Flavor Physics and CP Violation 2012

The LHCb upgrade

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on behalf of the LHCb collaboration

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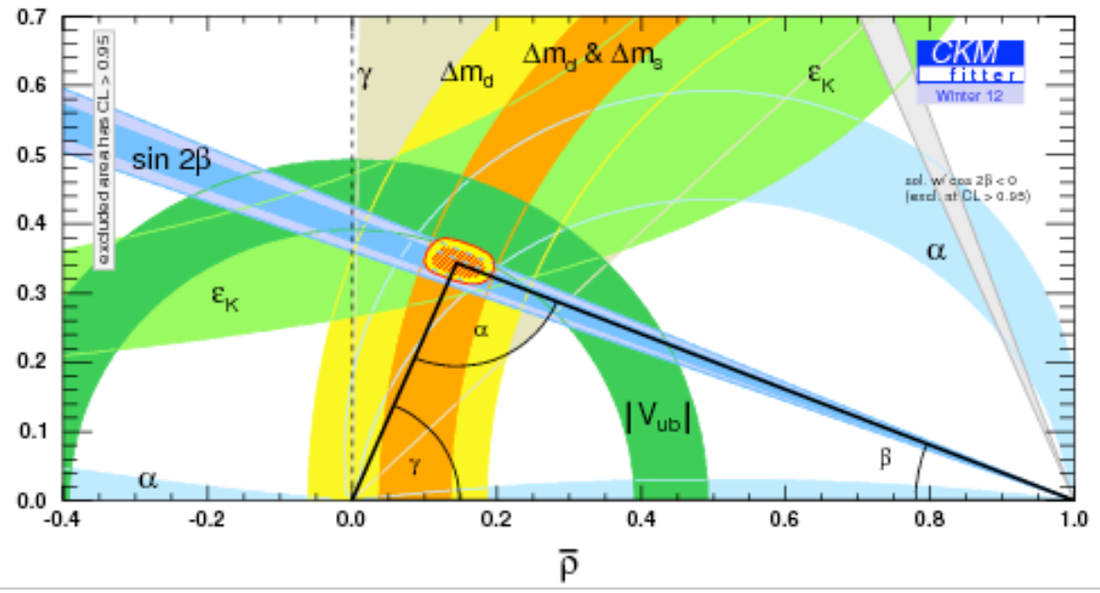
Outline

- *Introduction*
- *The LHCb detector*
- *The LHCb upgrade*
- *Conclusion*

Letter of intent for the LHCb upgrade, LHCC-I-018, 2011

CP violation measurements

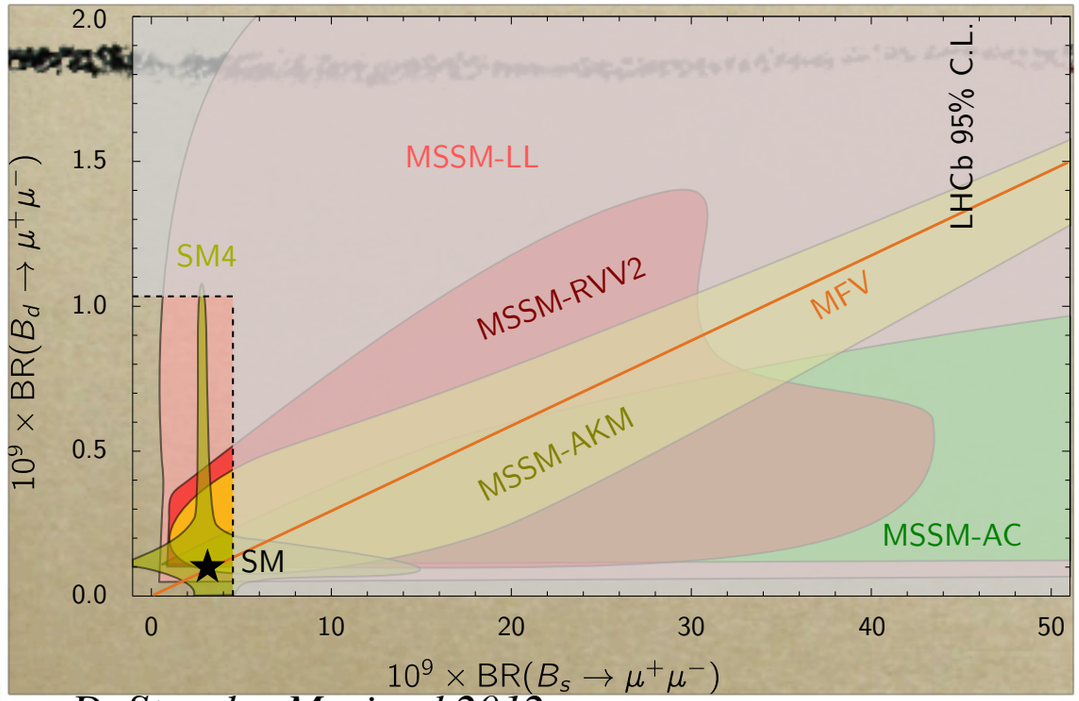
Moriond 2012



CKMfitter
$\overline{\rho} = 0.145 \pm 0.027$
$\overline{\eta} = 0.343 \pm 0.015$
$\alpha = (91.1 \pm 4.3)^\circ$
$\beta = (21.85^{+\ 0.80}_{-\ 0.77})^\circ$
$\gamma = (67.1 \pm 4.3)^\circ$

- *Flavour changing processes and CP violation are driven by CKM mechanism*

Highlight on hot measurements

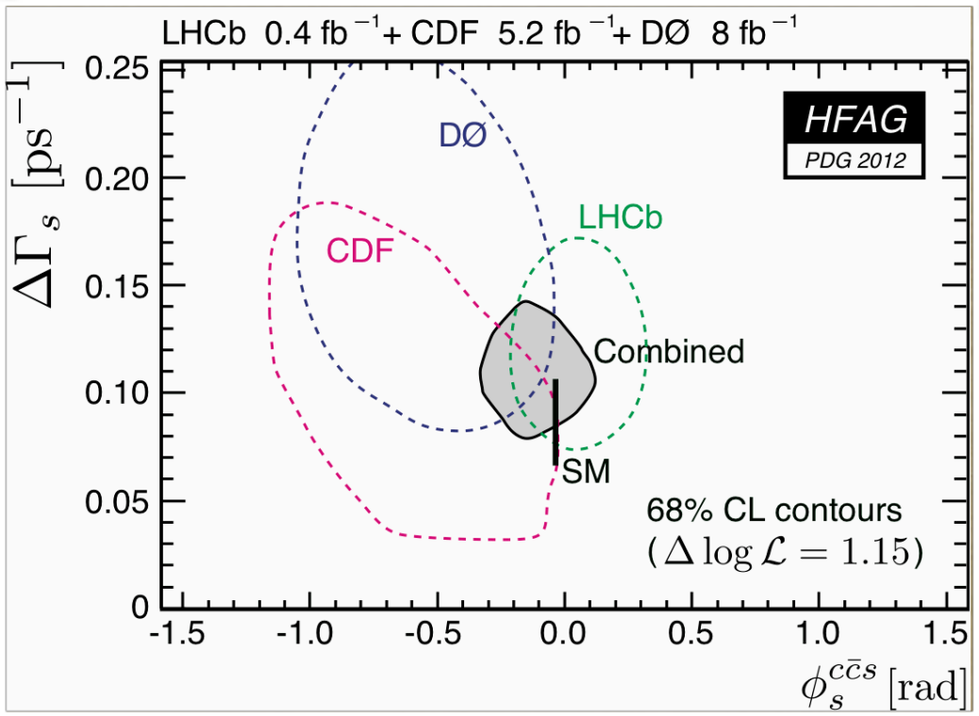


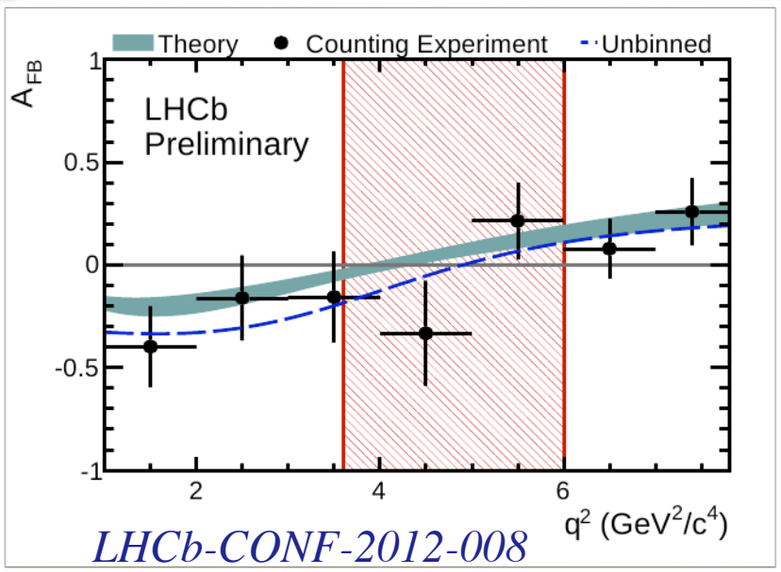
D. Straub - Moriond 2012

- *Branching fraction* $B_{d,s}$ ➜ μμ
- *CP violation phase in* B_s *mixing*
  $\Phi_s = -0.17 \pm 0.14 \pm 0.11$ *[HFAG]*
- A_{FB} *in* B ➜ K^*μμ

