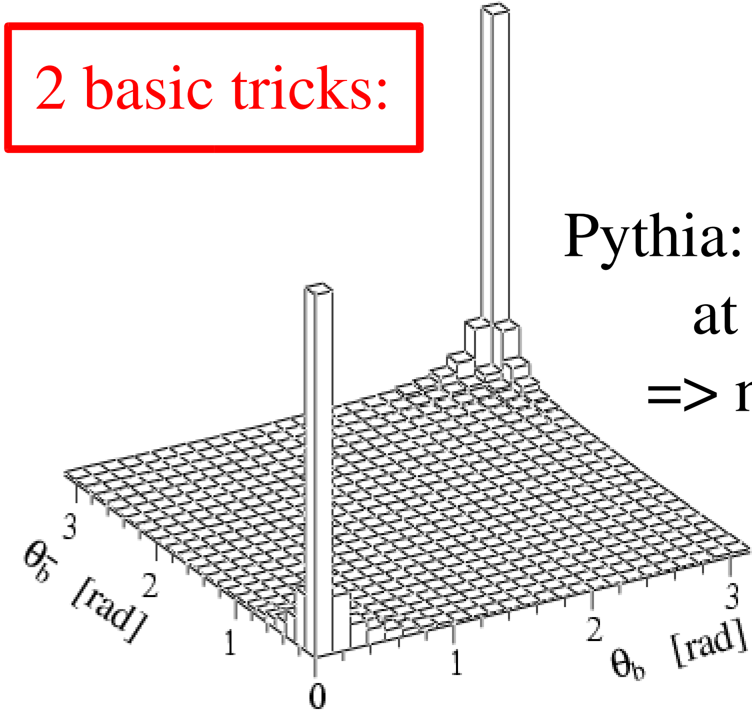
The LHCb experiment

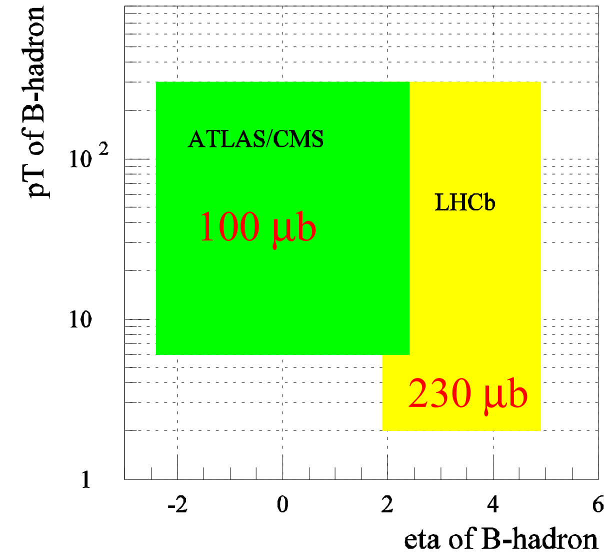
- Spectrometer
- Physics Program
- Trigger, Data, Computing

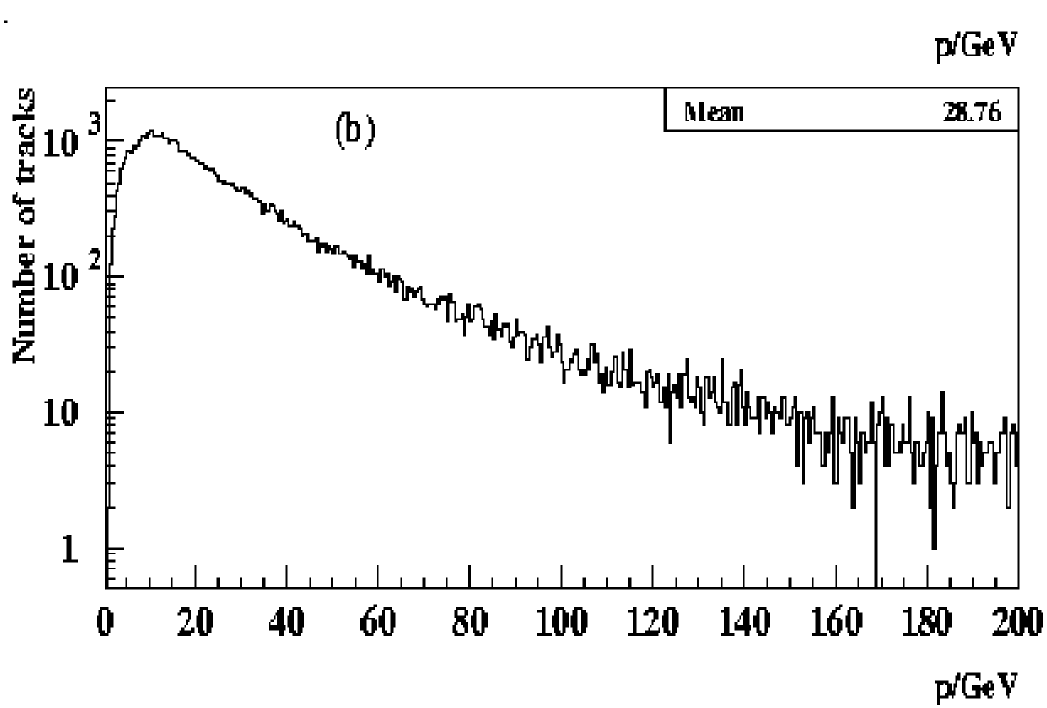
2 basic tricks:



Pythia: B meson production
at a 14 TeV pp collider
=> need forward detector

p_T *vs* η for detected B hadrons





Momentum distribution
of B decay products in LHCb:

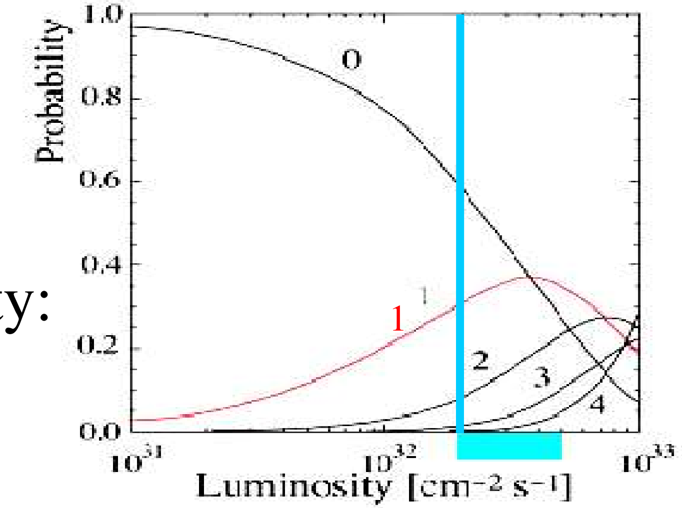
example $B_s \to D_s K$
high average $\overline{|p|}$ = 30 GeV/c

=> small multiple scattering
allows excellent resolutions
(momentum, livetime, mass)

Luminosity is adjustable by tuning the beam size (maximal reduction of factor 100 seems possible)

What is the optimal luminosity for LHCb?

