μb,

but $\sigma_{bb}/\sigma_{visible}$ = 0.8% ~10^{12} bb pairs/year (10^7 s)









… at LHC

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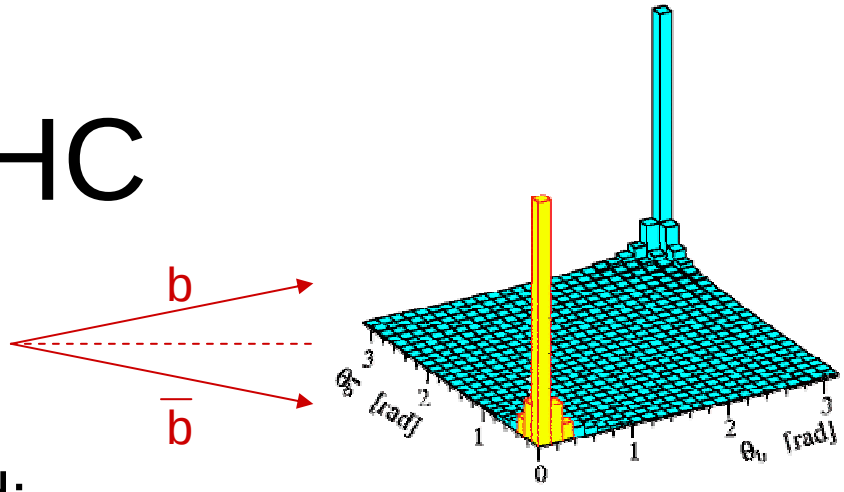

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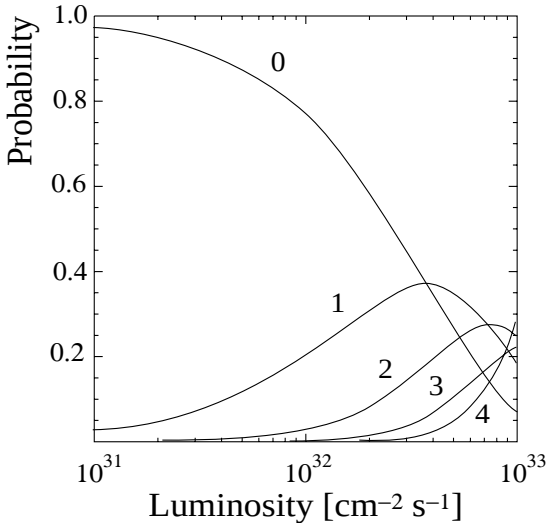
but $\sigma_{bb}/\sigma_{visible}$ = 0.8% ~10^{12} bb pairs/year (10^7 s)

LHCb (1,9<η<4,9)

12 mrad <θ< 300 mrad

n ~ 1 int./bunch crossing

at <L> = 2 x10^{32} cm^{-2} s^{-1}



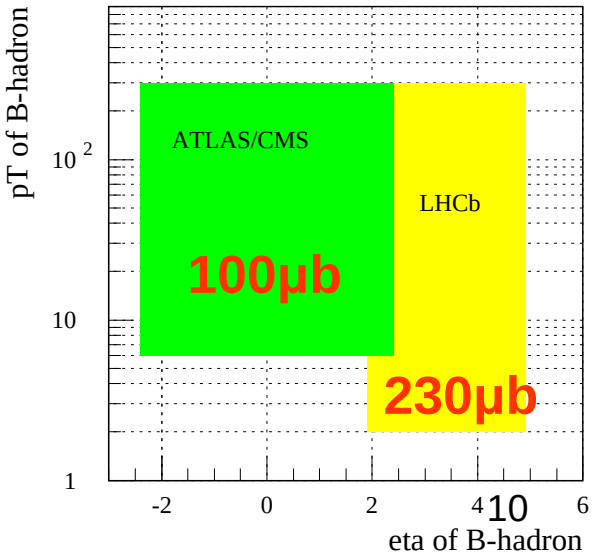
ATLAS/CMS:

n<5 int./bunch crossing

at <L> = 2 x10^{33} cm^{-2} s^{-1}

n=25 int./bunch crossing

at <L> = 10^{34} cm^{-2} s^{-1}



LHCb - detector requirements

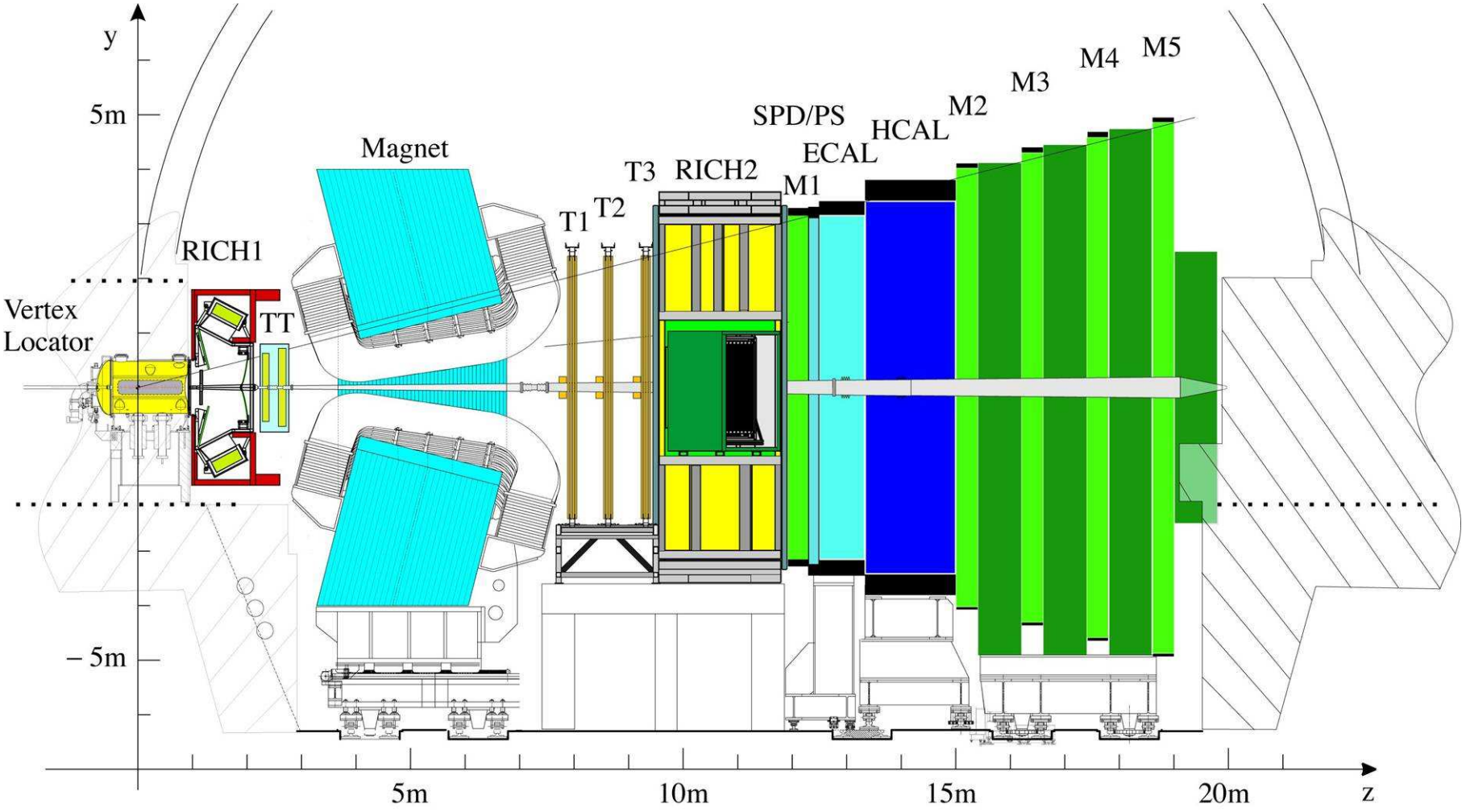
Vertexing, to measure decay points and reduce backgrounds
Tracking, to reconstruct tracks and measure well their momenta