$$q_0^2 = (4.9\ ^{+1.1}_{-1.3})\,\mathrm{GeV}^2/c^2$$

SM like

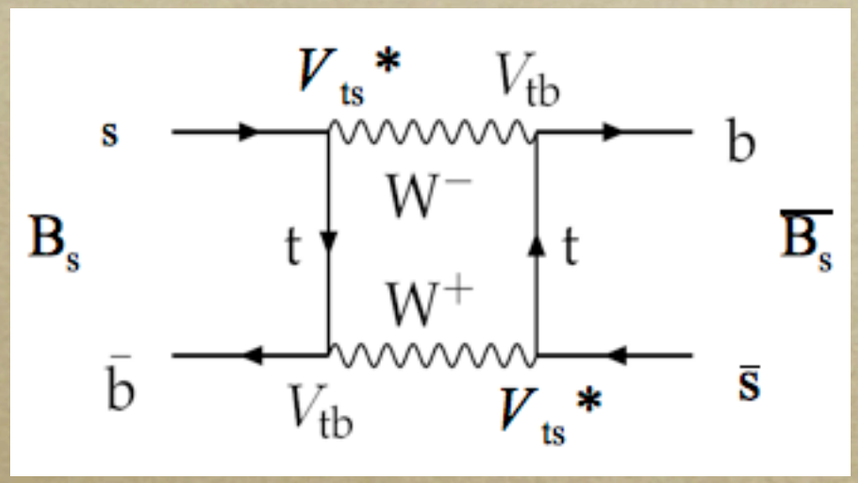


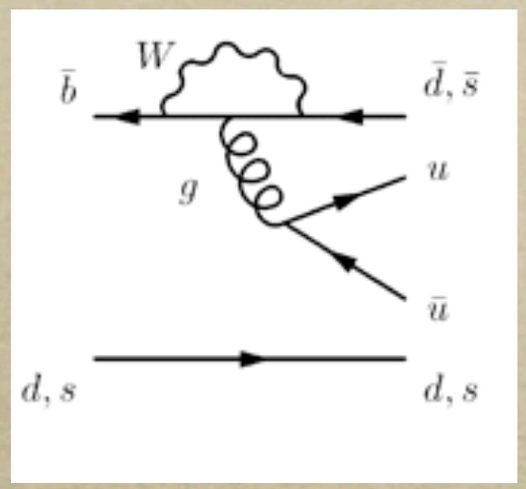


LHCb-CONF-2012-008

Indirect search for new physics

- *Flavour changing processes are mediated by box and penguin amplitudes*





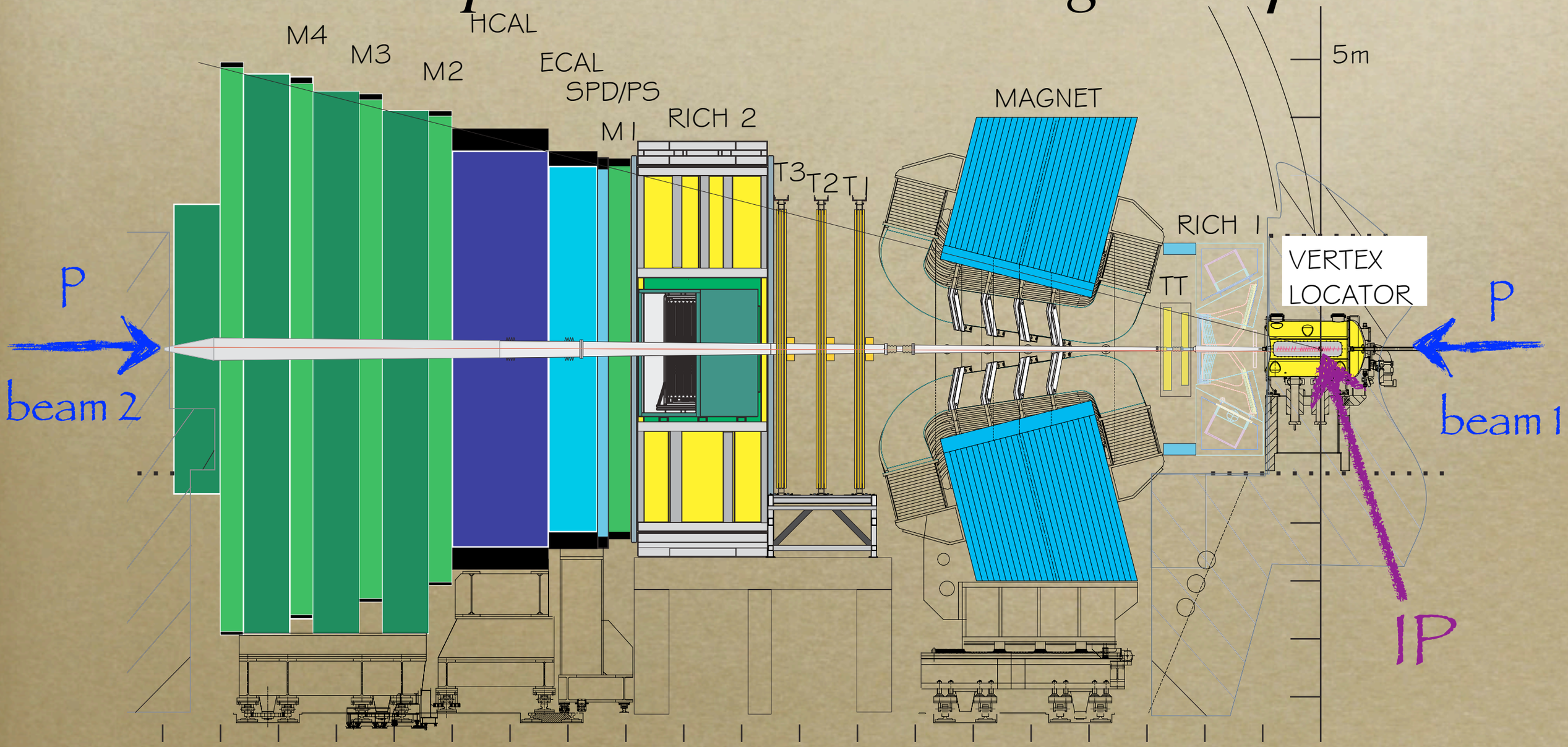
Sensitive to the coupling and the mass of the new particle

- *To probe new particles, measure observables*
  - *involving flavour changing processes suppressed or forbidden in the SM*
  - *well predicted in the SM*

and look for deviation with respect to expectation

The LHCb Detector

Forward spectrometer covering $2 < \eta < 5$

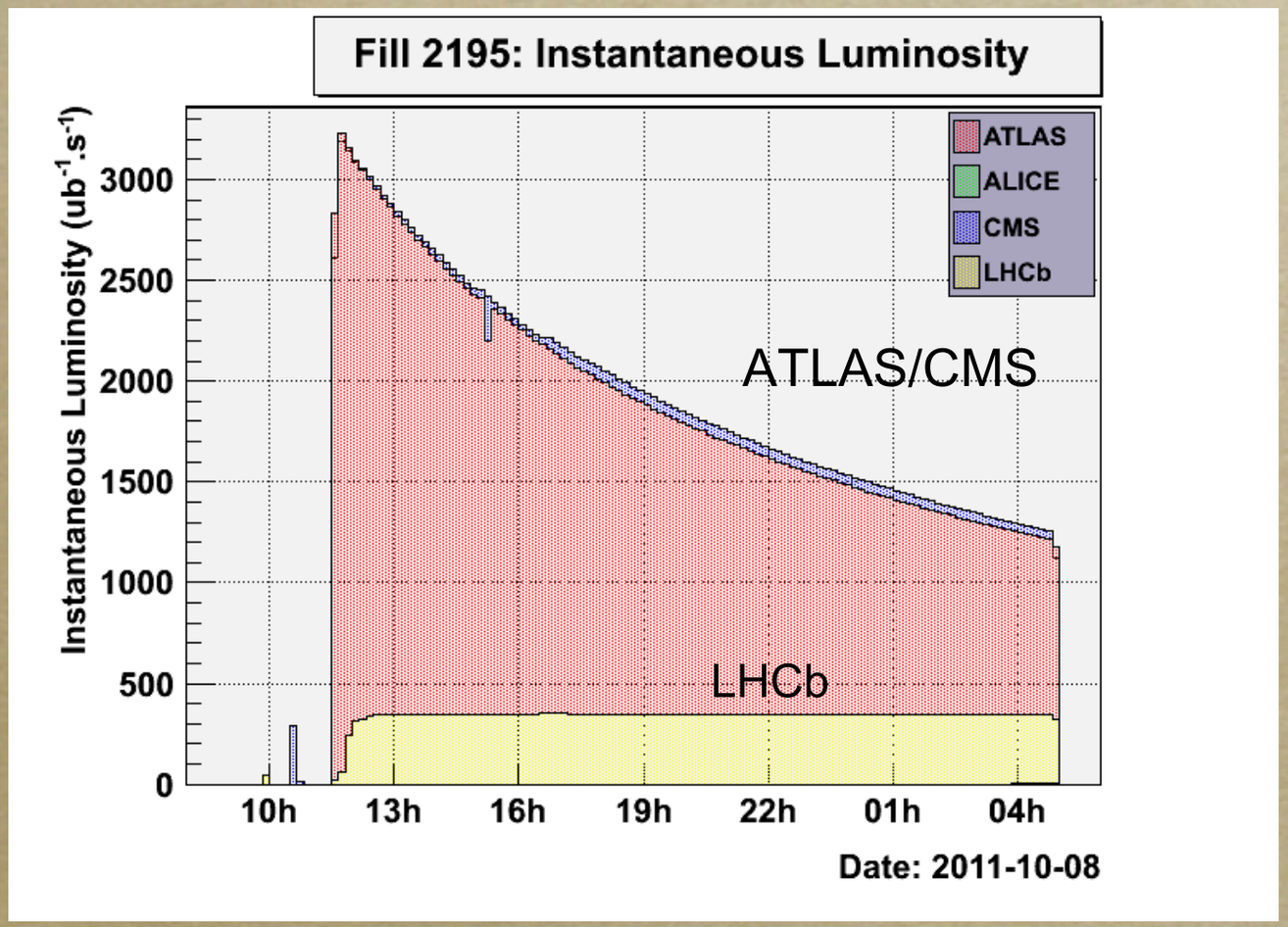


*More details: The LHCb detector at LHC, JINST **3** (2008) S08005*

LHCb operation conditions

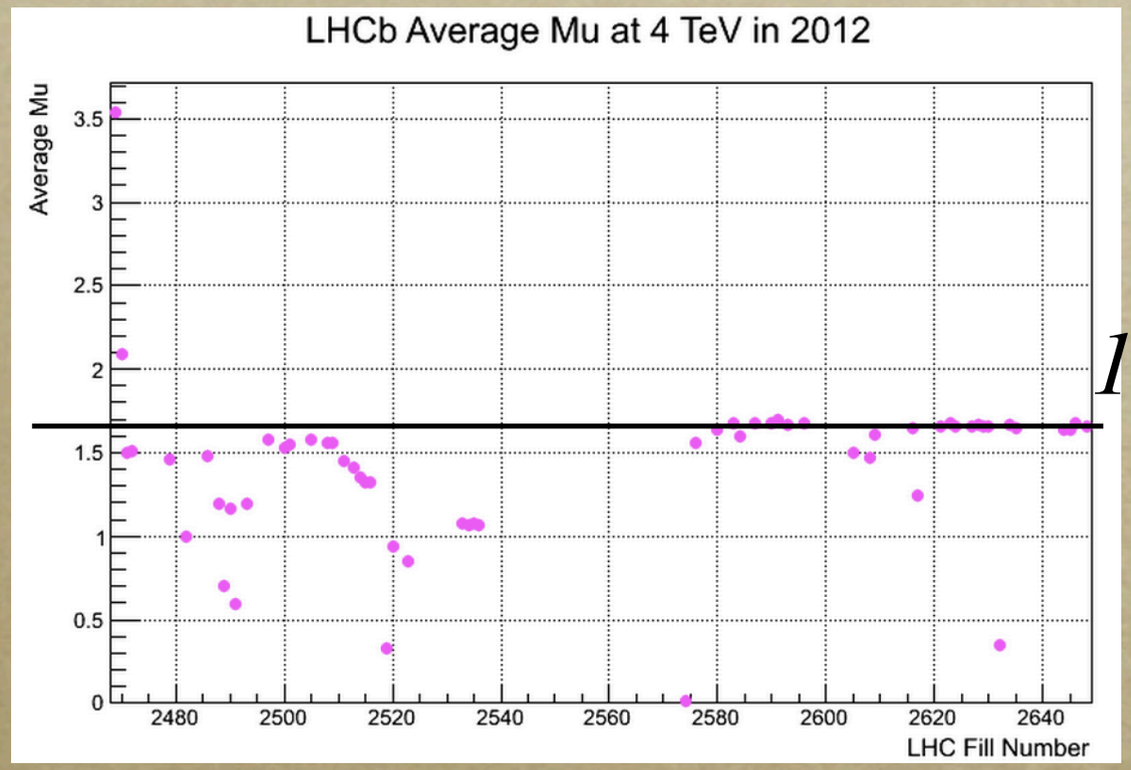
2011 *7 TeV*

- *Recorded luminosity 1.1 fb^{-1}* *[0.037 fb^{-1} in 2010]*
- *Constant luminosity of ~$3.5\times10^{32}cm^{-2}s^{-1}$* *[design 2×10^{32}]*
- *Interactions per beam crossing ~ 1.4* *[design 0.4]*