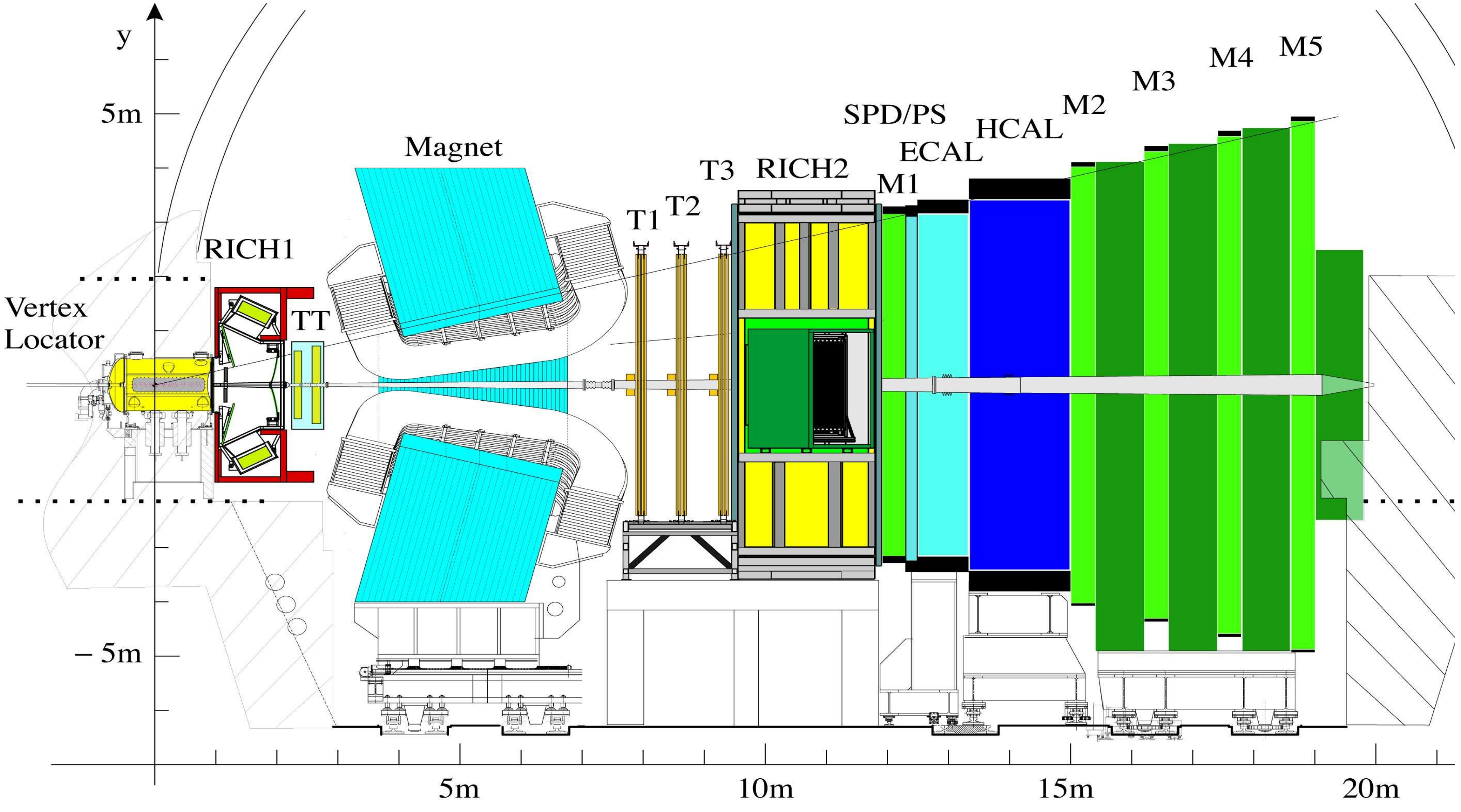
- Operate with several vertices per bunch crossing (trigger, reconstruction)?
- Probability for n interactions vs luminosity:



- Also detector occupancy and radiation damage is an issue

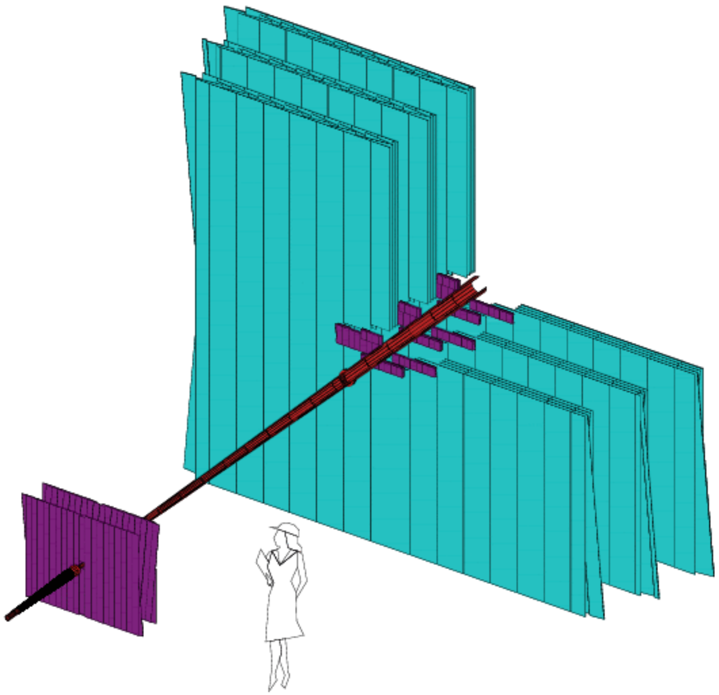
=> choose $L \sim 2 \times 10^{32}$ cm^{-2}s^{-1} to start with

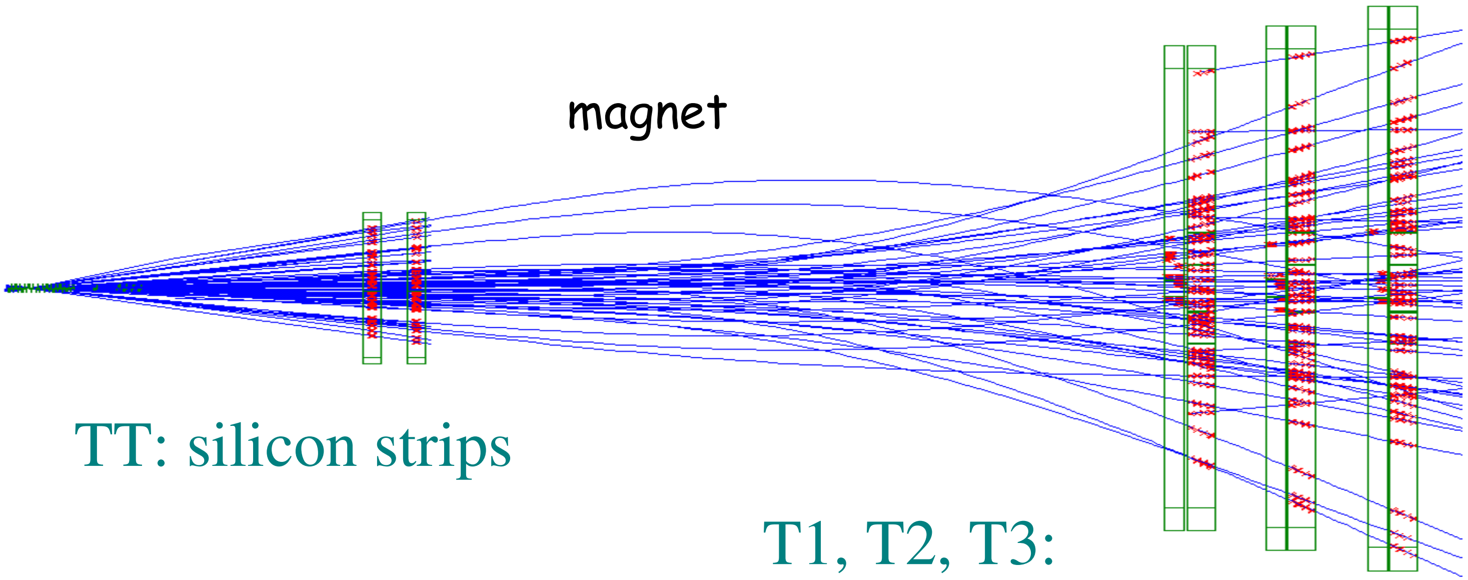
LHCb: a magnetic dipole spectrometer
+ vertex detector + Calo + particle ID
fitted in existing pit at IP8