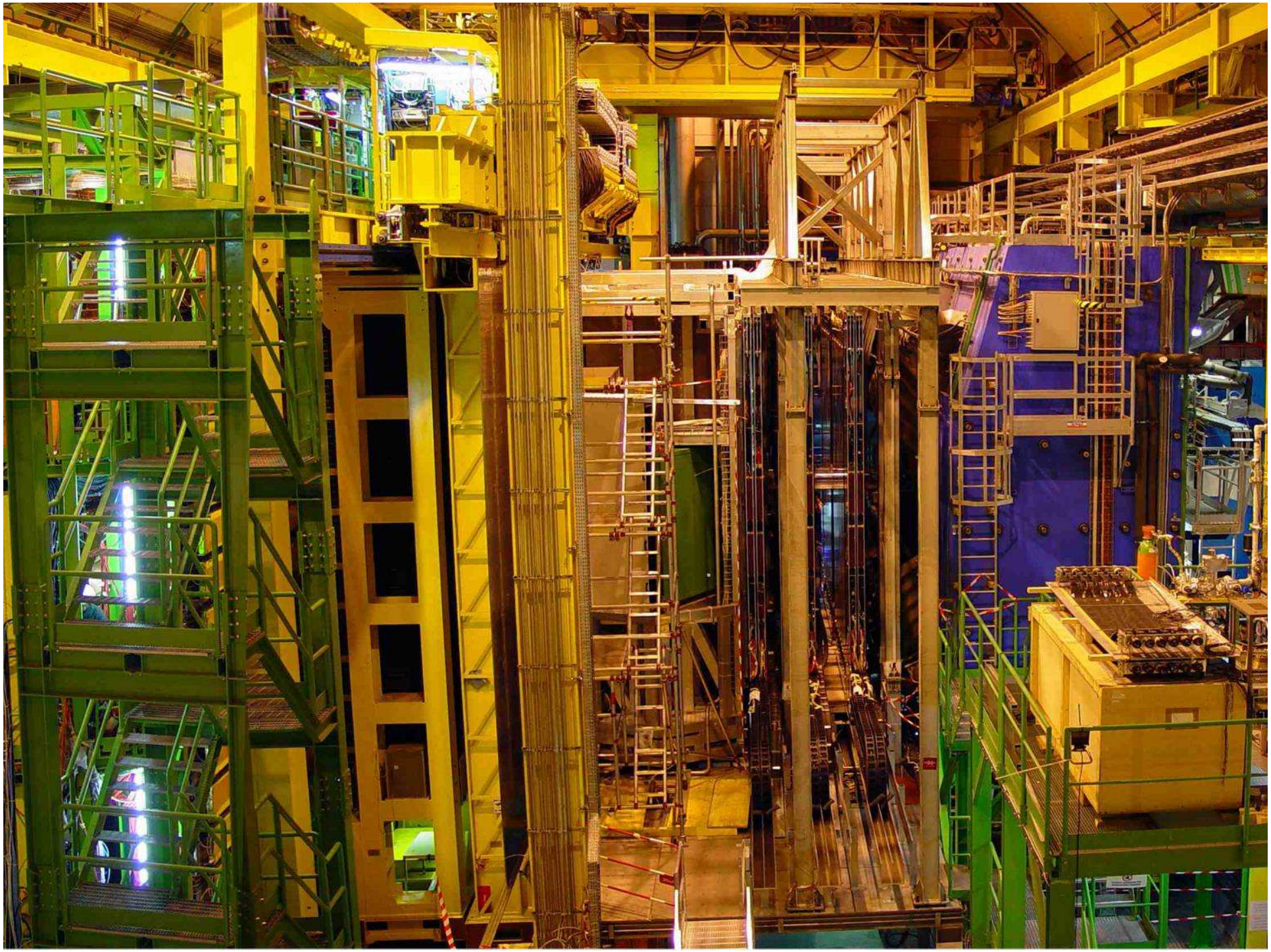
Particle Identification, to eliminate backgrounds from one mode to another where kinematical separation is not sufficient

Triggering, to select interesting events from huge background

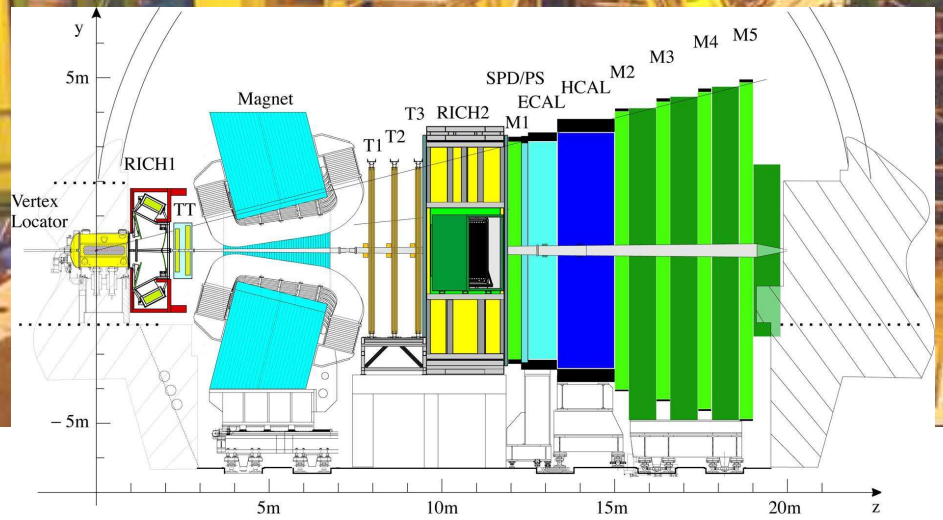
High speed DAQ coupled to large computing for data processing