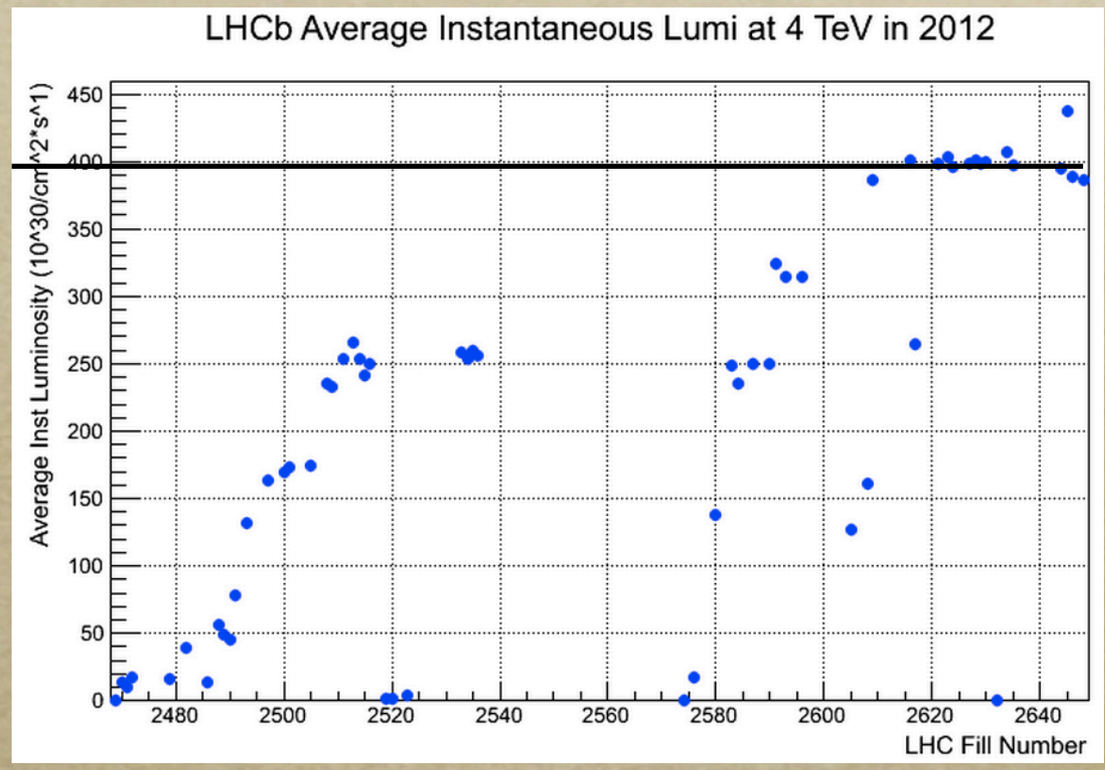


LHCb operation conditions

2012 *8 TeV*



1.6



4.0

- *Recorded luminosity 0.28 fb^{-1} (until May 24th)*
- *Intend to collect 1.5 fb^{-1} before 2013 shutdown*
- ***and to collect ~ 5 fb^{-1} before 2018 shutdown***

Golden observables for LHCb

- *Branching fraction* $B_{d,s} \rightarrow \mu\mu$
- *CP violation phase in* B_s *mixing*
- A_{FB} *in* $B \rightarrow K^*\mu\mu$
- *Angle* γ *in* $B_{(s)} \rightarrow D_{(s)} K$ *mediated by tree amplitude*
- *Photon polarisation in* $B_s \rightarrow \phi\gamma$
- *CP violation in charm*
- ...

Golden observables for LHCb

Observable	*State of art*	*Sensitivity @ 5 fb^{-1}*	*Theory uncertainty*
$BF(B_s \rightarrow \mu\mu)$		$\sim 10^{-9}$	0.2×10^{-9}
$BF(B^0 \rightarrow \mu\mu)/BF(B_s \rightarrow \mu\mu)$			~ 5%
CP violation phase ϕ_s	~ 0.1 rad	~ 0.02 rad	~ 0.002 rad
zero of $A_{FB}(q^2)$ $[B \rightarrow K^*\mu\mu]$	~ 1 GeV^2	~ 0.14 GeV^2	~ 0.05 GeV^2
Angle $\boldsymbol{\gamma}$ *(tree)*	~ 20°	~ 4°	*negligible*

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- *Sources of observed processes likely to have the SM patterns*
- *Need to increase sensibilities* → ***LHCb Upgrade***

LHCb upgrade: Targets

- *Reach experimental sensibilities comparable or better than theoretical uncertainties*
- *Increase the annual yield by a factor 5 for leptonic channels and by a factor 10 for hadronic ones*
- *Collect* ***50 fb^{-1}***
- *Enlarge core physics program*
  - *Leptons flavour physics [Majorana neutrino, LV in* τ *decays]*
  - *Electroweak physics [sin $2\theta_{eff}$, M_W]*
  - *Exotic search [hidden valleys ...]*
  - *QCD [central exclusive production]*

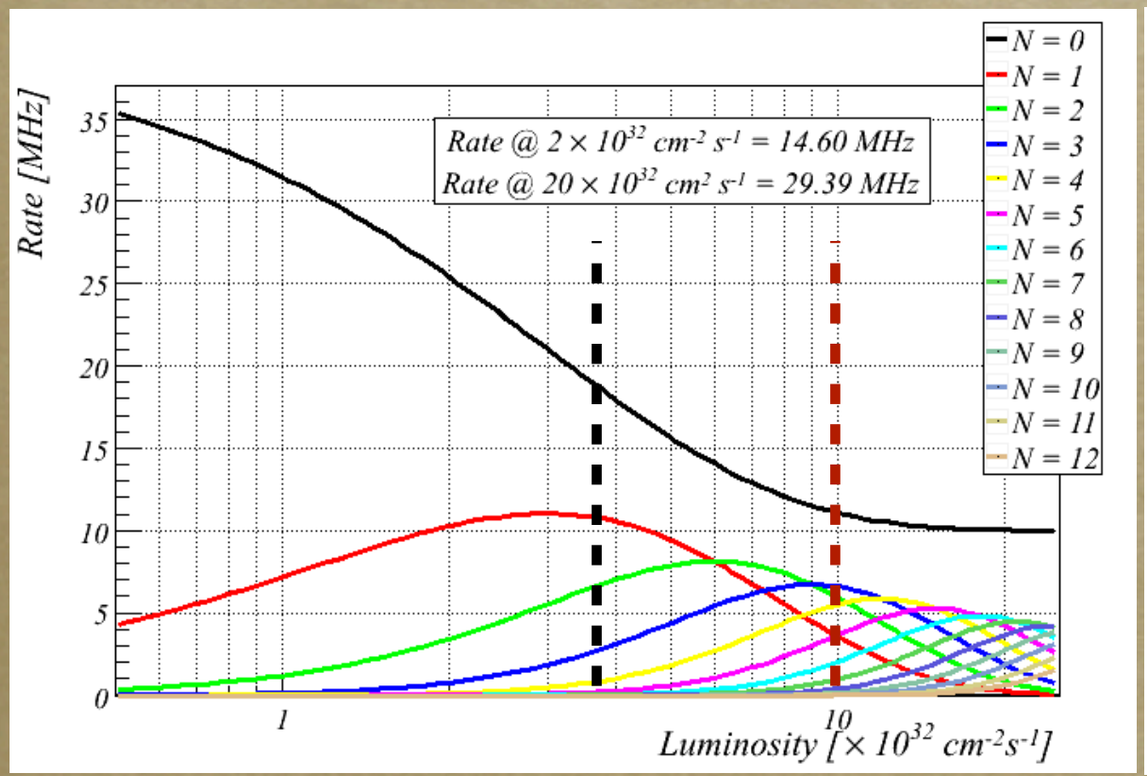
Running conditions

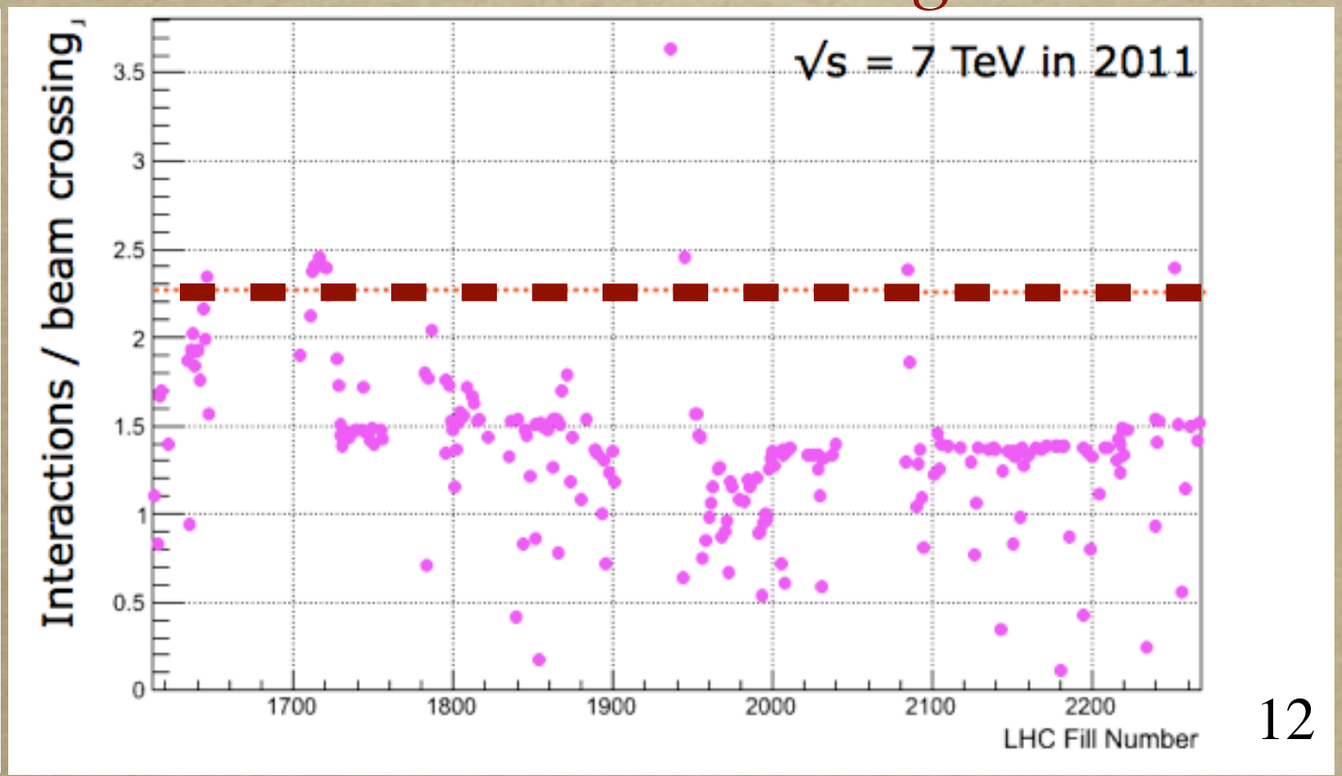
★ *Constant luminosity of ~ $10^{33}cm^{-2}s^{-1}$ with 25 ns bunch spacing*