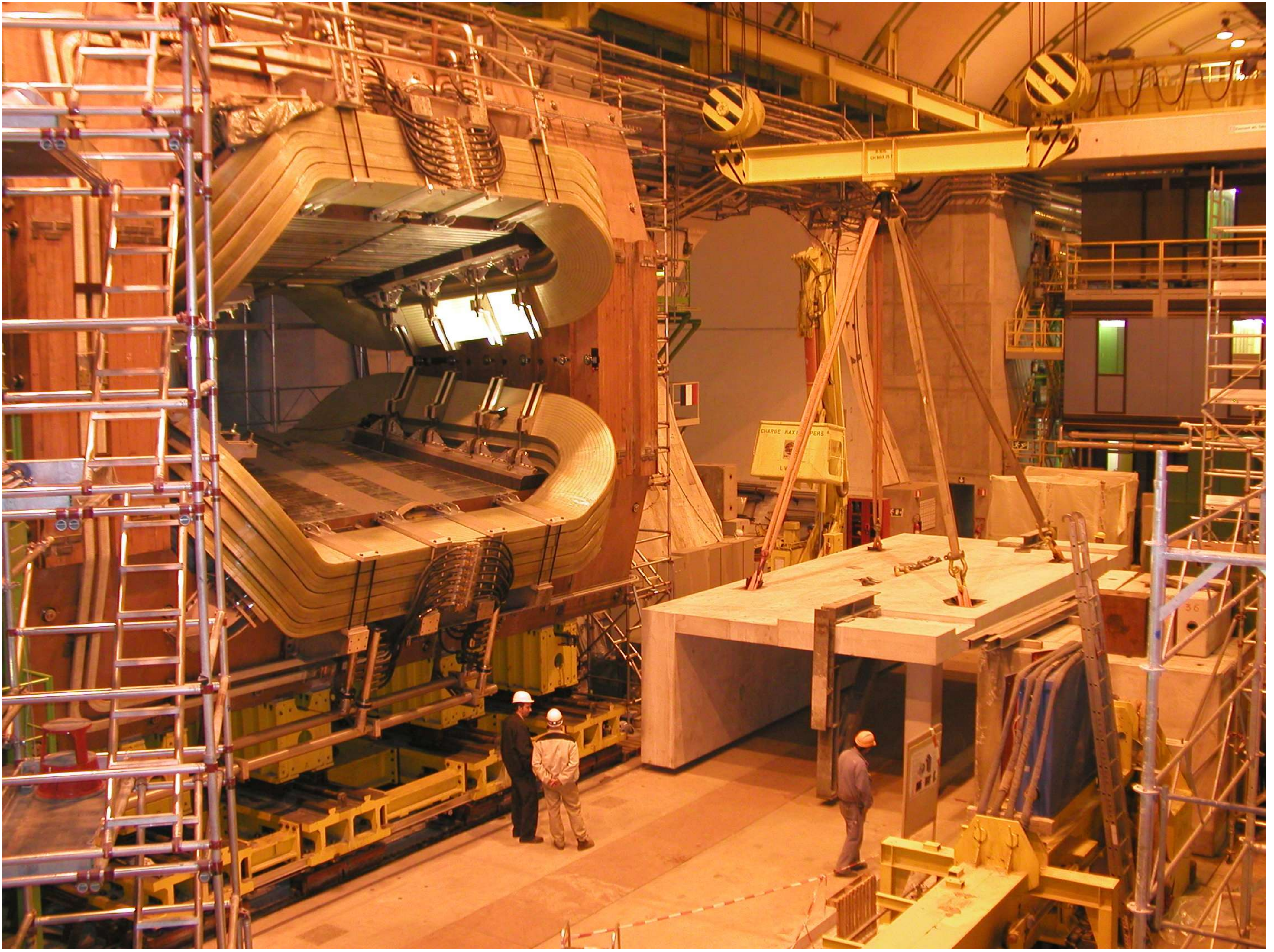


Spectrometer features:

Length: 10 m
Max. Field (on axis): 1.1 T
$\int B\, dl = 4$ Tm
Detector hit position resolution 30-100 μm
Amount of dead material: ca. 15% X_0 ...
... + 25% from vertex det. + RICH1
Momentum resolution 0.4%

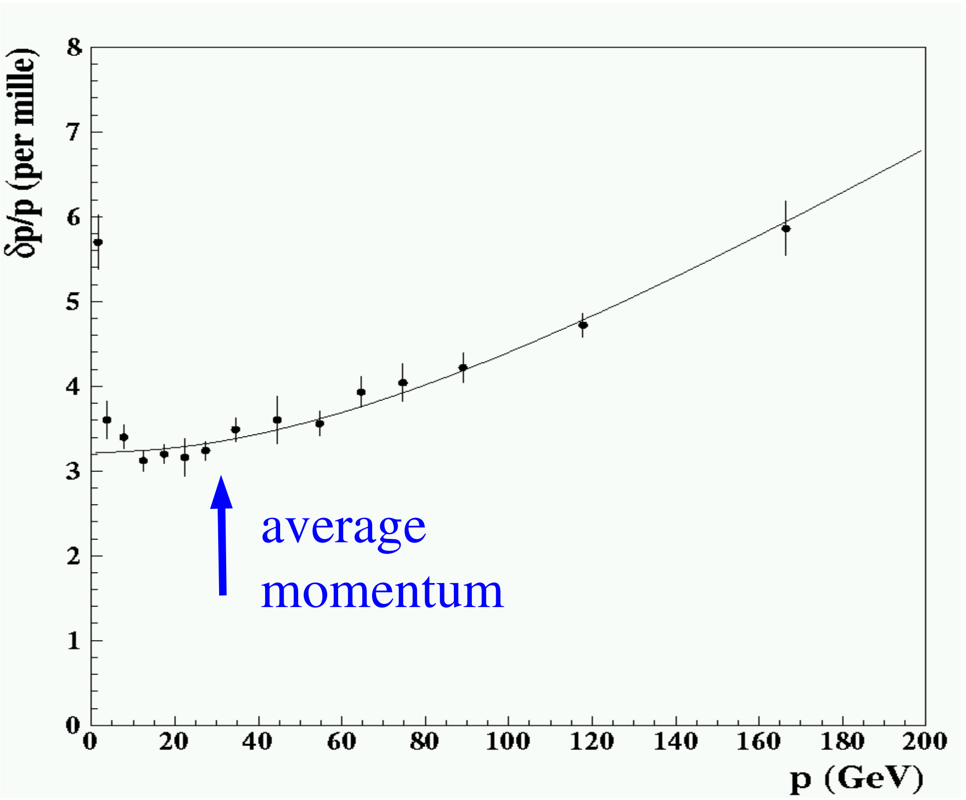




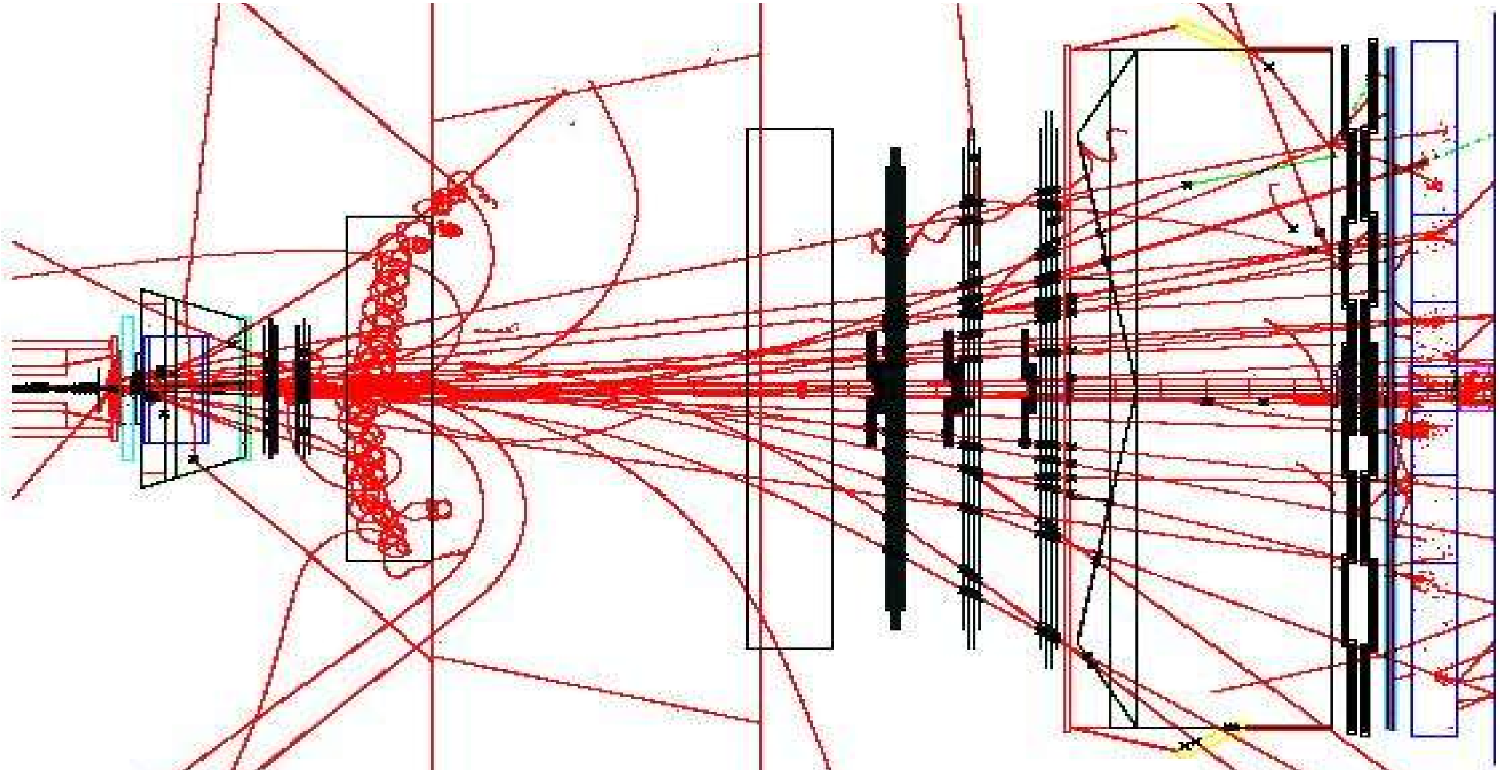


Contributions to momentum resolution:

- hit position resolution: ~ p
- multiple scattering: constant



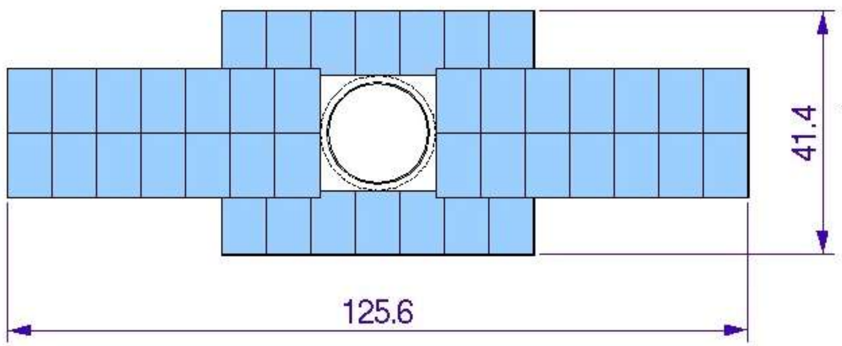
Detailed Geant simulation:



Silicon tracker: inner part of T1, T2, T3 and TT

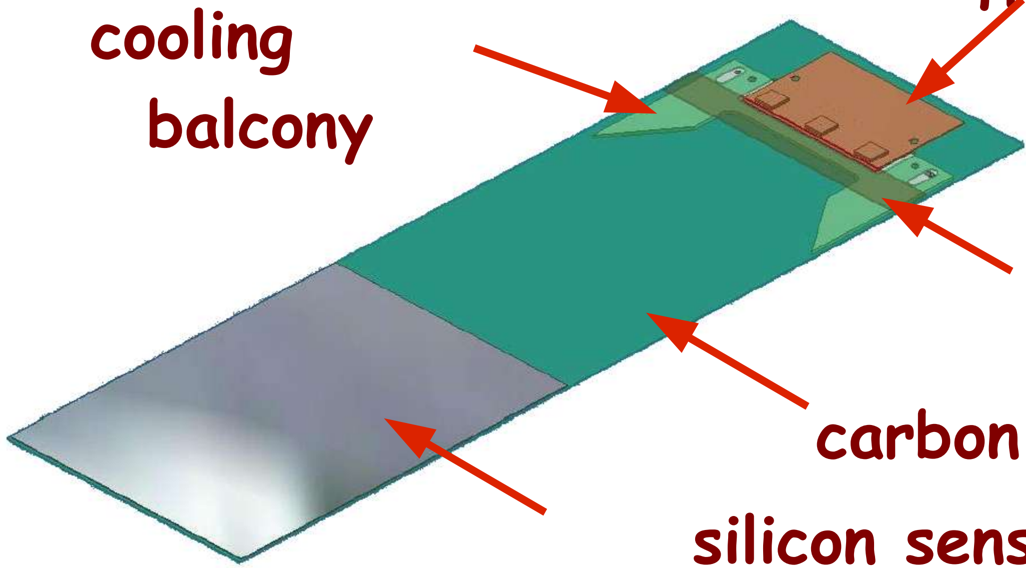
Zurich, Lausanne, MPI-HD, Santiago, Kiev

T1, T2, T3 stations produced in Lausanne

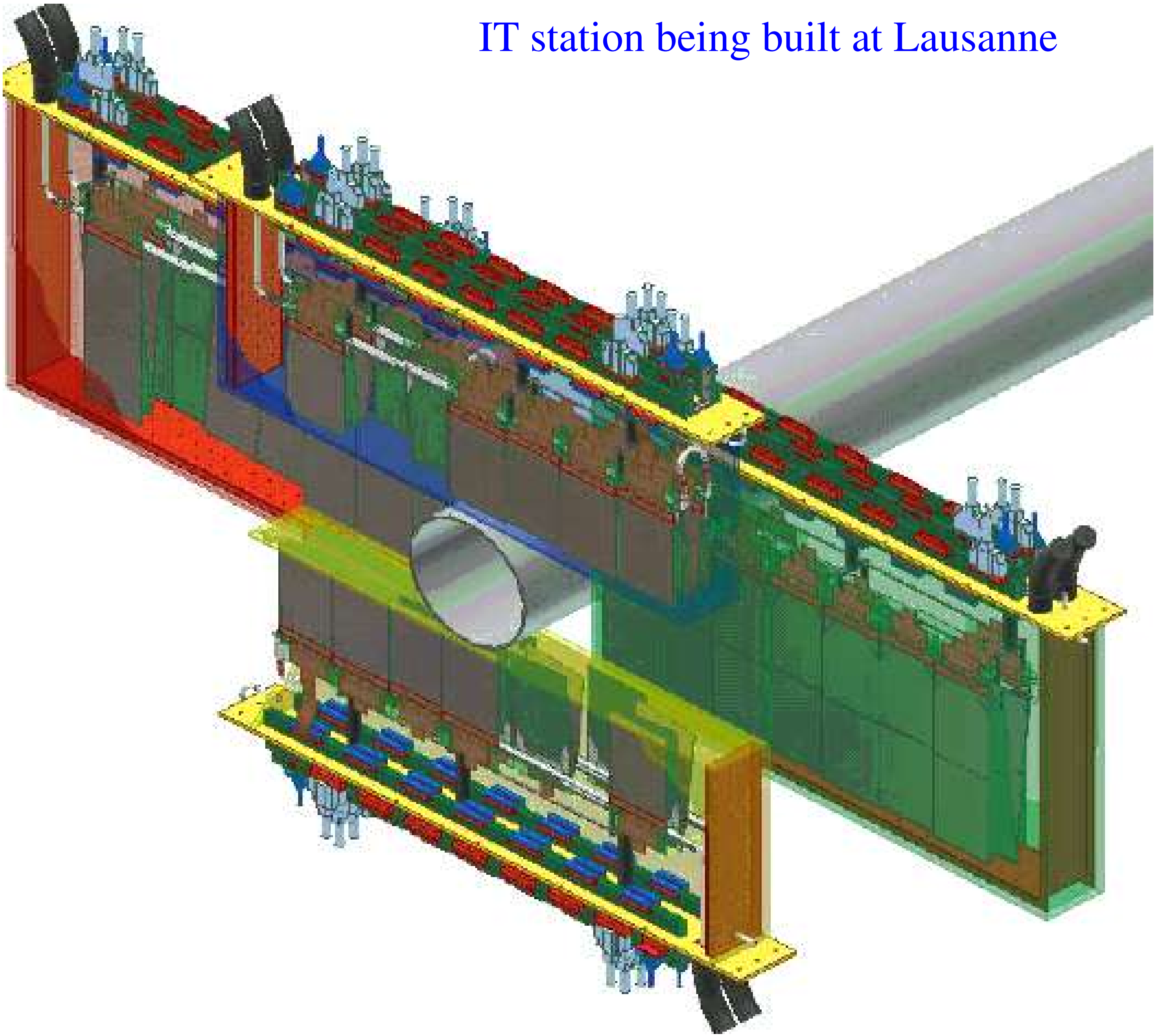


Silicon sensors (HPK):

- single-sided p-on-n
- 300 μm / 400 μm thick
- 108 mm long strips
- 384 readout strips
- 198 μm pitch
- 50 μm wide implants