LHCb detector

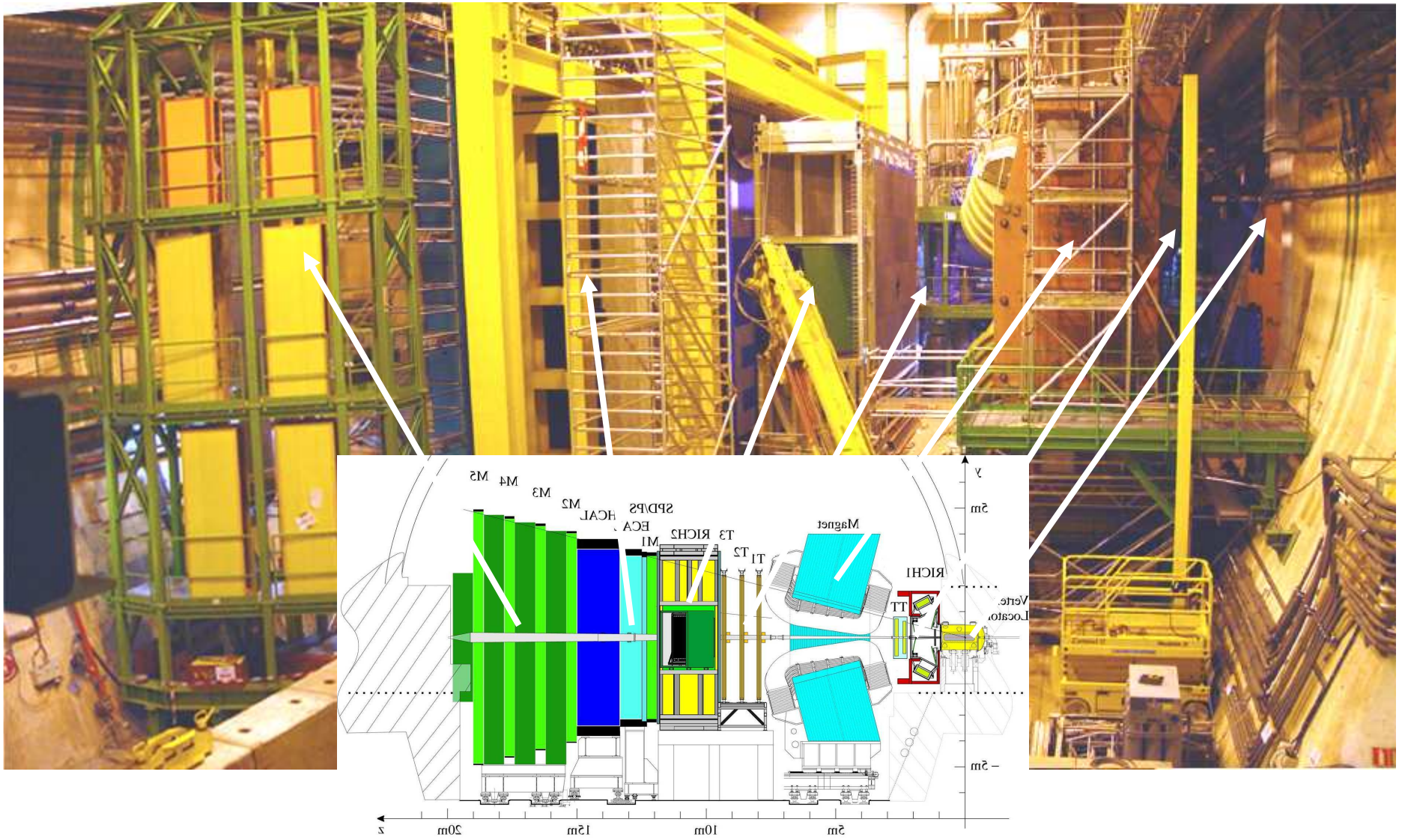




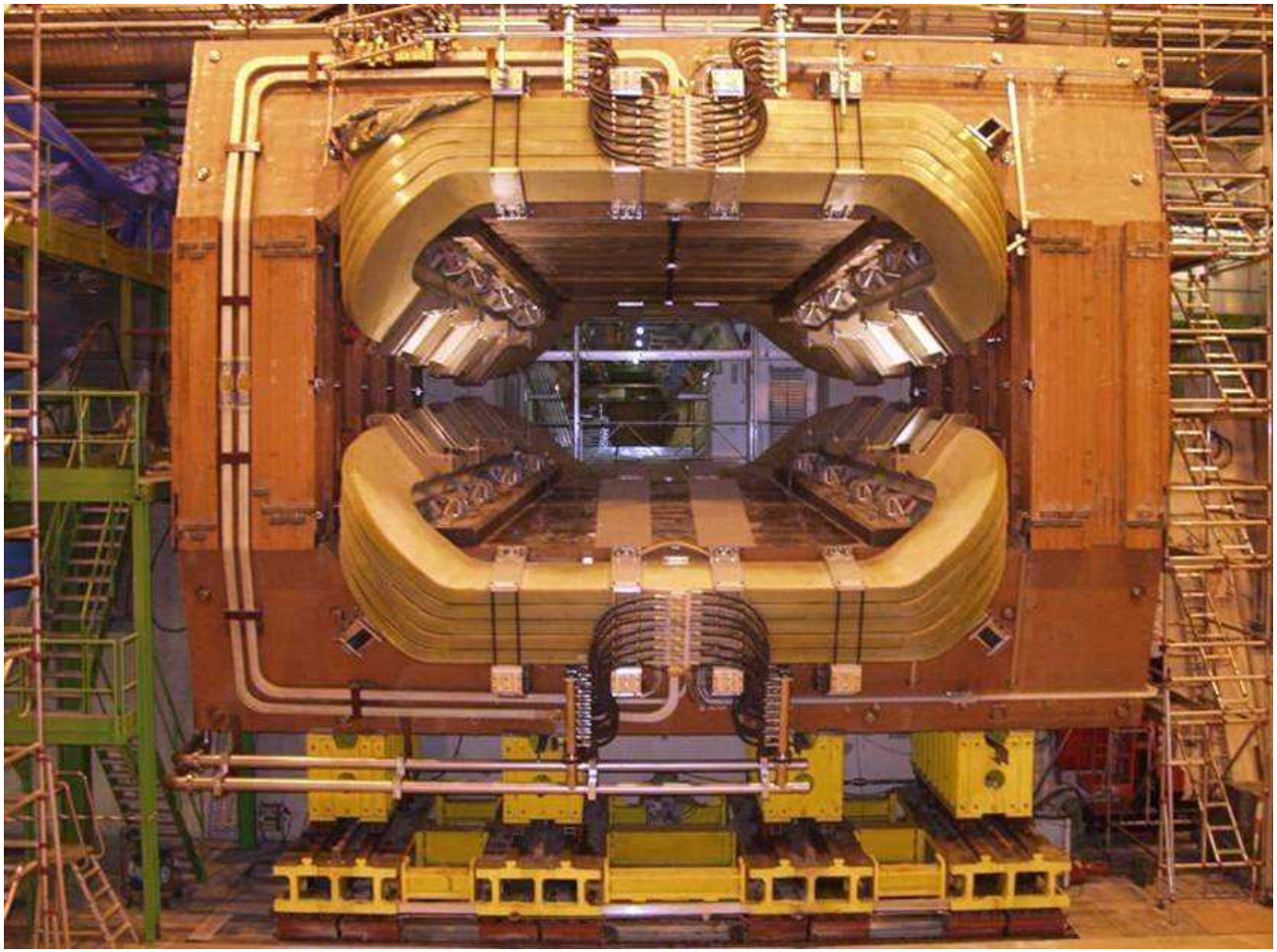
LHCb detector



LHCb detector

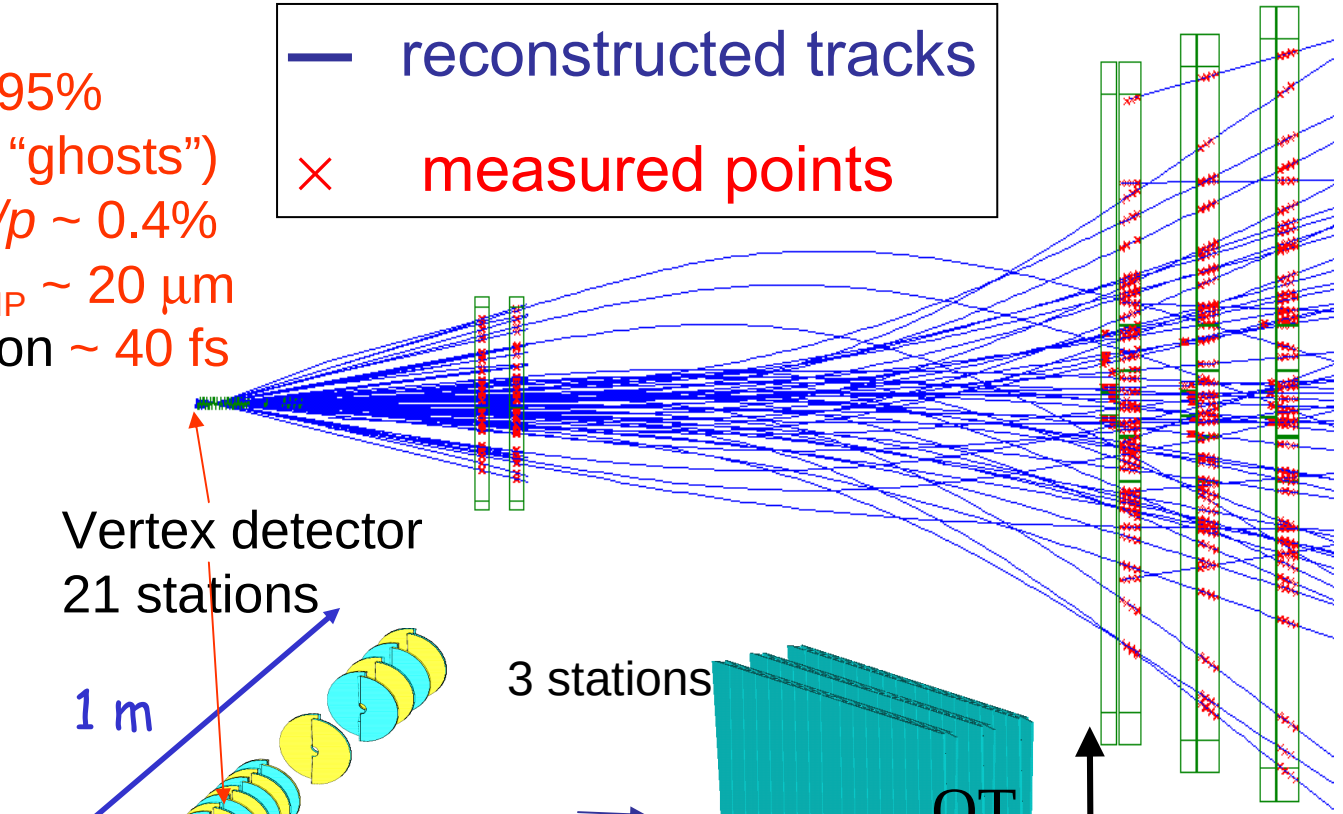


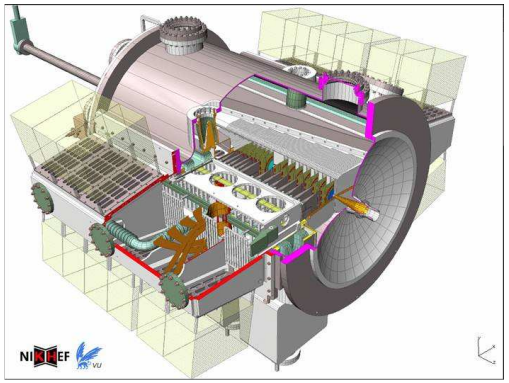
Magnet



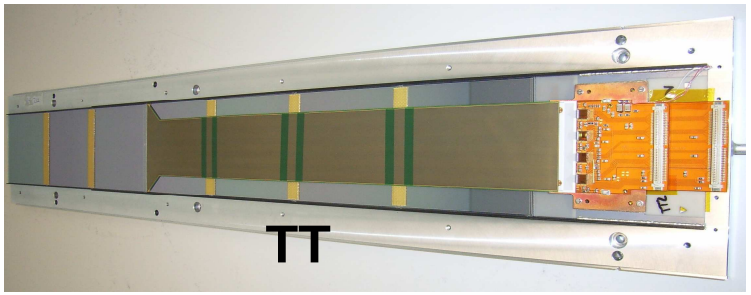
Vertexing and tracking

recontr. efficiency >95%
(4% “ghosts”)
mom. resolution $\Delta p/p$ ~ 0.4%
impact parameter σ_{IP} ~ 20 μm
Proper time resolution ~ 40 fs