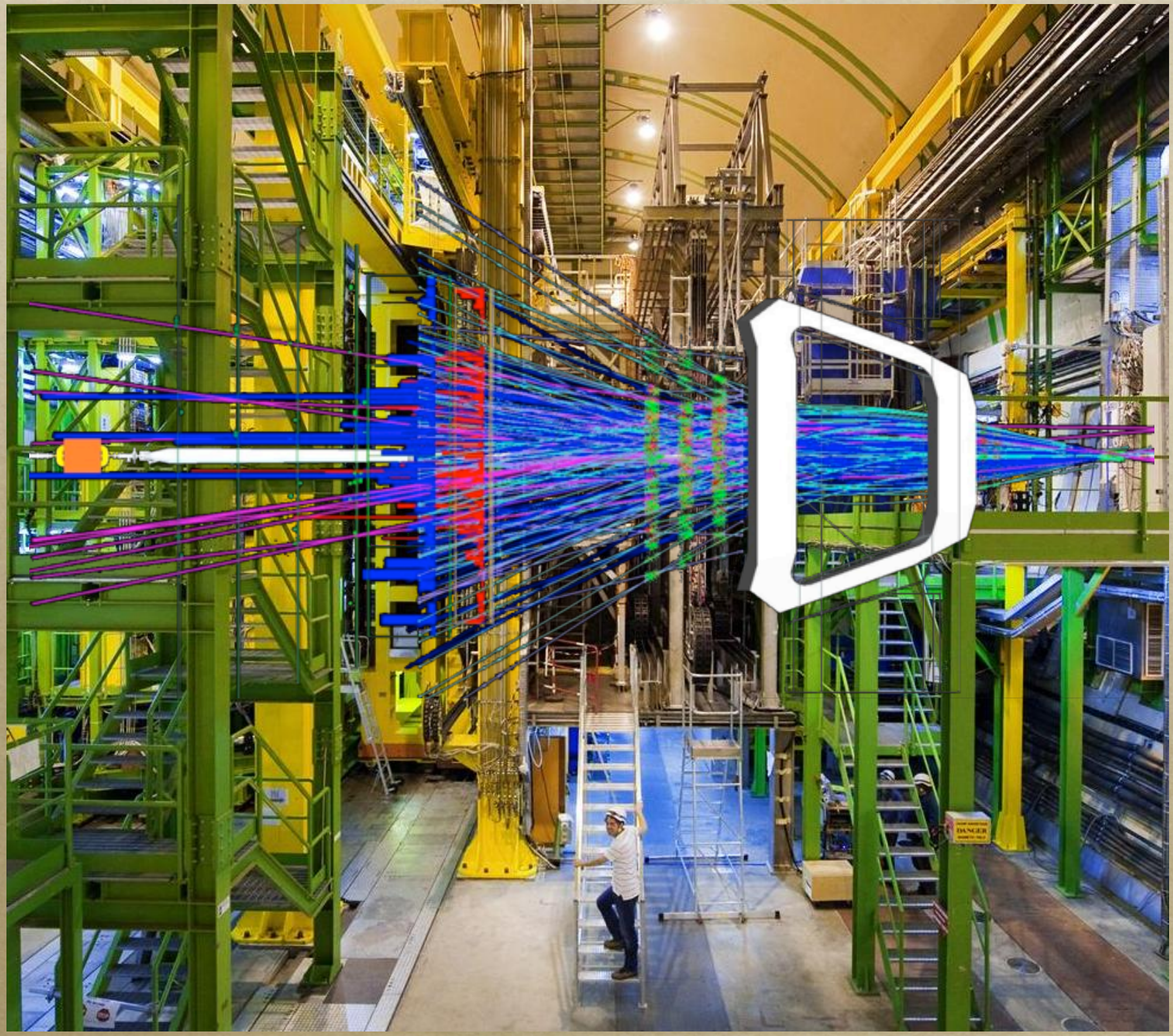
✶ *sub-systems should sustain peak luminosity of $2\times10^{33}cm^{-2}s^{-1}$*

★ *Interactions per beam crossing ~ 2.3*

Already tested during 2011






DANGER

Trigger: current strategy

40 MHz

Pileup
PS, SPD, ECAL, HCAL
Muon

Level 0
p_T *of* γ, $e^{\pm}$, $h^{\pm}$, $\mu^{\pm}$
custom electronics

1 MHz

All detector information

High Level Trigger
tracking and vertexing
inclusive/exclusive selections
CPU farm

4 kHz

Trigger: current strategy

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PS, SPD, ECAL, HCAL
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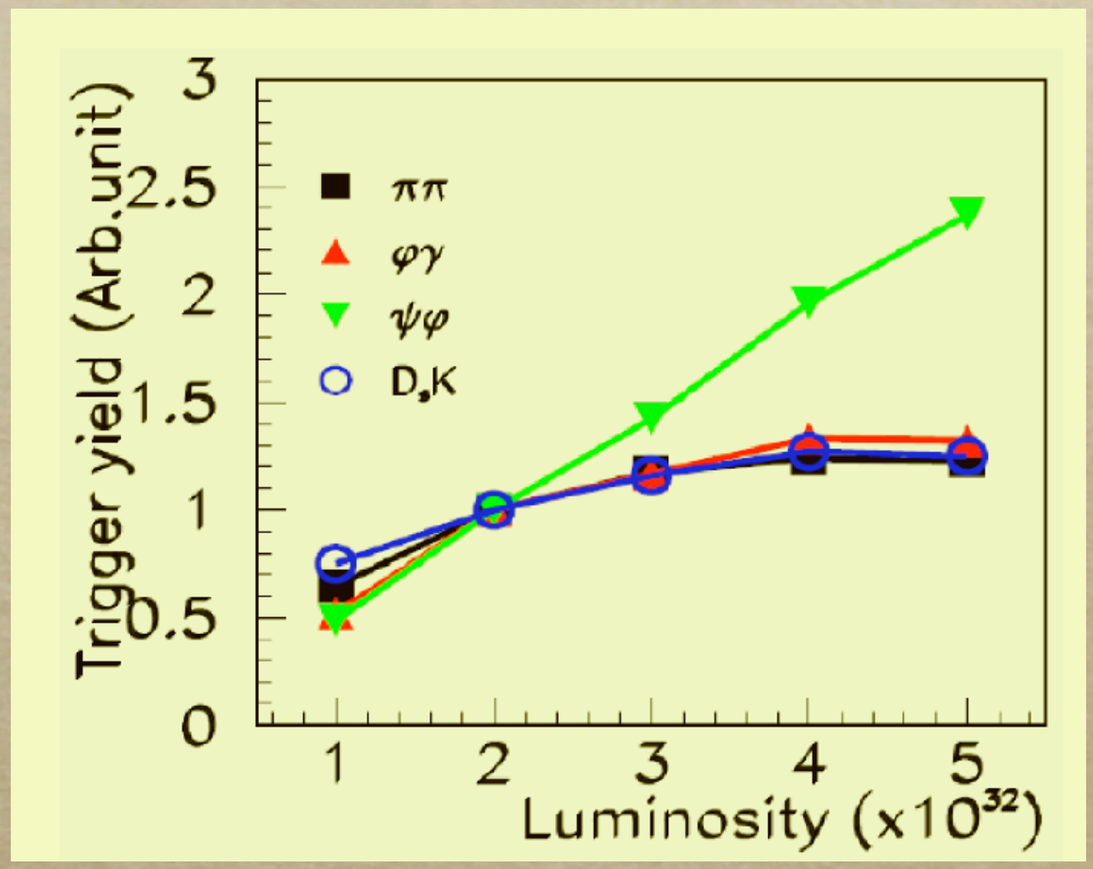

Saturates with increasing luminosity

Trigger: upgrade

40 MHz

ECAL, HCAL
Muon

Low Level Trigger
p_T of γ, $e^{\pm}$, $h^{\pm}$, $\mu^{\pm}$
custom electronics

1 - 40 MHz

All detector information

High Level Trigger
tracking and vertexing
inclusive/exclusive selections
CPU farm

20 kHz

LLT efficiencies

LLT rate (MHz)	*1*	*5*	*10*
$B_s \to \phi\phi$	*0.12*	*0.51*	*0.82*
$B^0 \to K^*\mu\mu$	*0.36*	*0.89*	*0.97*
$B_s \to \phi\gamma$	*0.39*	*0.92*	*1.00*

Trigger: upgrade

40 MHz

ECAL, HCAL
Muon

Low Level Trigger
p_T *of* γ, $e^{\pm}$, $h^{\pm}$, $\mu^{\pm}$
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All detector information

High Level Trigger
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A challenge to read out
LHCb at ***40 MHz***

Tracking

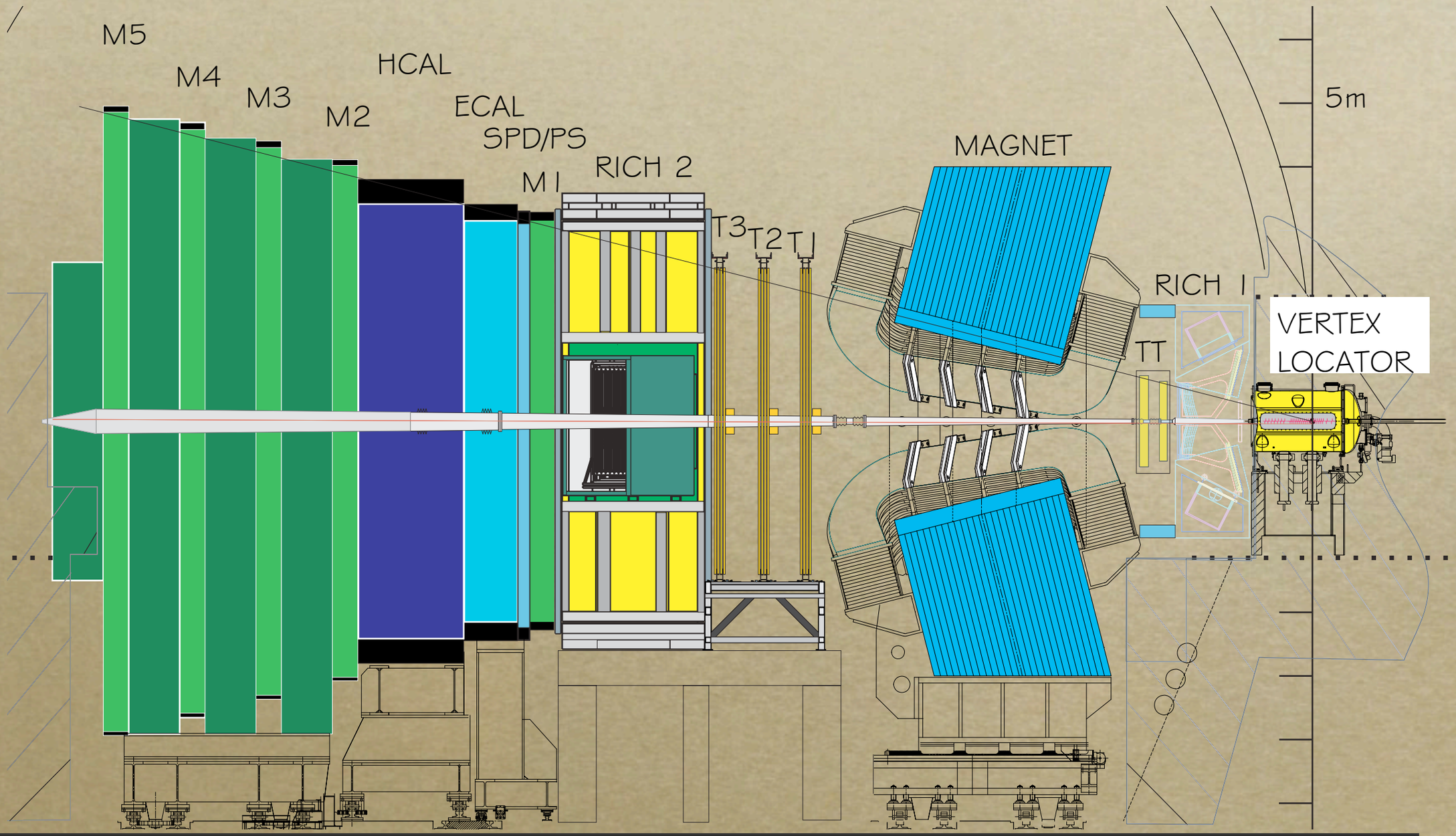
At high luminosity, increase of

- *number of primary vertices*
- *track multiplicity*
- *detectors occupancy*
- *number of ghost tracks*
- *bunch-to-bunch spillover*