IT station being built at Lausanne



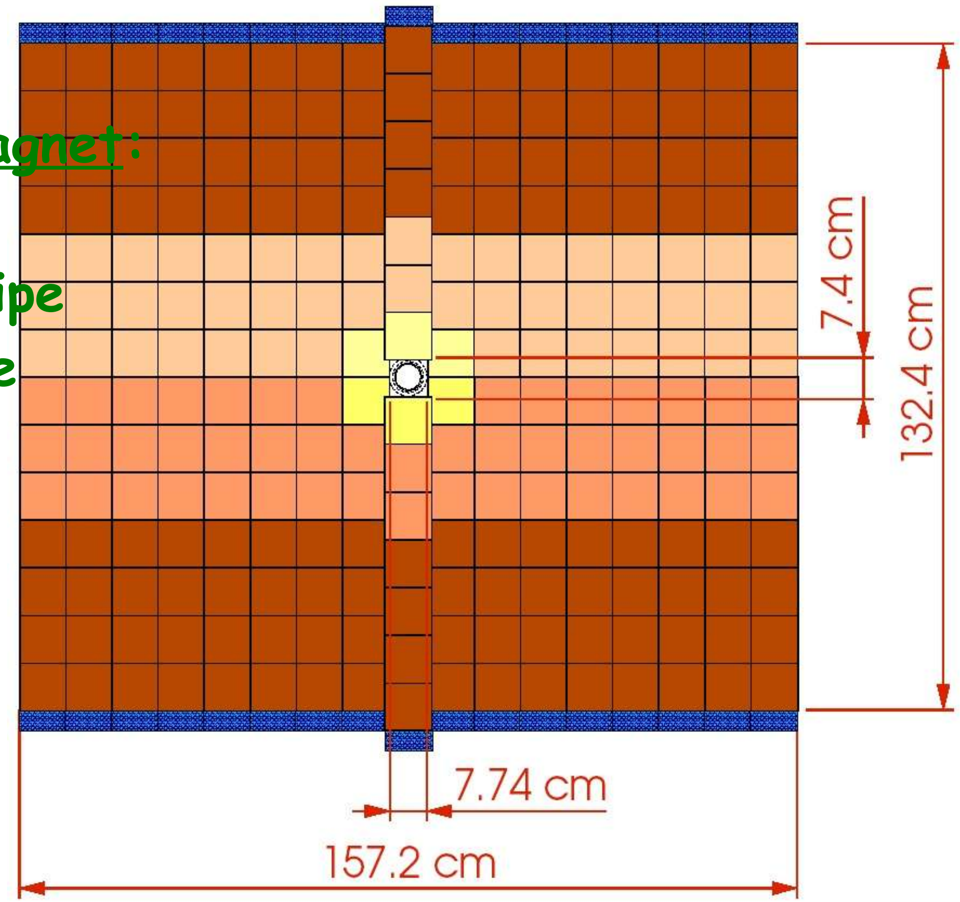
TT station (Zurich)

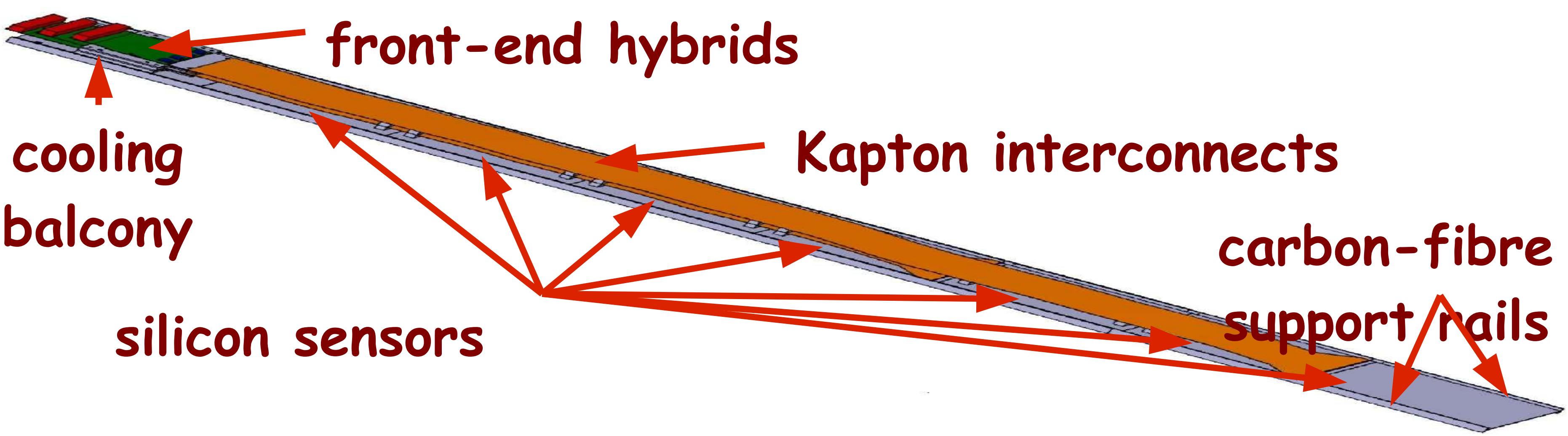
<u>Level-1 trigger / tracking upstream of magnet</u>:

- 4 detection layers
- 14-sensor ladders left/right of beam pipe
- 7-sensor ladders above/below beam pipe
- each ladder several readout sectors
- all hybrids outside of acceptance

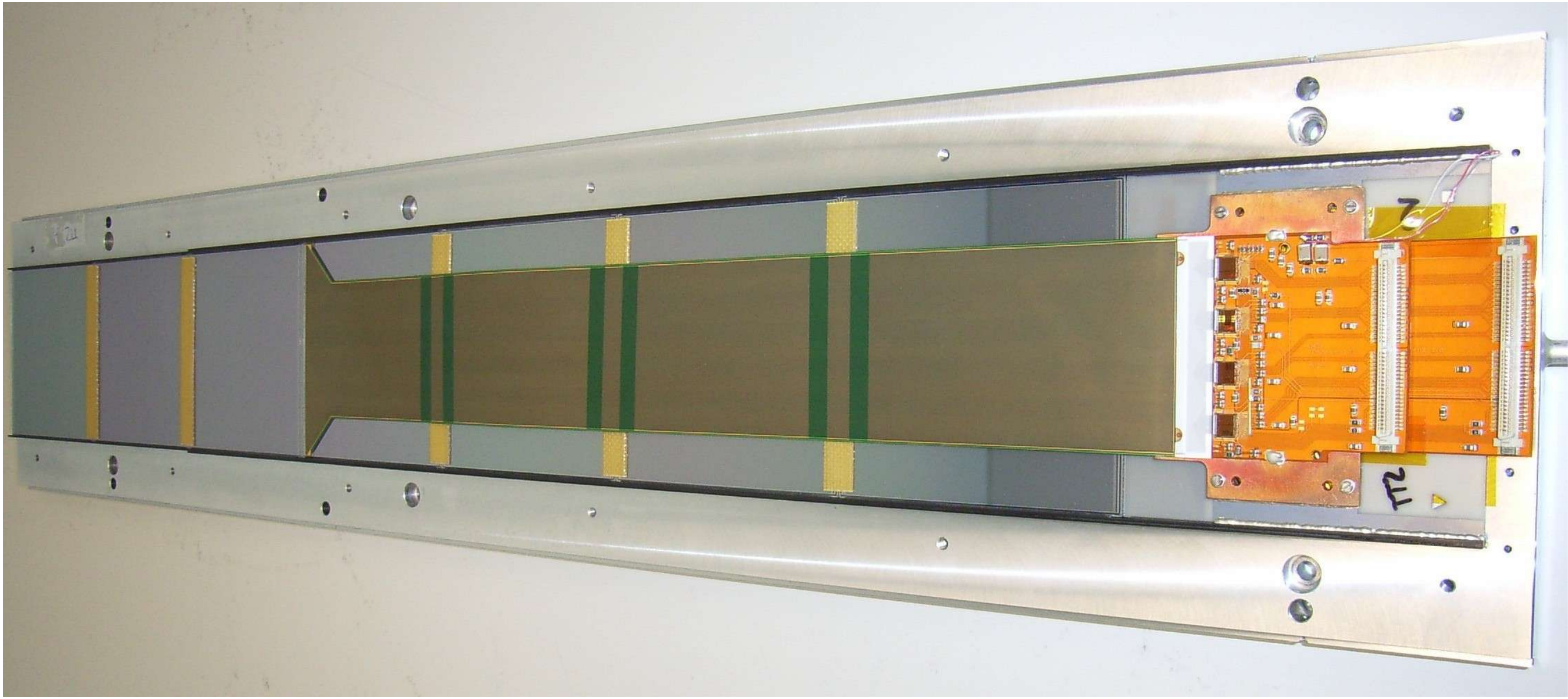
<u>CMS-OB2 sensors</u> (HPK):