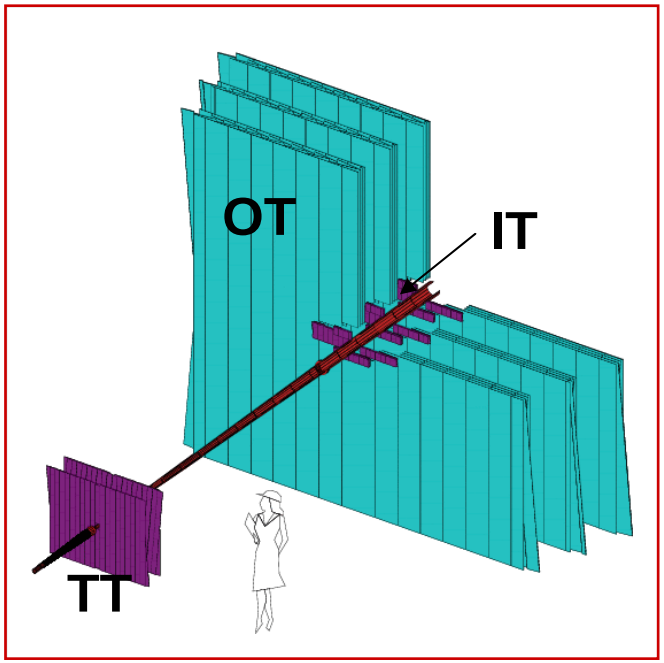


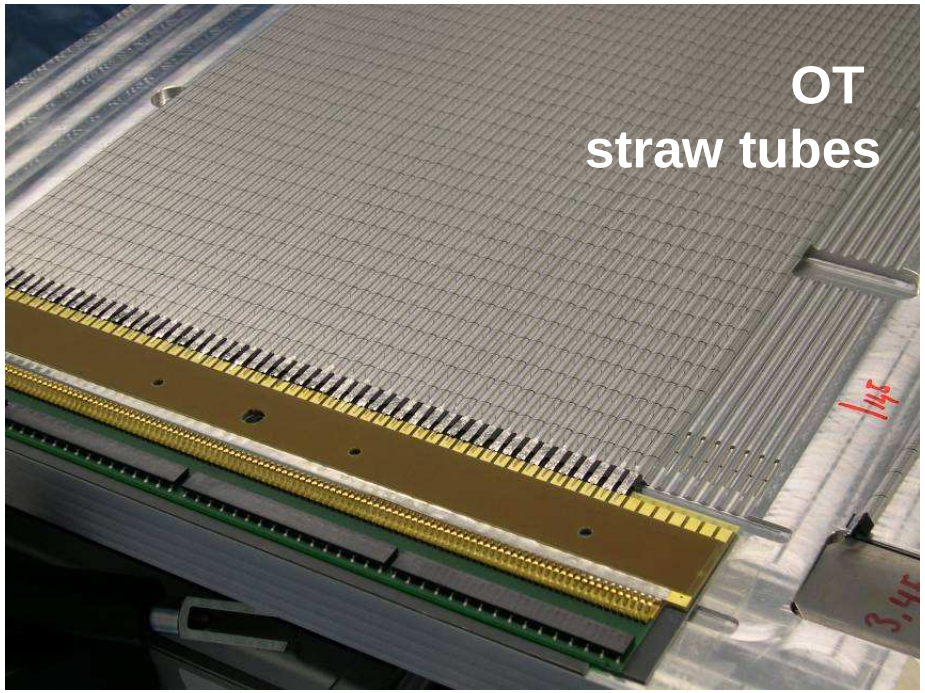


Tracking chambers

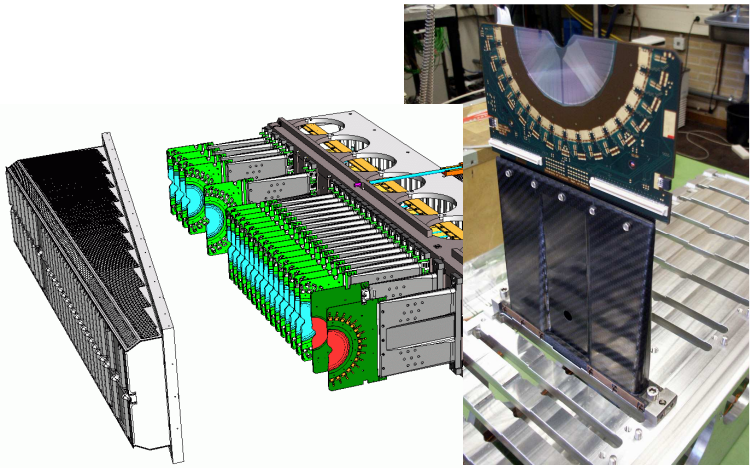


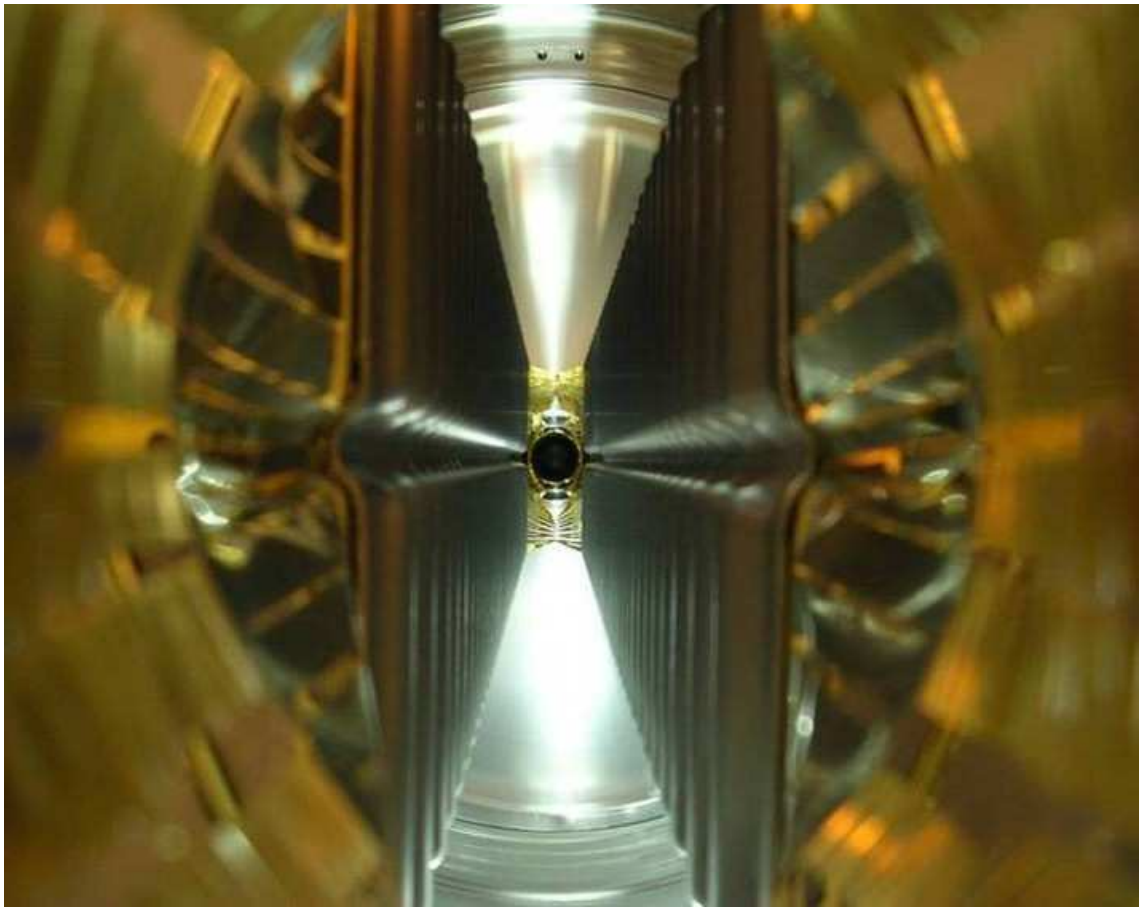
Silicon chambers

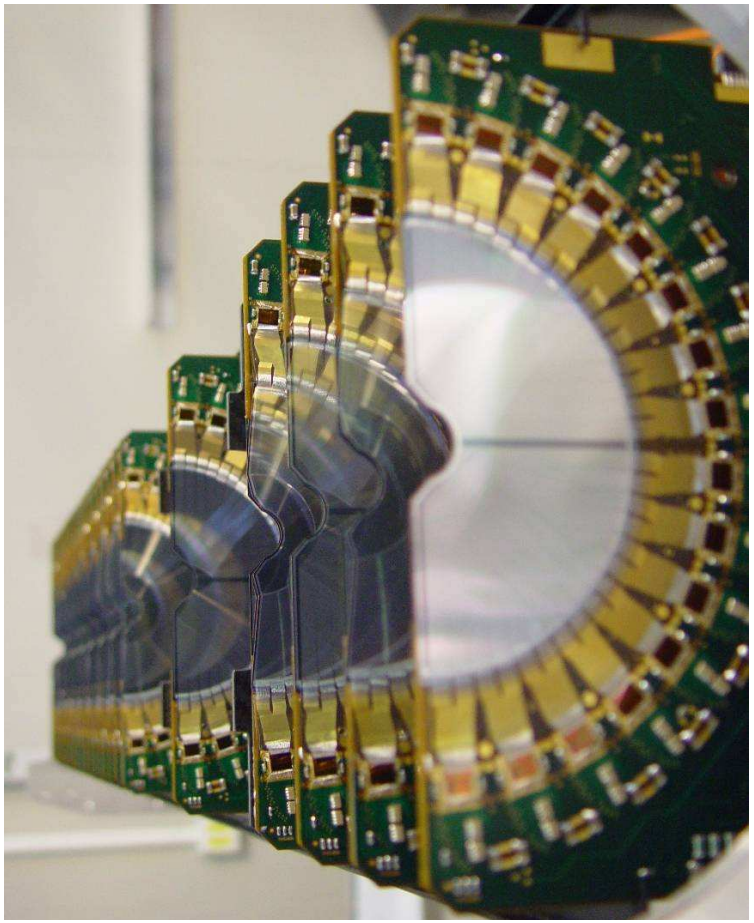