Challenge to keep

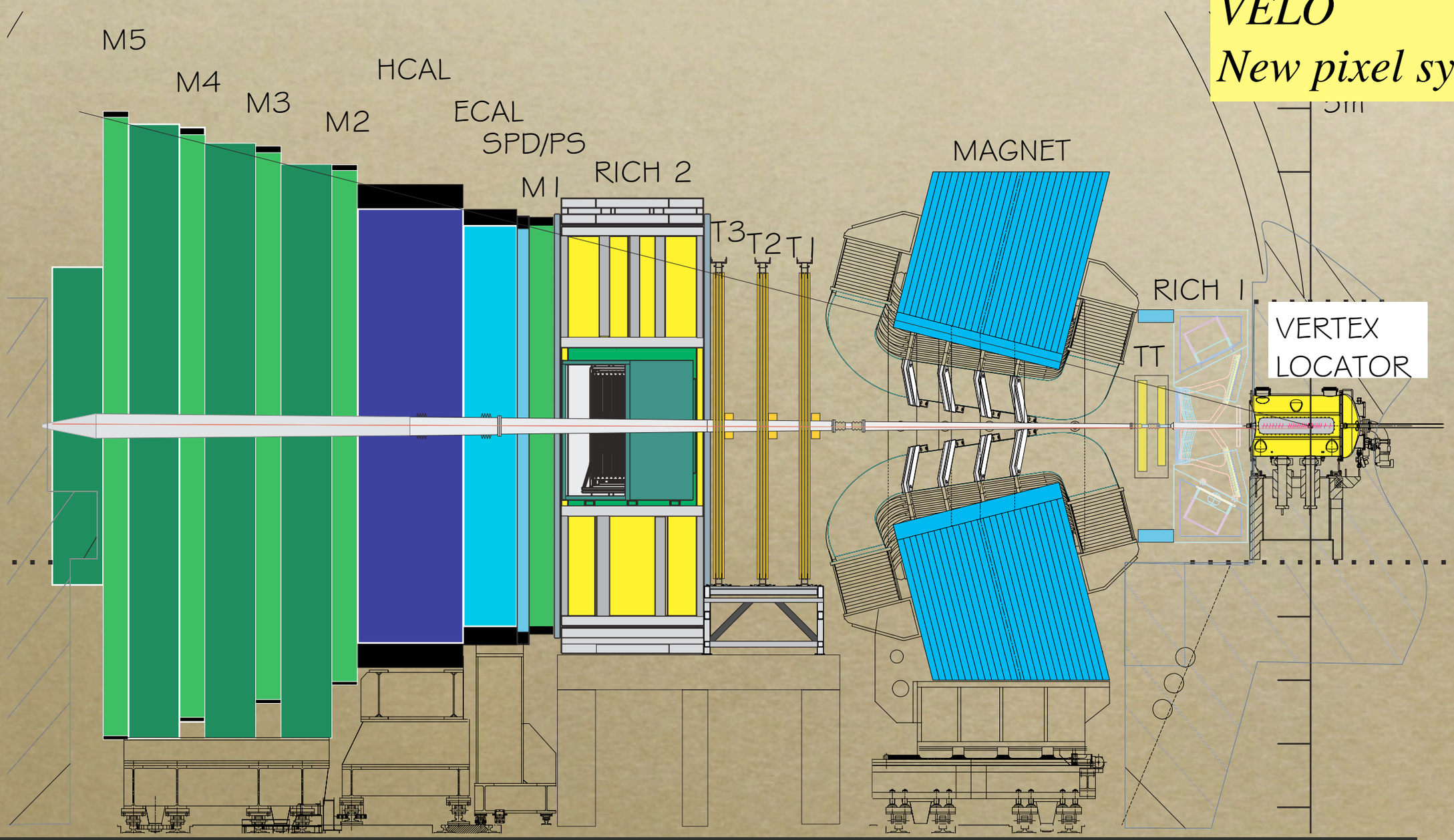
- *momentum resolution* $[\sigma(p)/p \sim 4\times10^{-3}]$
- *high efficiency* $[\sim 90\%$ *if* $p \geq 5$ *GeV]*
- *low ghost rate* $[\sim 10\%]$
- *low processing time* $[25$ *ms]*
- *low material budget*