- p-on-n, 500 μm thick
- 91.57 mm long strips
- 512 readout strips
- 183 μm pitch
- 46 μm wide implants





final ladder production for TT station in Zurich



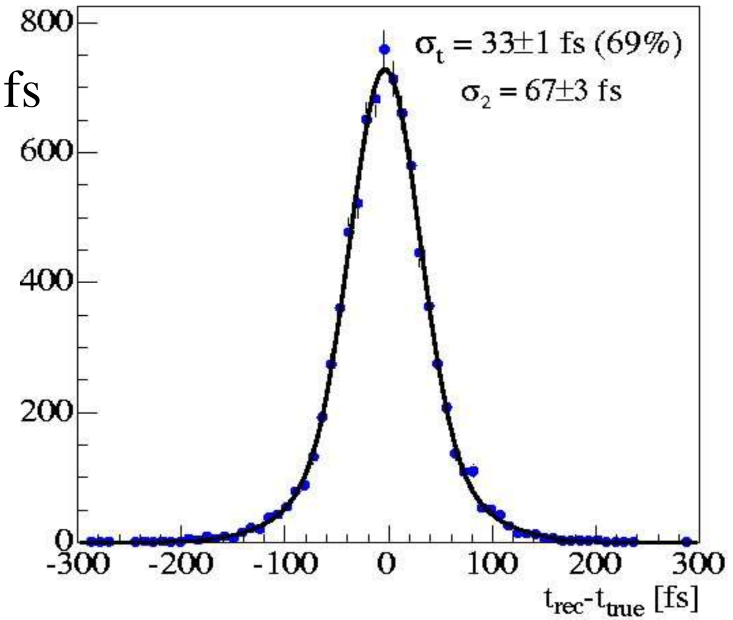
Swiss contributions to the LHCb experiment:

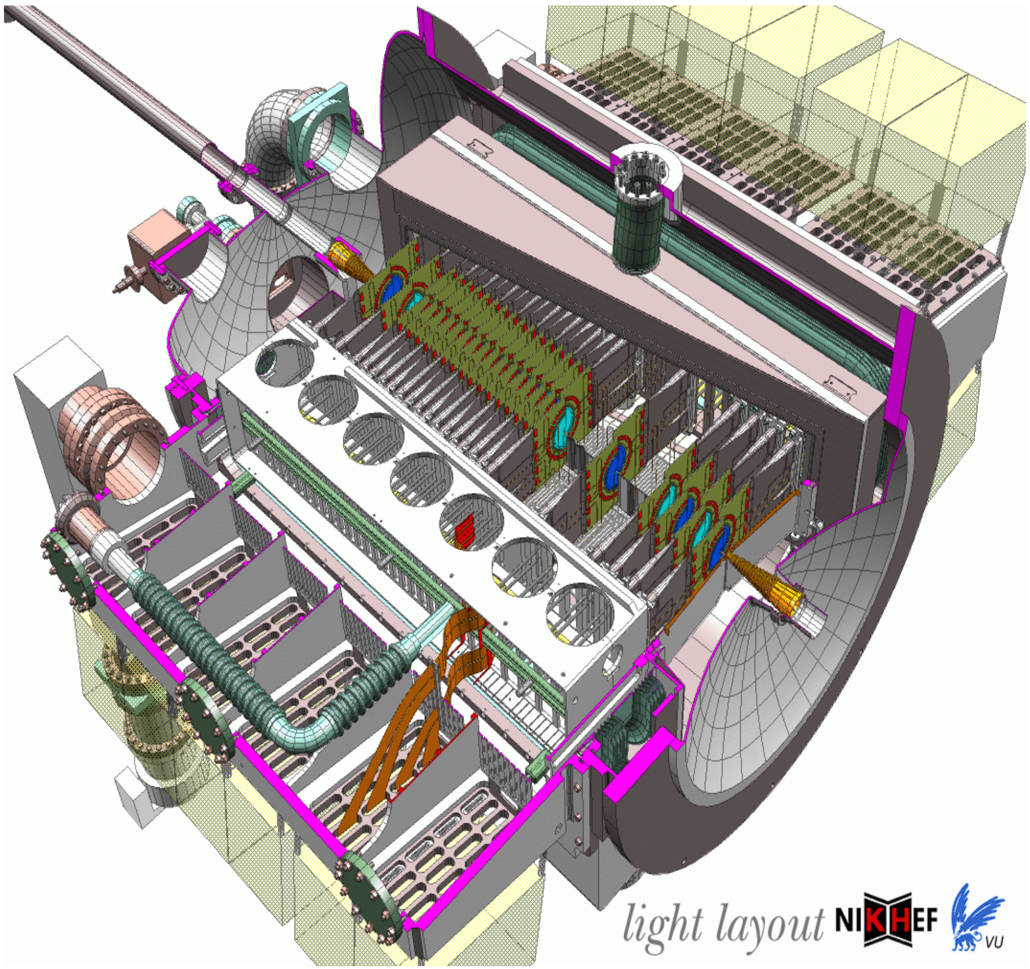
- Silicon tracking stations: TT, IT: about 12 m^2 silicon strip detector (R&D, sensors, ladder construction, station mechanics)
- Readout electronics (also for other subsystem) and development of second level trigger algorithm
- Preparation of software for HLT trigger, reconstruction and analysis
- Management

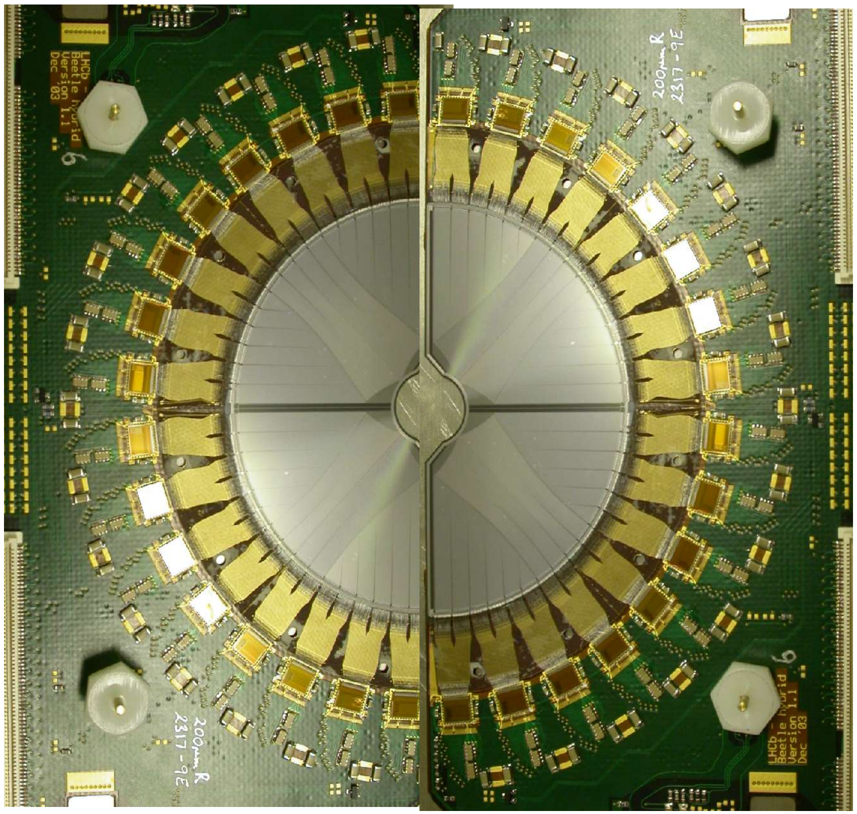
Vertex detector (VELO):