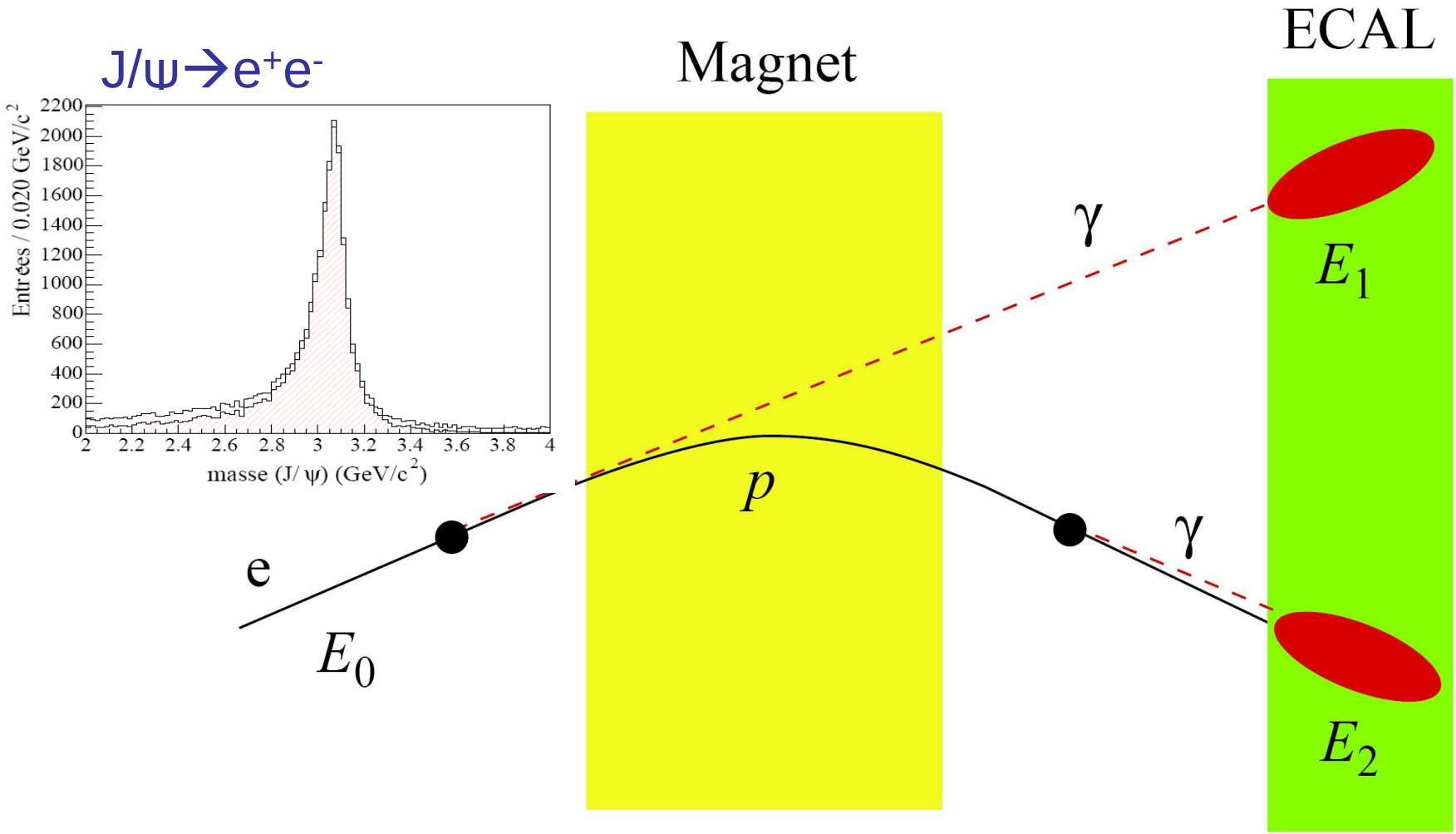
Vertex detector



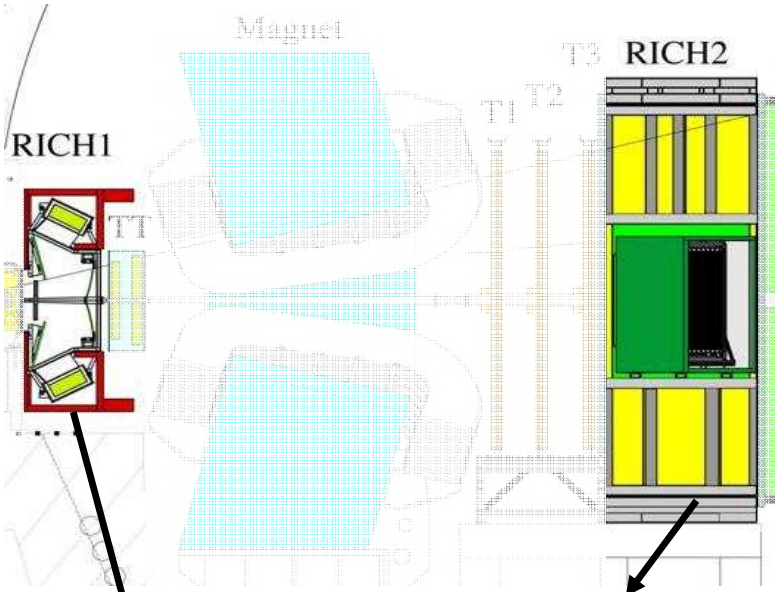




Electron ID and reconstruction

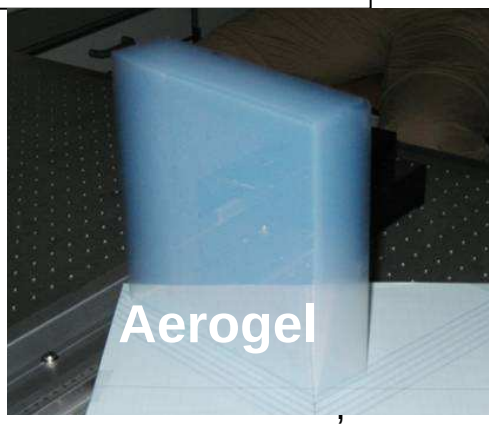


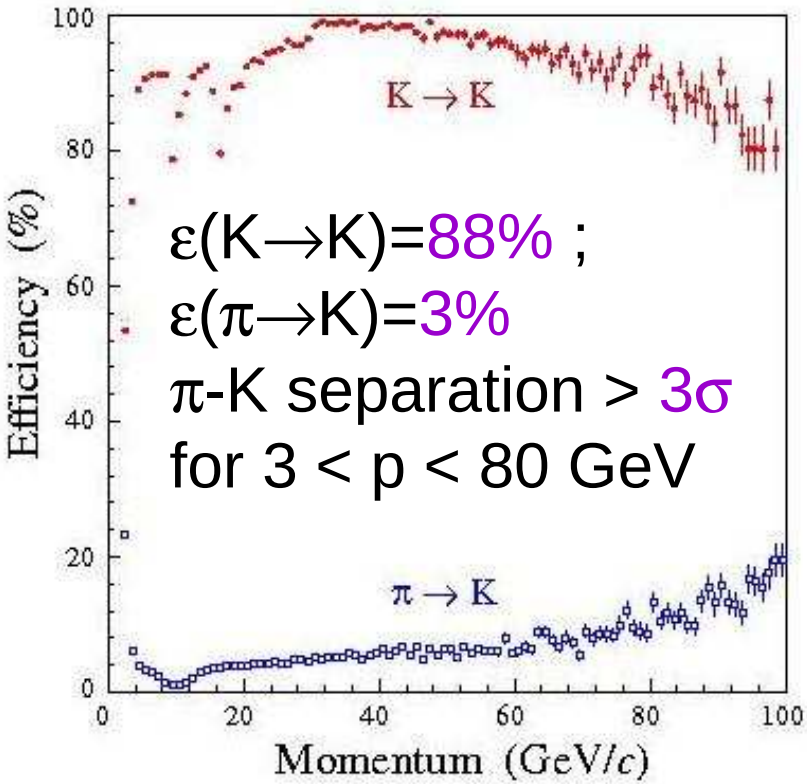
Particle ID

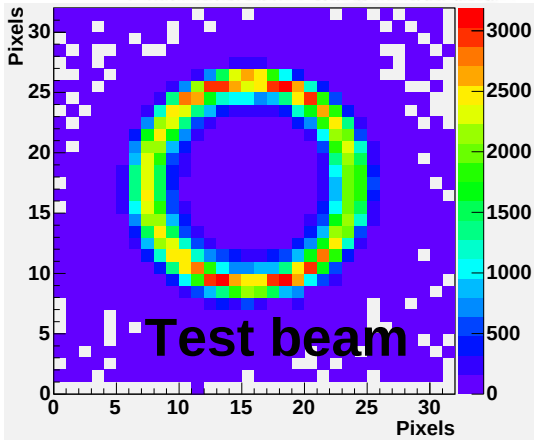