Detector modifications



Replace all the front-end electronics and DAQ network

Detector modifications



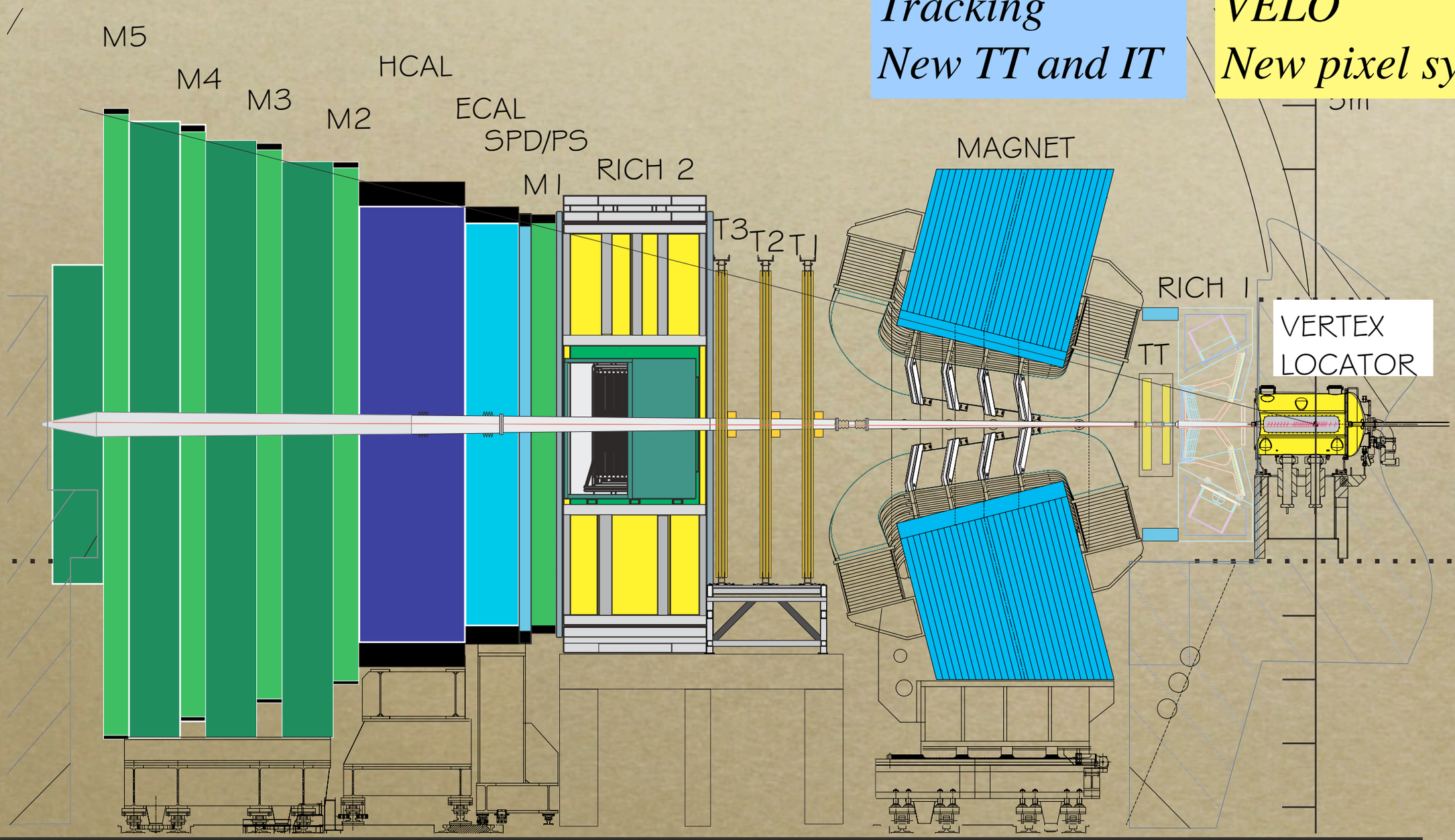
VELO
New pixel system

Replace all the front-end electronics and DAQ network

Detector modifications

Tracking
New TT and IT

VELO
New pixel system



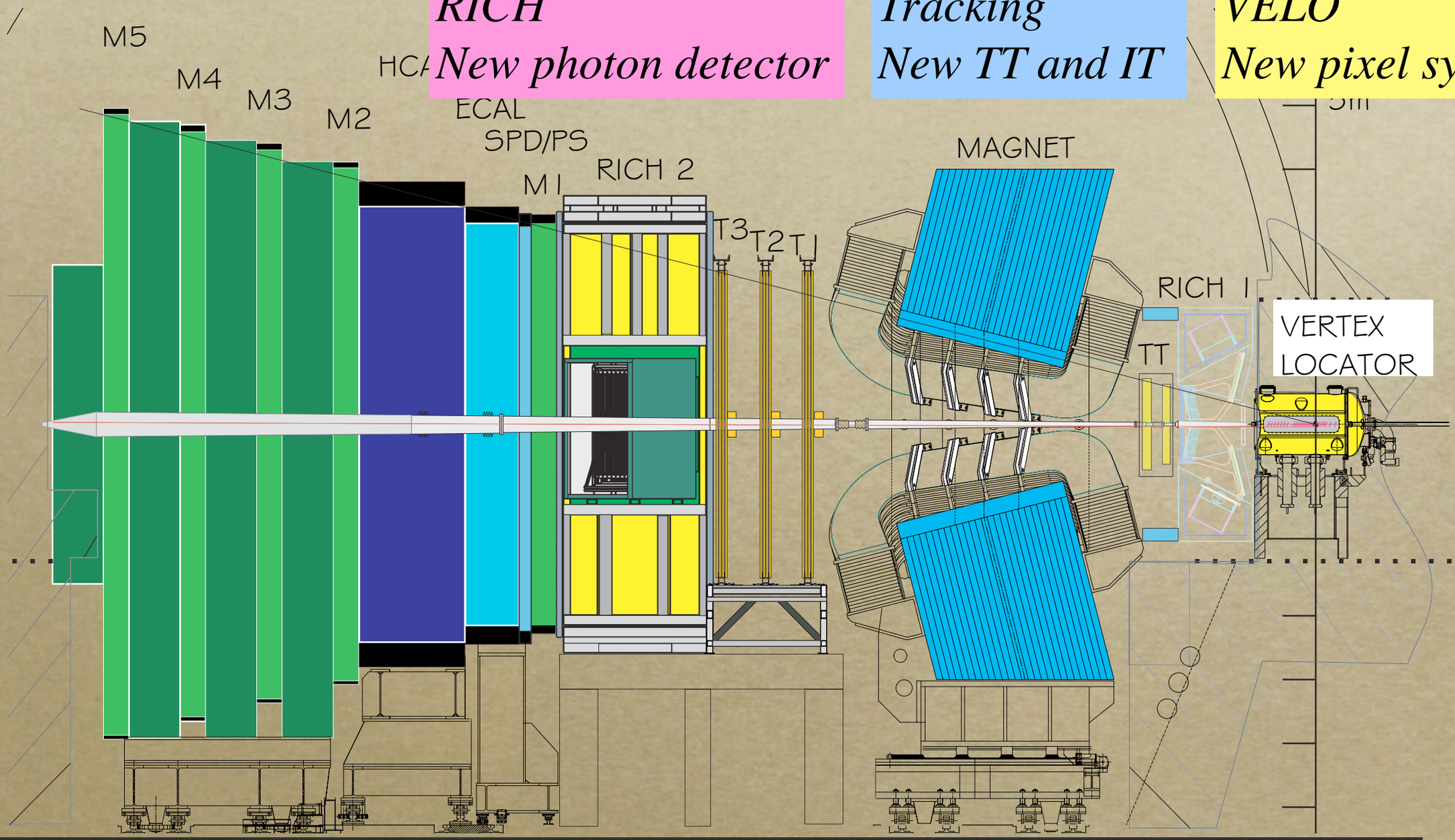
Replace all the front-end electronics and DAQ network

Detector modifications

RICH
New photon detector

Tracking
New TT and IT

VELO
New pixel system



Replace all the front-end electronics and DAQ network

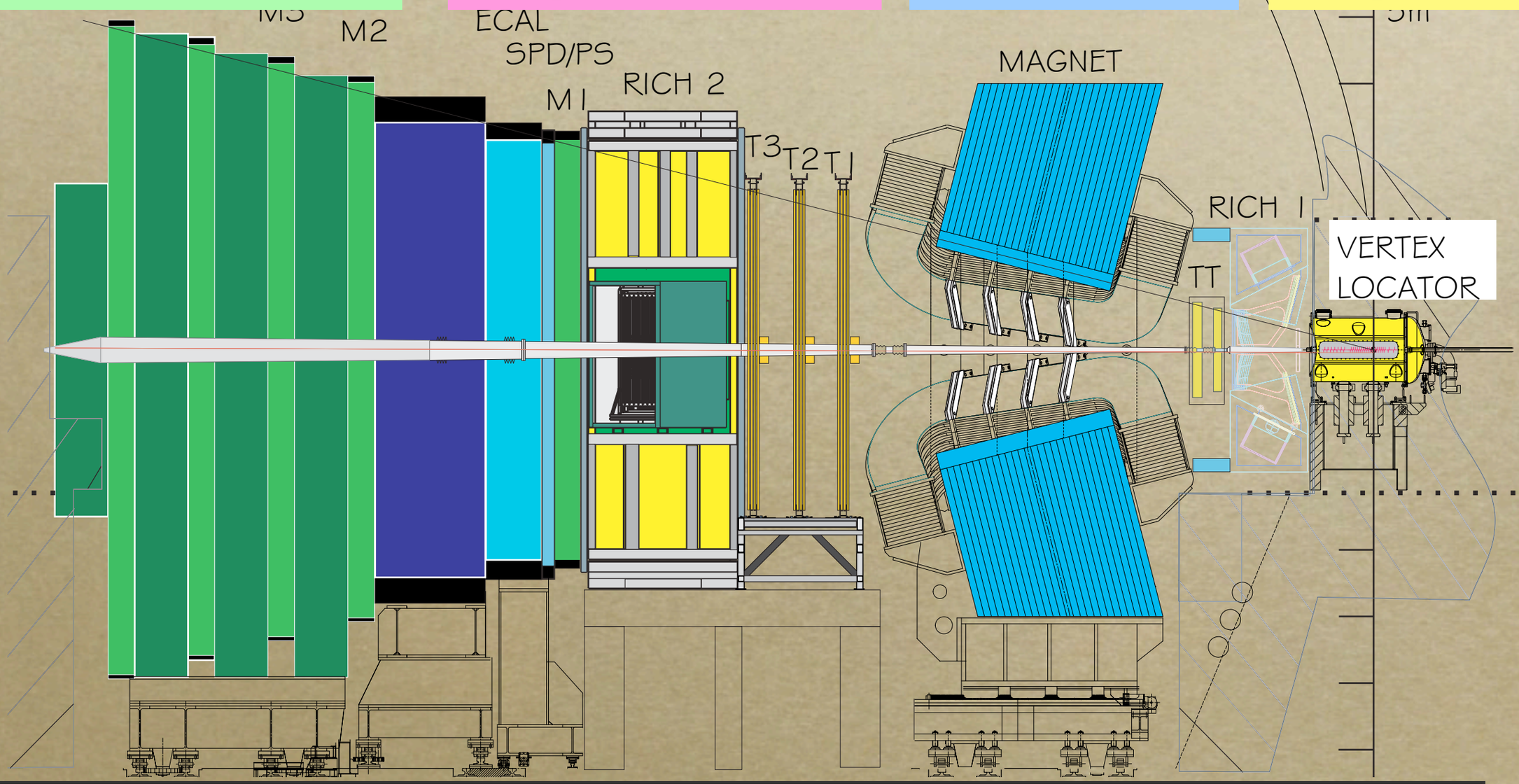
Detector modifications

CALO + Muon
Remove SPD+PS+M1

RICH
New photon detector

Tracking
New TT and IT

VELO
New pixel system

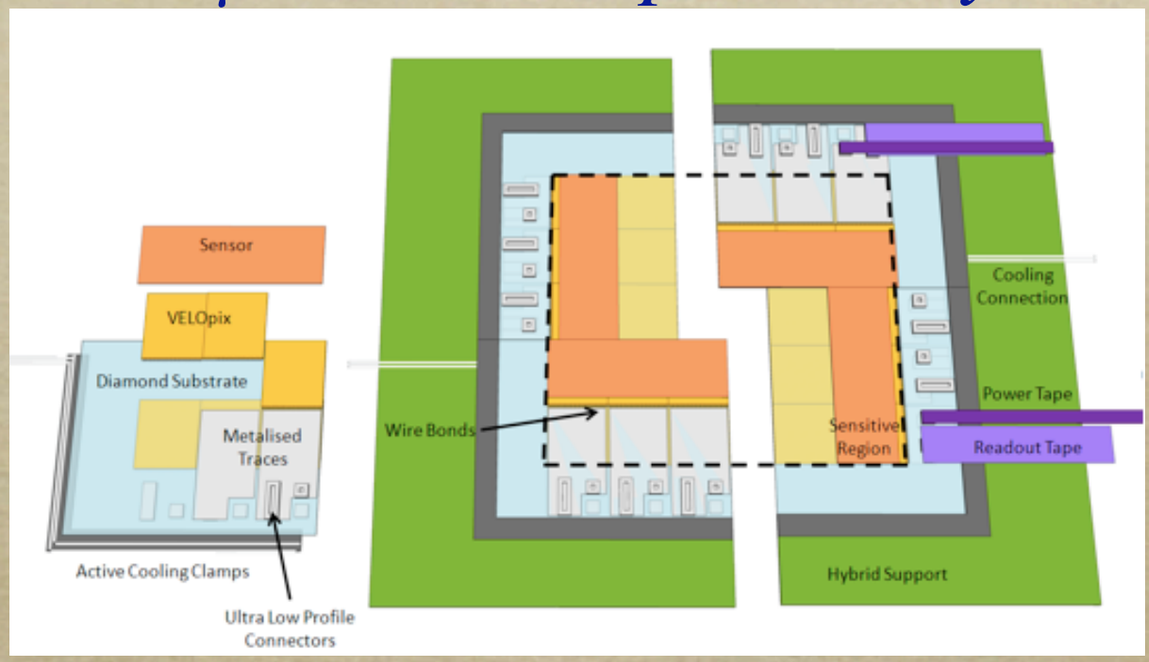


Replace all the front-end electronics and DAQ network

VELO upgrade

Strip detector (r,φ) with a pitch 35-100 μm to be replaced by

- *Pixel detector*
  - *low occupancy channels*
  - *reduce combinatorial for tracking*
  - *very high data rate ≥ 12 Gbit*
- *VELOPix ASIC based on TimePix/Medipix chip*
  - *256×256 pixels*
  - *square pixel 50×50 μm²*
- *Alternative option based on strips*



Tracker upgrade

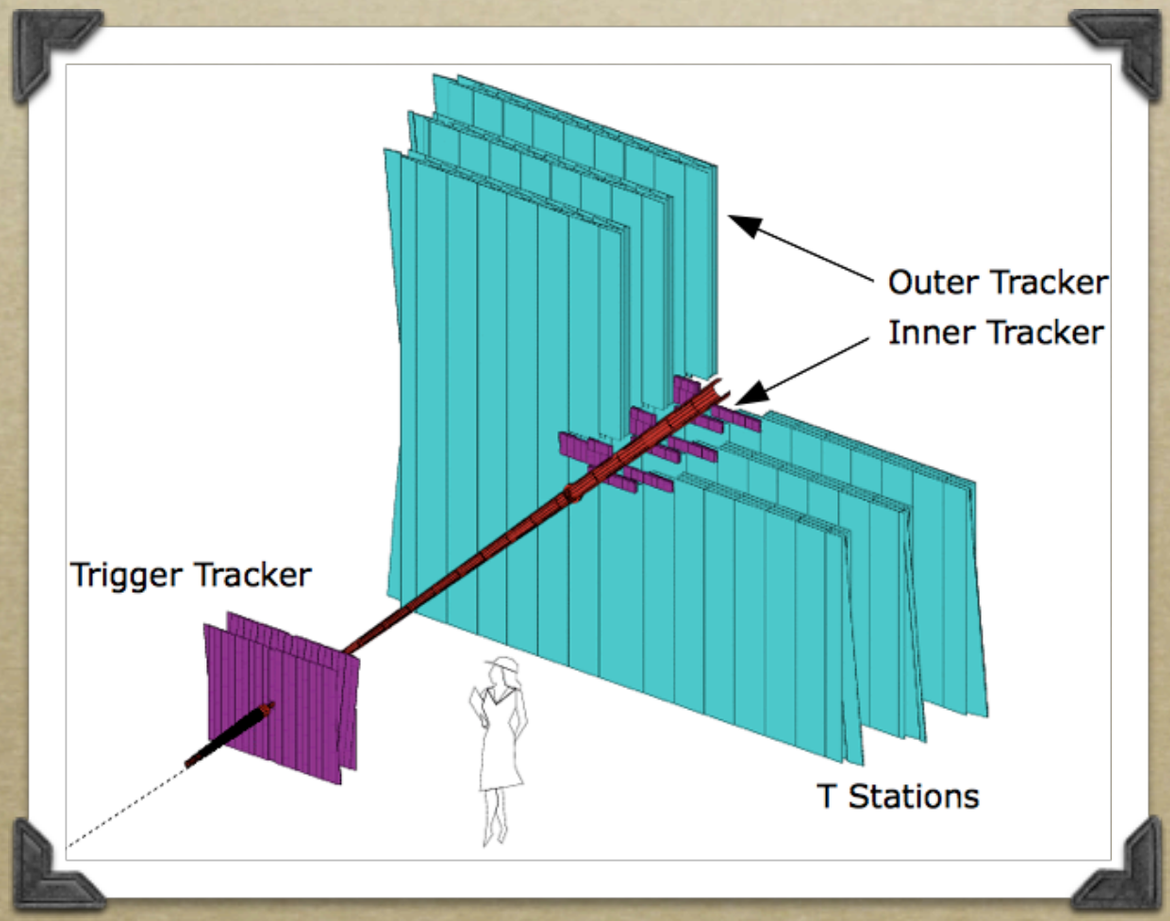
Micro-strips silicon *and* ***gaseous*** *detectors. To be replaced by*