- *rϕ* geometry
- 21 stations
- approaching 8 mm to beam

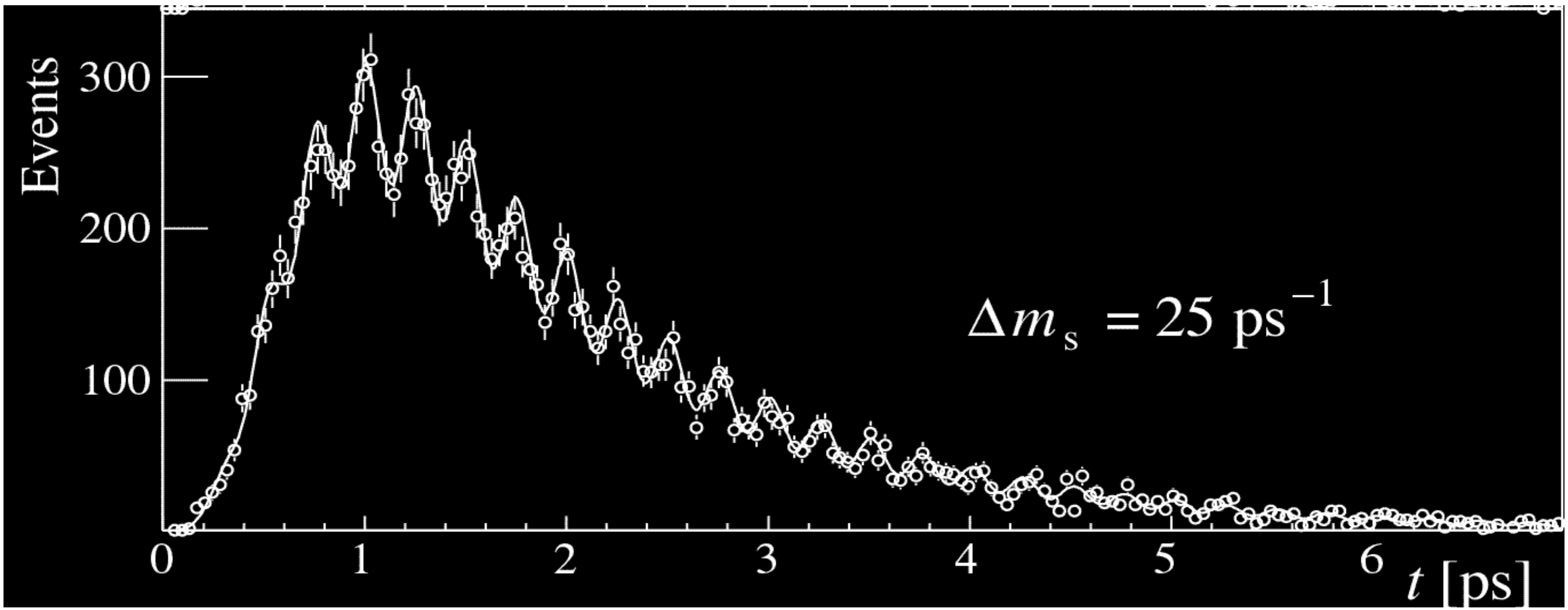
proper time resolution ~ 40 fs







Simulation of Δm_s using $B_s \to D_s^- \pi^+$ decays



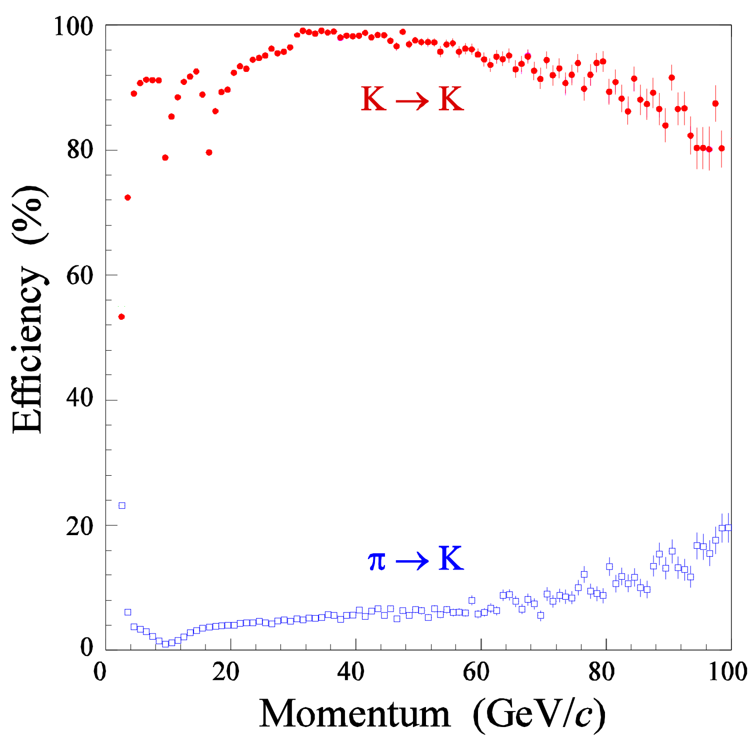
=> 5σ observation of B_s oscillation

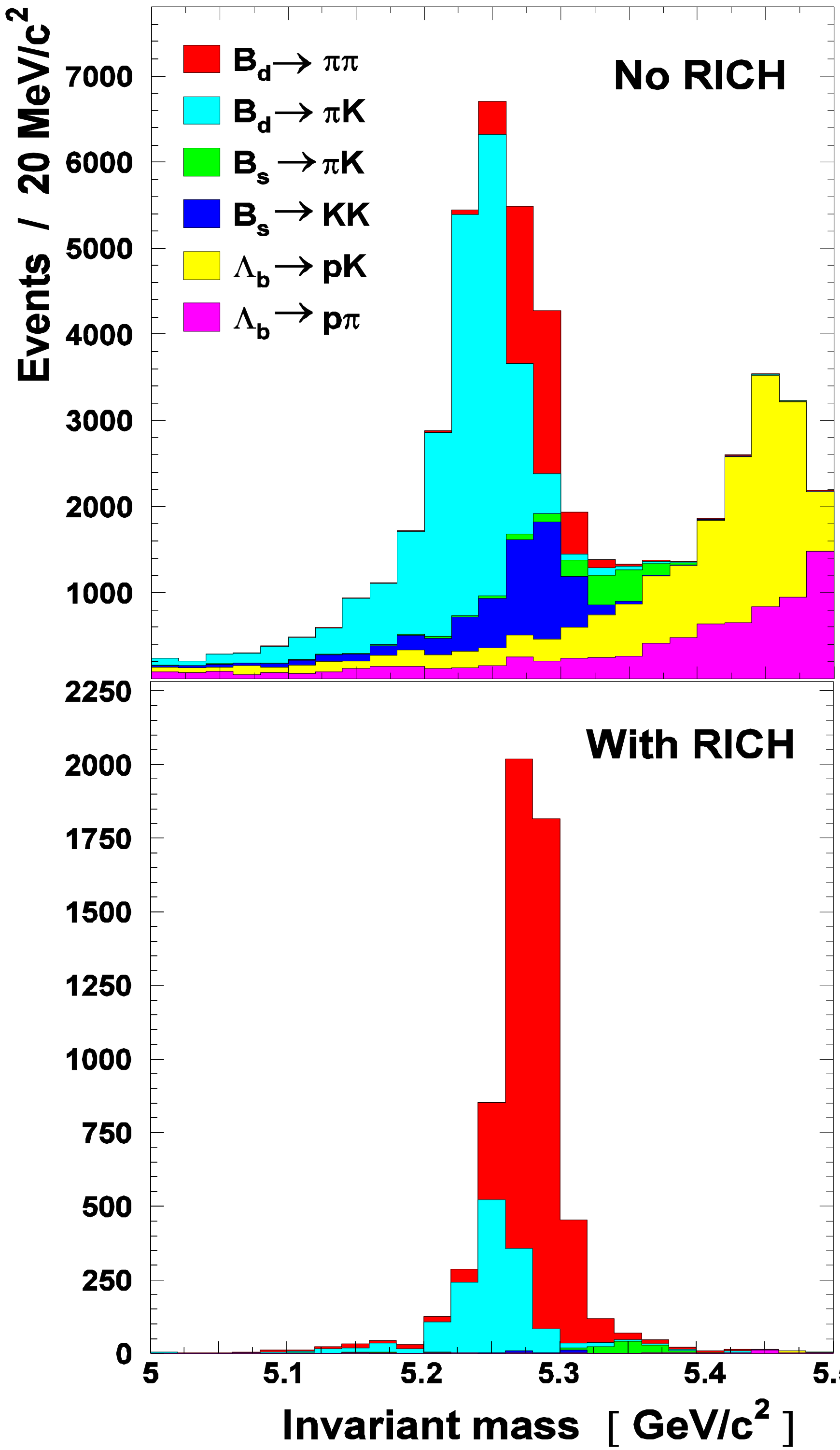
for $\Delta m_s < 68$ ps^{-1} (in 10^7 sec)

RICH: 2 detectors with 3 radiators to cover full momentum range.

novel photodetectors: HPD

- photocathode, Si pixel det.
- 500 vacuum tubes
- 1024 pixels 2.5×2.5 mm²





What to measure?

A wealth of interesting B meson decay channels!

- Precise measurement of B^0_s-$\overline{B^0}_s$ mixing: Δm_s, $\Delta\Gamma_s$ and phase $\phi_{s.}$

  $B_s \to D_s\pi$, …
  $B_s \to J/\psi\phi$, $B_s \to J/\psi\eta^{(')}$

- Precise γ determinations, including from processes at tree-level, in order to disentangle possible NP contributions

  $B_s \to D_sK$, $B^0 \to D^0K^{*0}$,
  $B^0 \to \pi\pi$ & $B_s \to KK$, …

- Several other measurements of CP phases in different channels for over-constraining the Unitarity Triangles

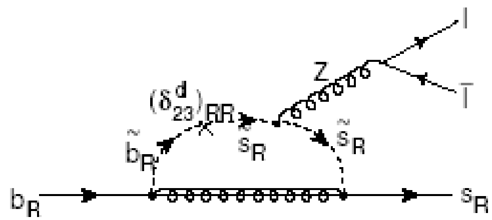
  $B^0 \to \phi K_s$, $B_s \to \phi\phi$, ...
  $B^0 \to \rho\pi$, $B \to \rho\rho$, …

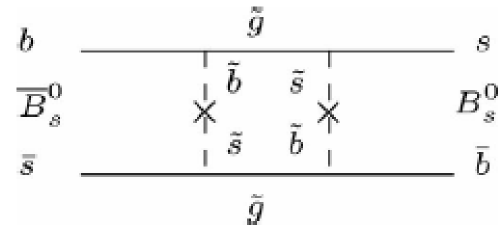
- Search for effects of NP appearing in rare exclusive and inclusive B decays

  $B^0 \to K^*\gamma$, $B^0 \to K^{*0}l^+l^-$,
  $b \to sl^+l^-$, $B_s \to \mu^+\mu^-$...