High momentum tracks
CF_4: 16 ~100 GeV

Low momentum tracks
Aerogel: 2 ~10 GeV
C_4F_{10}: 10 ~60 GeV







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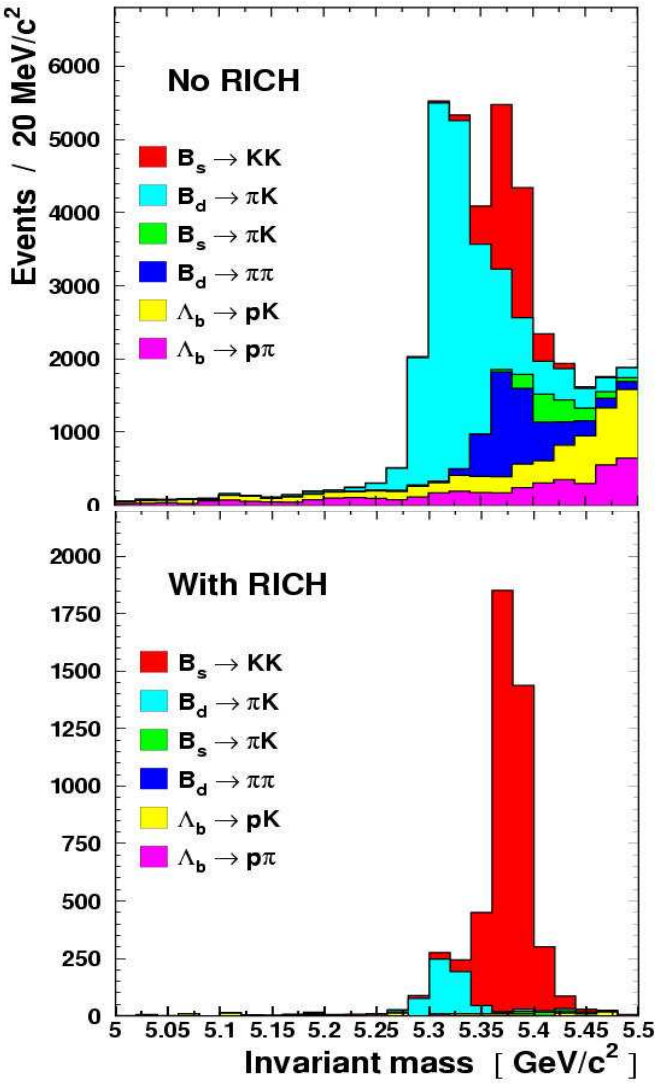
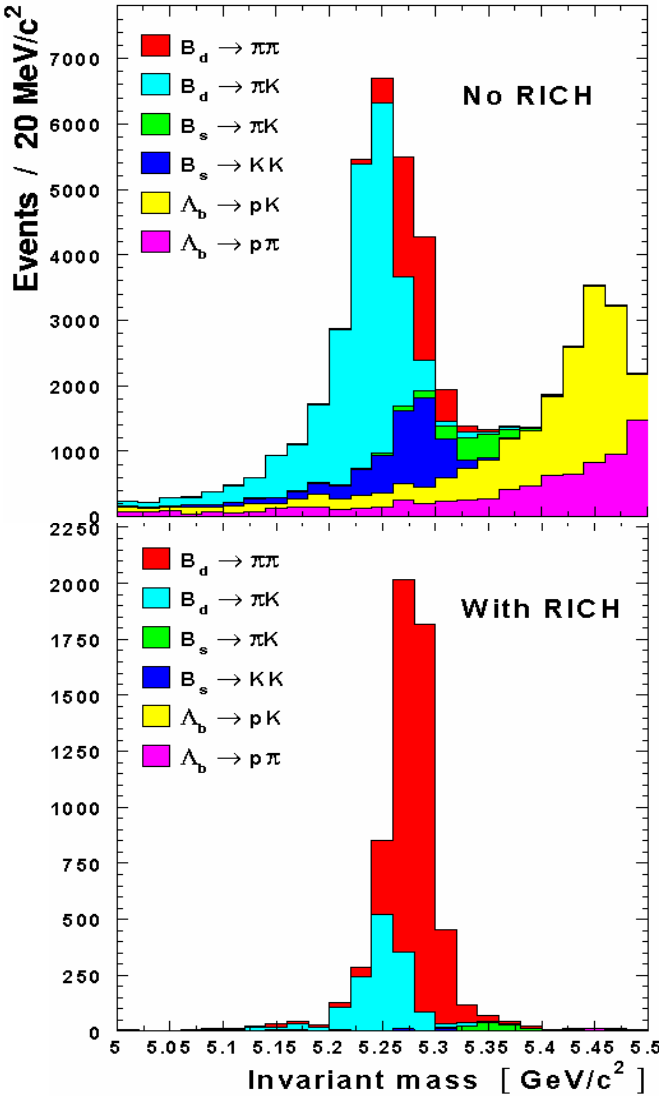