- *TT*

micro-strips silicon detector with greather η acceptance and finer granularity along the read out strips (vertical direction).

or

scintillating fibre + SiPM

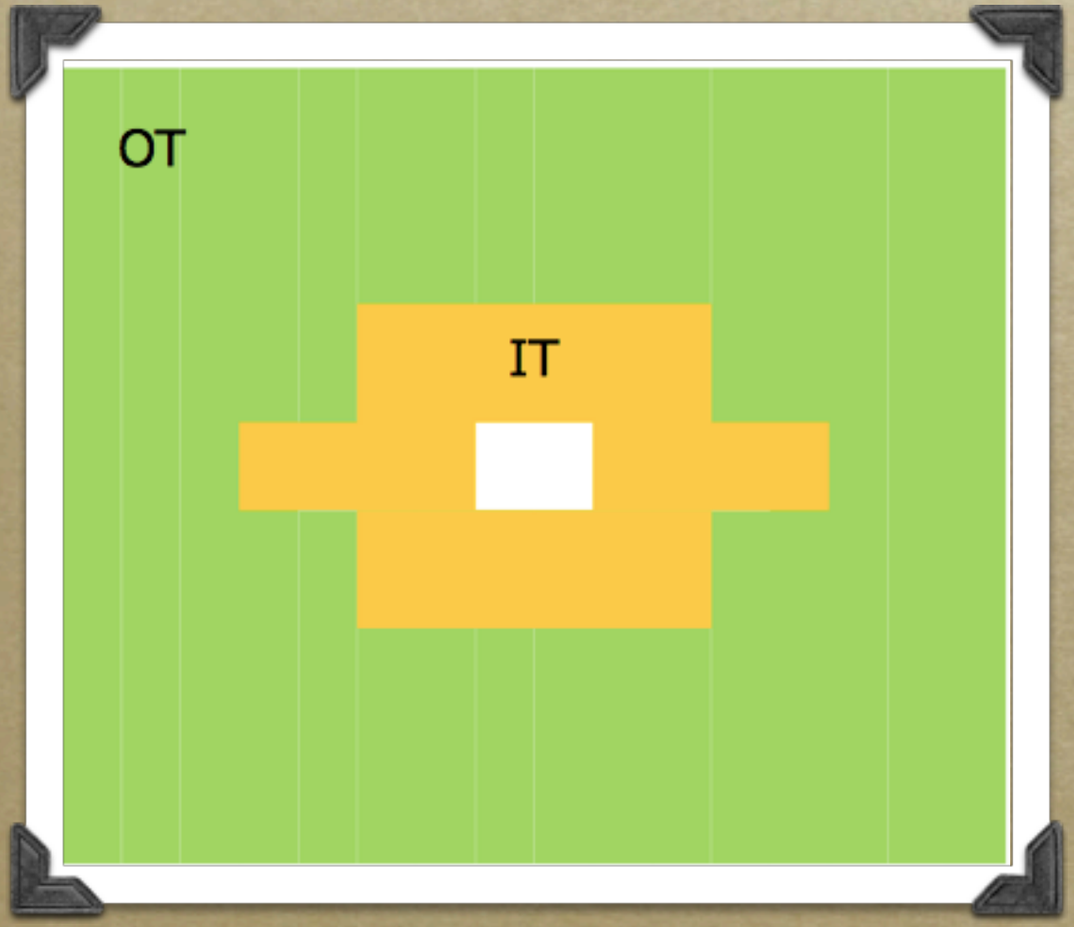


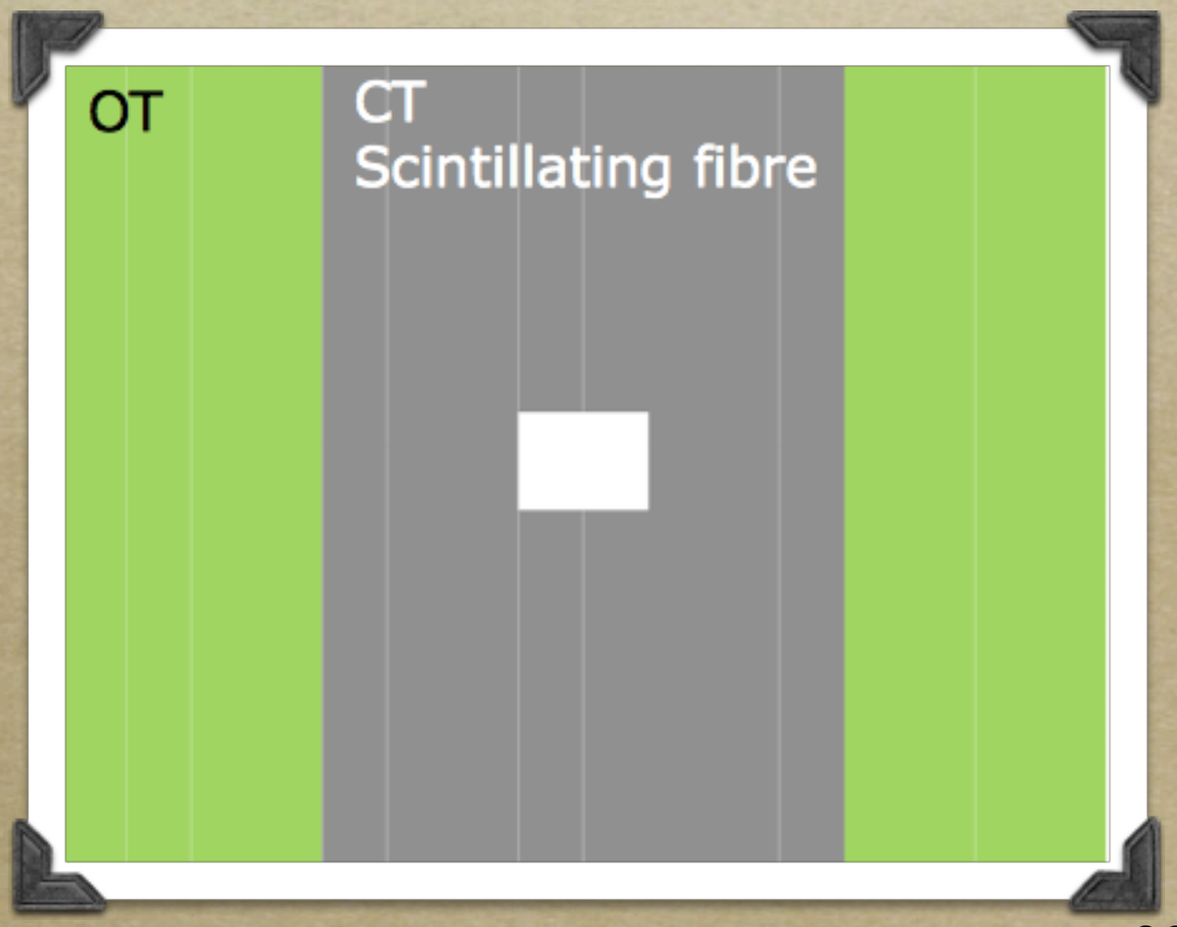
Tracker upgrade

- *T stations*

Light and larger IT *or* *Central Tracker*

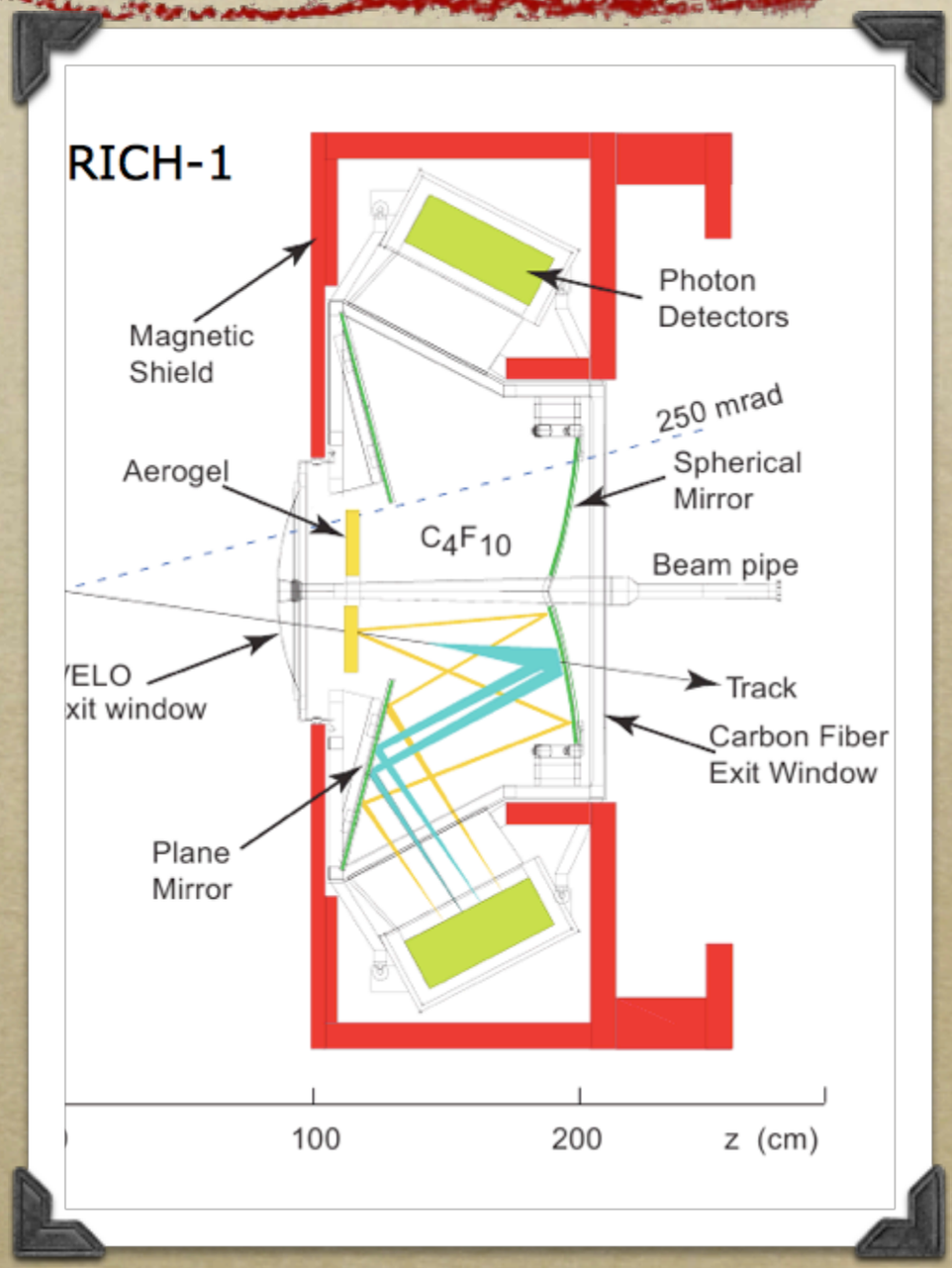
fibres + SiPM





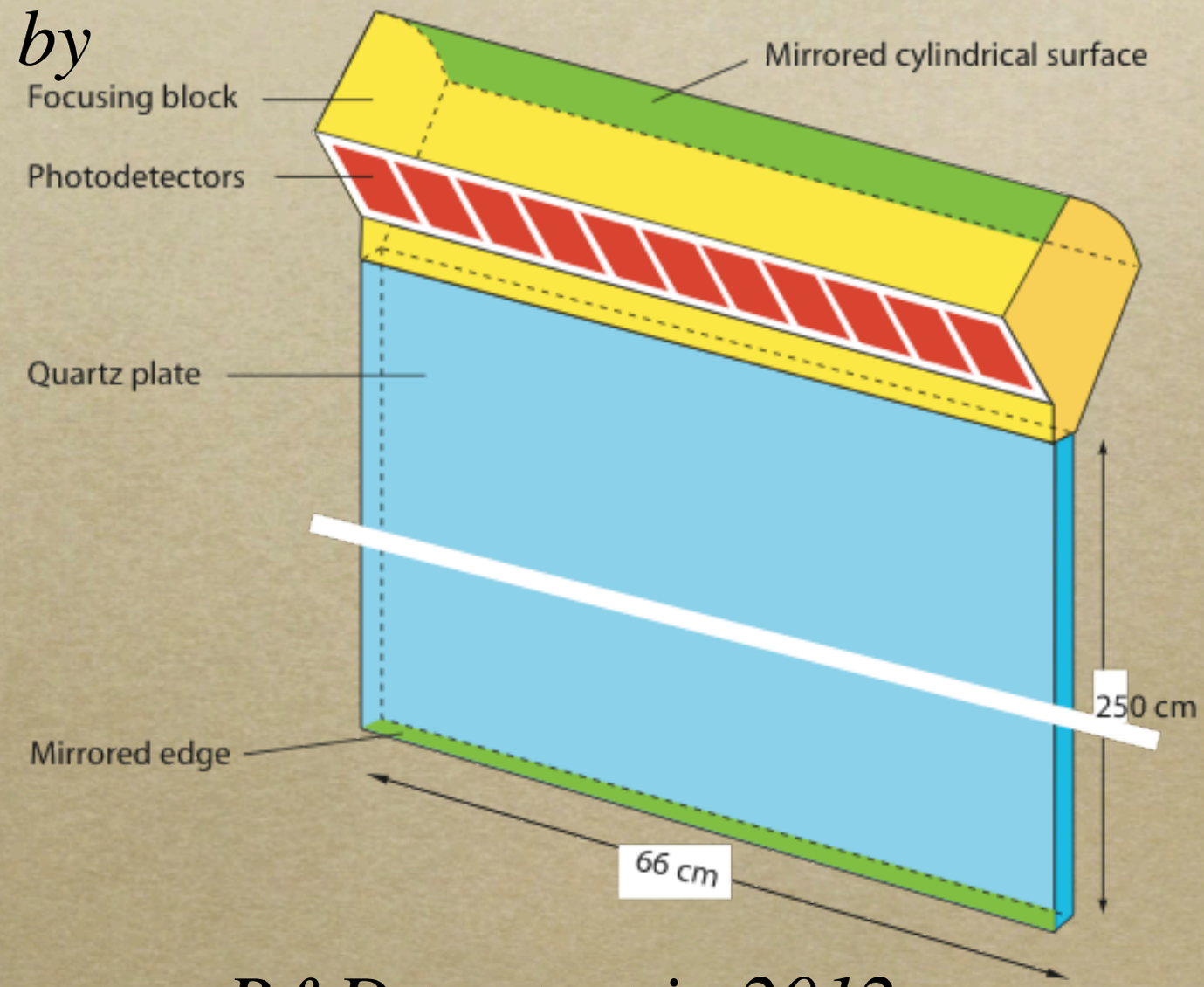
RICH upgrade

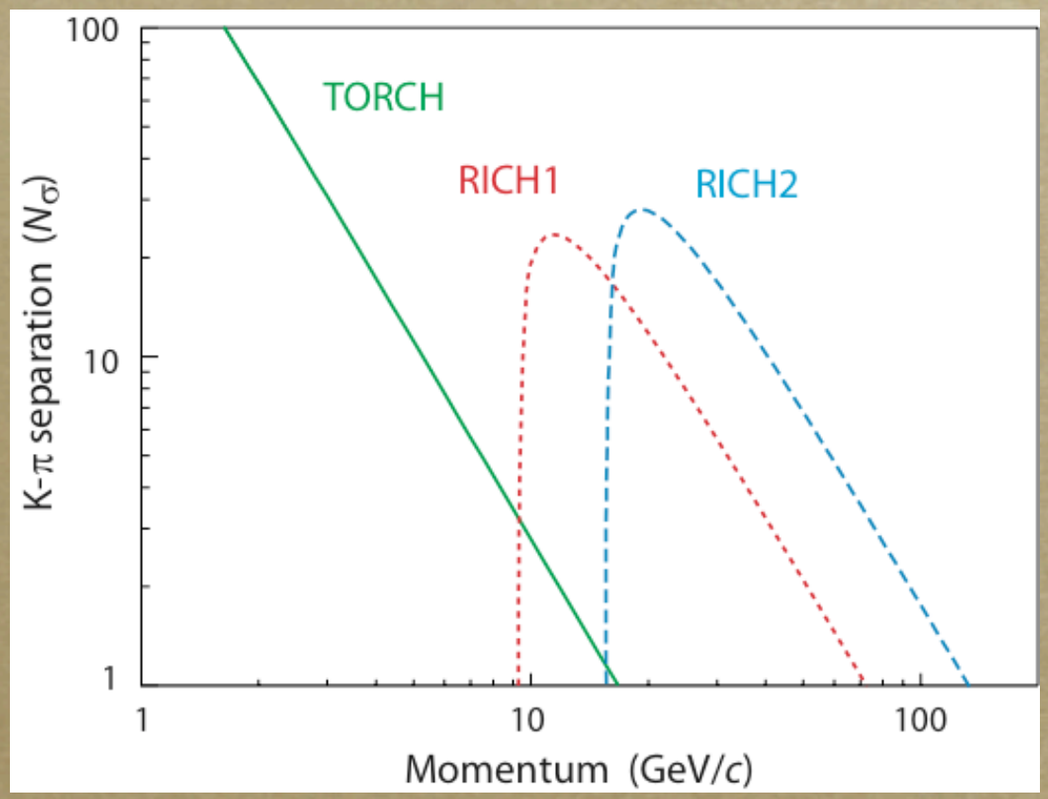
- *RICH1 and RICH2 - replace HPD by MaPMT and readout by a 40 MHz chip*
- *RICH1 - remove aerogel*



RICH upgrade

- *Proposal - replace aerogel by a time-of-flight detector TORCH (Time Of internally Reflected CHerencov light)*





R&D to start in 2012

LHCb upgrade physics program

Type	*Observable*	*Current precision*	*Sensitivity @ 5 fb^{-1}*	*Sensitivity @ 50 fb^{-1}*	*Theory uncertainty*
Gluonic penguin	$S(B_s \to \Phi\,\Phi)$	-	*0.08*	*0.02*	*0.02*
	$S(B_s \to K^{*0}\,\bar{K}^{*0})$	-	*0.07*	*0.02*	*< 0.02*
	$S(B_s \to \Phi\,K^0)$	*0.17*	*0.15*	*0.03*	*0.02*
B_s mixing	$2\beta_s\,(B_s \to J/\psi\Phi)$	*0.35*	*0.019*	*0.006*	*~ 0.003*
Right-handed currents	$S(B_s \to \Phi\,\gamma)$	-	*0.07*	*0.02*	*< 0.01*
	$A^{\Delta\Gamma s}(B_s \to \Phi\,\gamma)$	-	*0.14*	*0.03*	*0.02*
EW penguin	$A_T^{(2)}\,(B \to K^{*0}\mu\mu)$	-	*0.14*	*0.04*	*0.05*