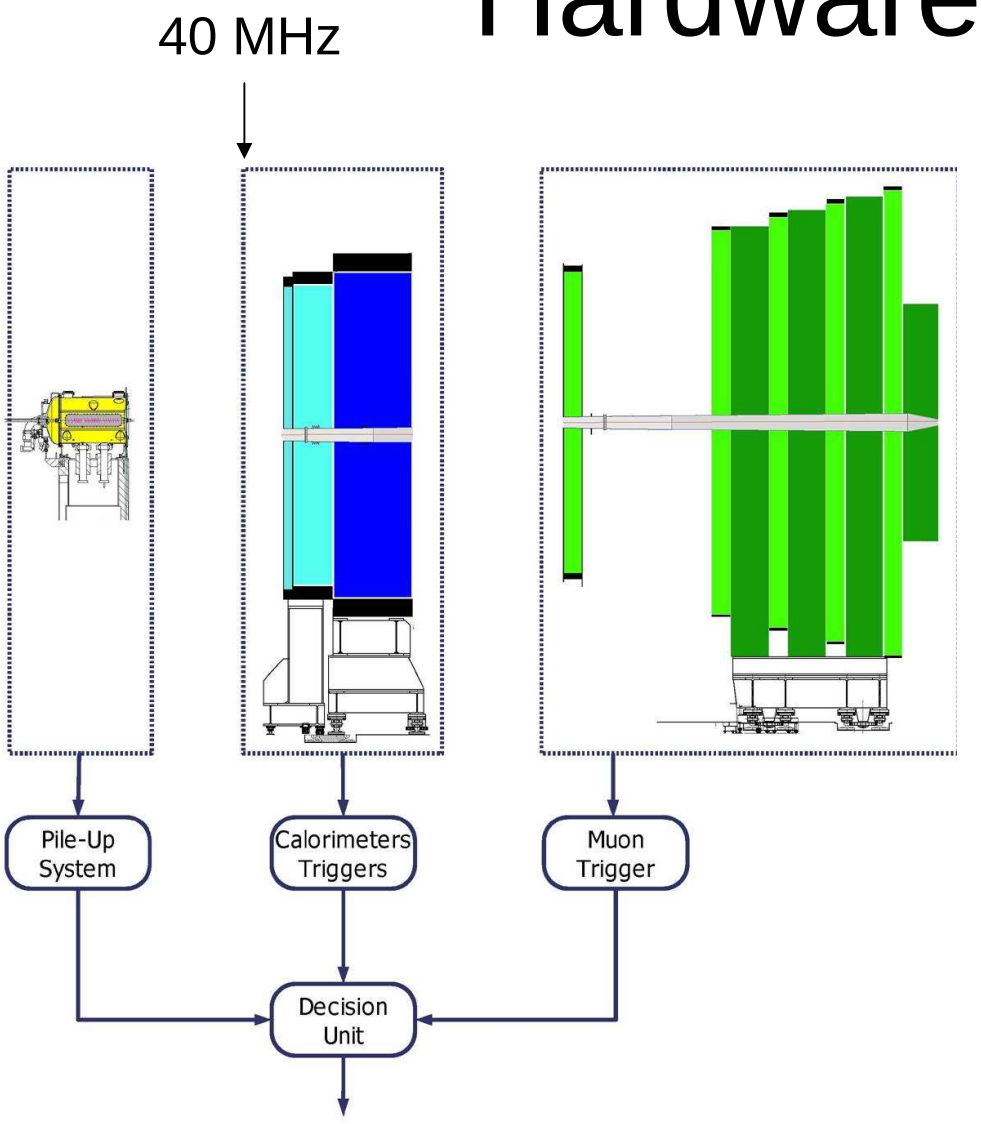
… unique on hadron colliders

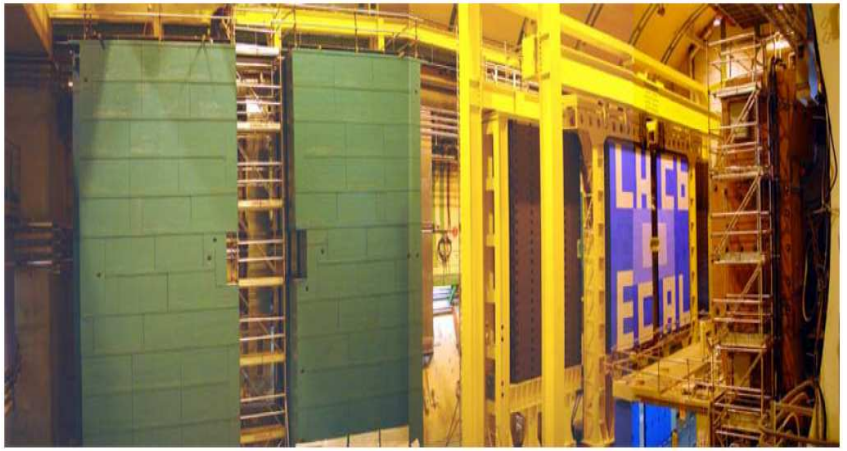
Calorimeters

Beam pipe


TRANSPORT
Three sections in Beryllium,
last section in stainless steel

Hardware trigger

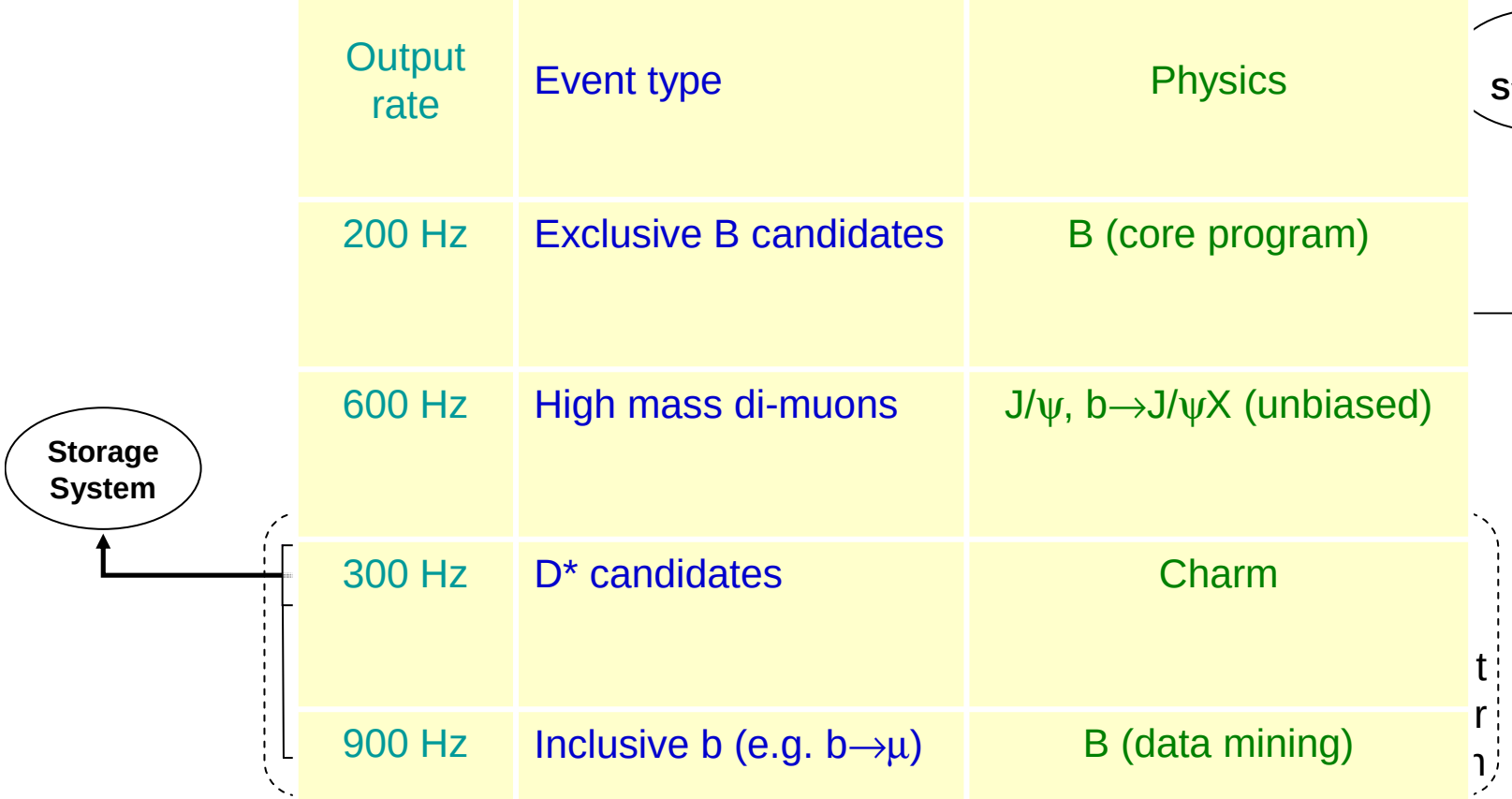




"High p_T" e, γ, hadrons,
"High p_T" μ, $\mu\mu$
pileup info

Software trigger and DAQ

Output rate	Event type	Physics
200 Hz	Exclusive B candidates	B (core program)
600 Hz	High mass di-muons	J/ψ, b→J/ψX (unbiased)
300 Hz	D* candidates	Charm
900 Hz	Inclusive b (e.g. b→μ)	B (data mining)

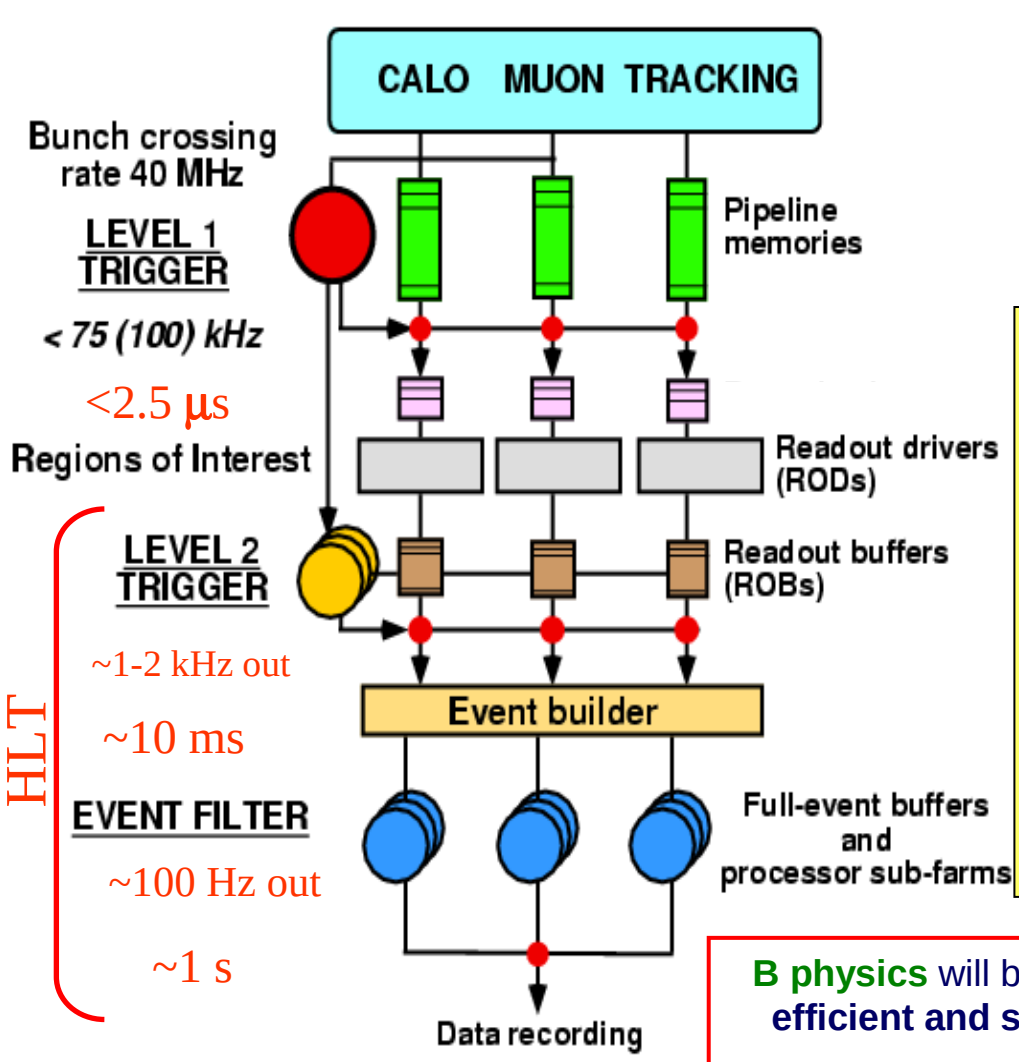


Full detector info available

2 kHZ

ATLAS Multi Level Trigger

(slide from M. Nedden (HU Berlin), at Manchester 2007)



LEVEL 1 TRIGGER

- Hardware based (FPGAs ASICs)
- Uses coarse granularity calorimeter and muon information
- Identifies **R**egions **o**f **I**nterest for further processing

LEVEL 2 TRIGGER

- Full granularity within **RoI**
- Confirm LVL1 trigger
- Combine info from different detectors in **RoI**s around LVL1

EVENT FILTER

- Refines LVL2 selection using "offline-like" algorithms
- Better alignment and calibration data available

HLT: software based

B physics will be using **~10%** of total trigger resources: **fast, efficient and selective trigger strategies needed.**

ATLAS trigger

- **Strategy for B physics trigger:**

- **High luminosity (> 2×10^{33} $cm^{-2}s^{-1}$):**
  - **LVL1: dimuon, p_T > 6 GeV/c each**
- **Low luminosity (or end of) fills:**
  - **LVL1: add single muon, p_T > 6–8 GeV/c**
  - **LVL2: look for objects around muon**
    - 2^{nd} muon (with lower threshold) in muon RoI
    - Single e/γ or e^+e^- pair in EM RoI
    - Hadronic b decay products in Jet RoI (e.g. $B_s \rightarrow D_s^-\pi^+$)

Trigger level	Total output rate	Output rate for B physics
LVL1	75 kHz	10–15 kHz
LVL2	2 kHz	1–1.5 kHz
EF	200 Hz	10–15 Hz

Slide from A. Schopper

CMS trigger

Trigger to cover widest range of discovery physics (Higgs, SUSY, …)

- **Level 1: (nominal) 3.2μs buffer, → 100 kHz**
- **HLT (High-Level Trigger): 1s buffer, 40 ms processing, → 100 Hz**

Trigger on B events:

- **Level 1: di-μ with p_T> 3 GeV/c each (or single μ with p_T> 14 GeV/c)**
- **HLT: Limited time budget**
  - **→ restrict B reconstruction to RoI around μ or use reduced number of hits/track ($D_s\pi$)**

Trigger level	Total output rate (at start-up)	Output rate relevant for B physics
Level 1	50 kHz	14 kHz (1μ) 0.9 kHz (2μ)
HLT	100 Hz	~ 5 Hz of incl. b,c→μ+jet + O(1 Hz) for each excl. B mode

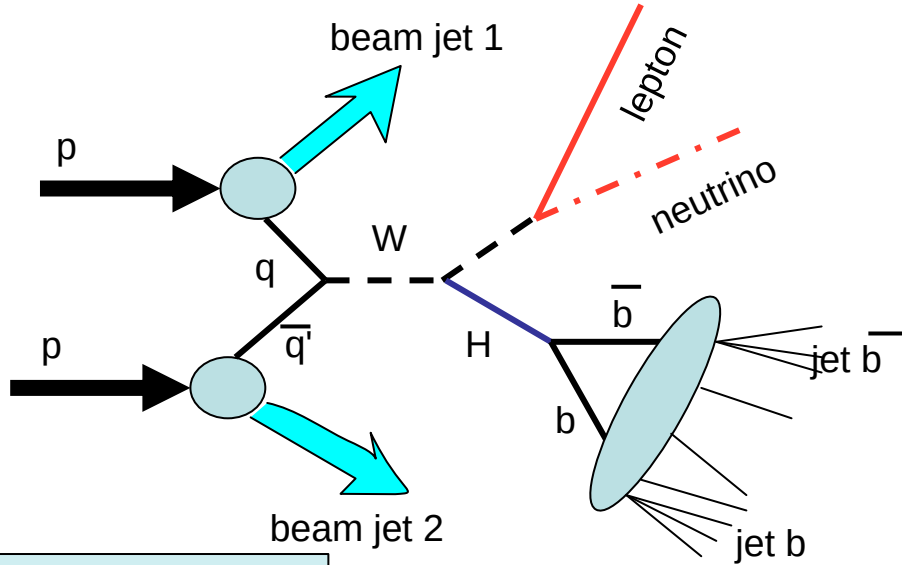
Slide from A. Schopper

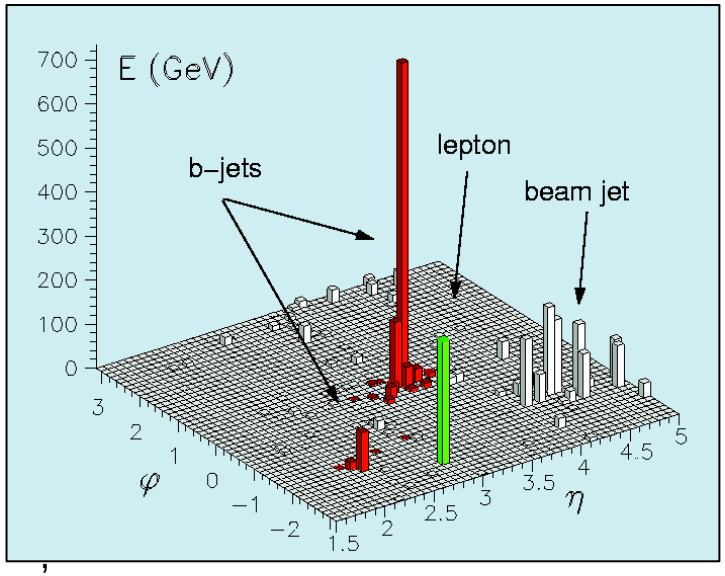
Final remarks

Excellent LHC experiments are very well prepared to observe first collisions in LHC this year and soon after to get
first physics results….

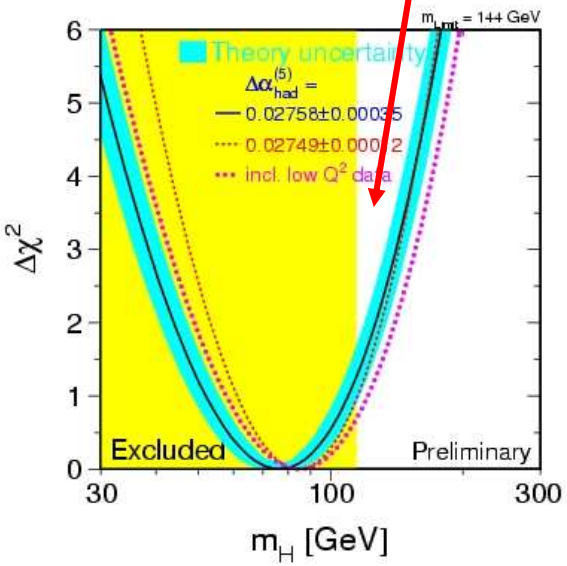
… to measure precisely angle γ, rare decays and … to get evidence for New Physics.

Bonus : light Higgs search (?)





LHCb
$H \rightarrow b\bar{b}$



Mesures indirectes

$m_H = 76^{+33}_{-24}$ GeV

Where from we get prediction for the Higgs mass?

Staszek Jadach and his group

Thank you…