	$s_0\,A_{FB}(B \to K^{*0}\mu\mu)$	-	*4%*	*1%*	*7%*
Higgs penguin	$BF(B_s \to \mu\mu)$	-	*30%*	*8%*	*< 10%*
	$BF(B^0 \to \mu\mu)/BF(B_s \to \mu\mu)$	-	-	*~ 35%*	*~ 5%*
Unitarity triangle angles	$\gamma\,(B \to D^{(*)}K^{(*)})$	*~ 20°*	*~ 4°*	*0.9°*	*negligible*
	$\gamma\,(B_s \to D_s K)$	-	*~ 7°*	*1.5°*	*negligible*
	$\beta\,(B^0 \to J/\psi K^0)$	*1°*	*0.5°*	*0.2°*	*negligible*
Charm CPV	A_Γ	*2.5×10^{-3}*	*2×10^{-4}*	*4×10^{-5}*	-
	$A_{CP}^{dir}(KK) - A_{CP}^{dir}(\pi\pi)$	*4.3×10^{-3}*	*4×10^{-4}*	*8×10^{-5}*	-

LHCb time line

- *Letter of intend submitted in March 2011*
  - *Physics case fully endorsed by LHCC*
  - *40 MHz readout reviewed (challenging but feasible)*
- *Framework TDR to be submitted in June 2012*
  - *cost, milestones and institutes' scientific interest*
- *TRD(s) in 2013*
- *Production and quality control in 2014-2017*
- *Installation and commissioning in 2018*

Conclusions

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- *LHCb(2012) ~ 1.5 fb^{-1} @ 8 TeV and $4\times10^{32}cm^{-2}s^{-1}$*
- *LHCb(2017) ~ 5 fb^{-1} of recorded data*
- *LHCb upgrade has an exciting physics program*

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- *LHCb(2017) ~ 5 fb^{-1} of recorded data*
- *LHCb upgrade has an exciting physics program*
- *It is good opportunity to join the LHCb collaboration!*

谢谢！