Observables: decay rates, CP violation parameters, angular distributions

We might get measurable contributions from physics beyond standard model as contributions to SM penguin and box diagrams!





Simple answers to two common questions:

What does LHCb add to B-factories?

- B_s decays
- B_c decays
- B_d different systematics (and more statistics)
- b baryons

What does LHCb add to CMS and Atlas?

- better proper time resolution
- 2* better invariant mass resolution (10 MeV on B mass in J/ $_s$)
- Pion/Kaon particle id
- Trigger sensitive to pure hadronic final states
- program extends over whole LHC era, not only “low lumi” phase

Preparation of physics analysis of the Swiss groups (incomplete list)

- Optimisation studies for B_s oscillation measurement by $B_s \to D_s \pi$
- Rare decays, sensitive to new physics: $B_s \to \mu\mu$
  $B_s \to X_s \mu\mu$
- Measure time dependant CP violation of $B_s \to J/\psi\, \eta(')$
  allows to determine $\phi_s = arg\, V_{ts}$ (in standard model)
- Jet reconstruction, and light Higgs selection and sensitivity
- Others

\+ Contributions to track reconstruction software, tagging etc.

Trigger

Event rate

Latency:

40 MHz

Level-0: high p_T (μ, e, γ, h) + pile-up veto
FPGA based, data stored on detector

4 μs

1 MHz

Level-1: high IP, high p_T tracks (Vtx, TT)
processor farm, data stored in local buffers

1 ms

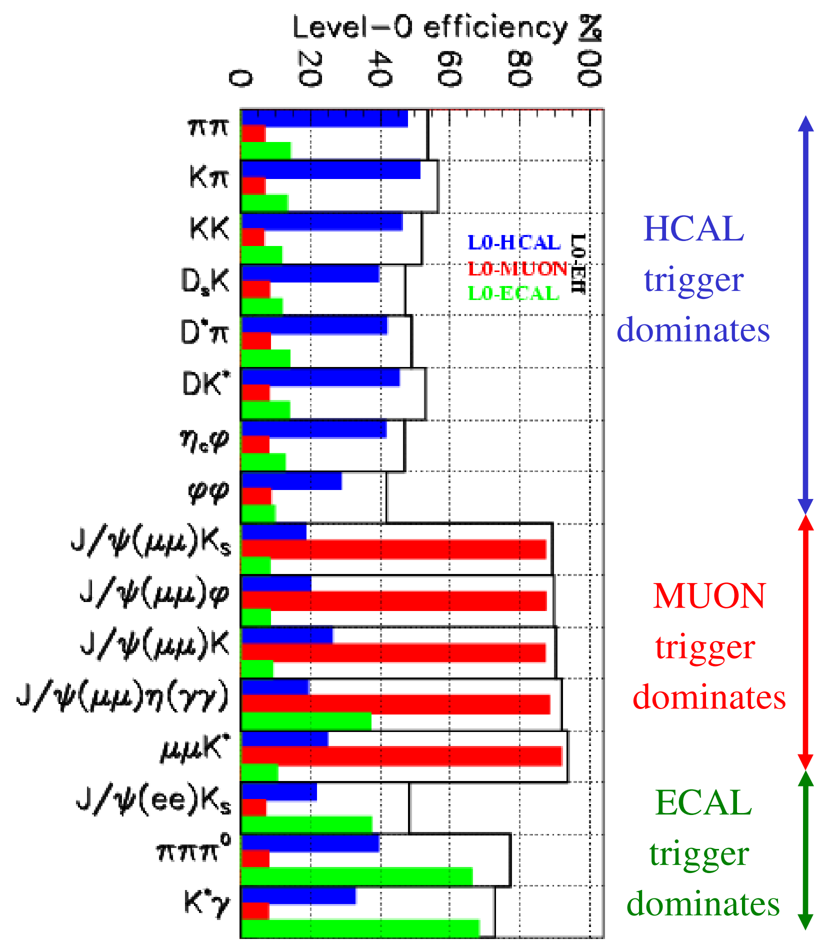
40 kHz

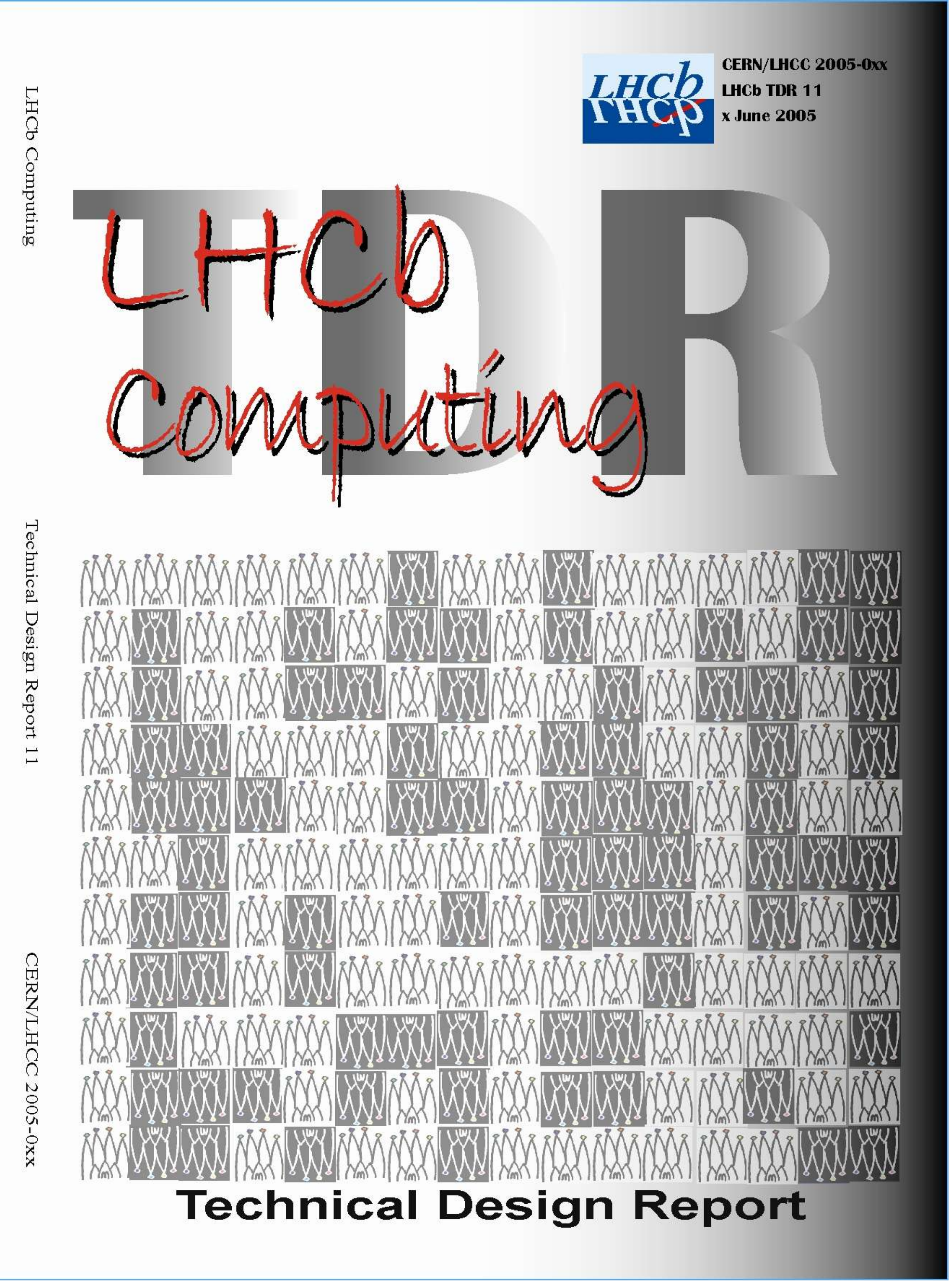
HLT: use complete event data
processor farm

10 ms

200 Hz
+ 1.8 kHz

HLT 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 (mixing&CPV)
900 Hz	Inclusive b (e.g. b→μ)	B (data mining)

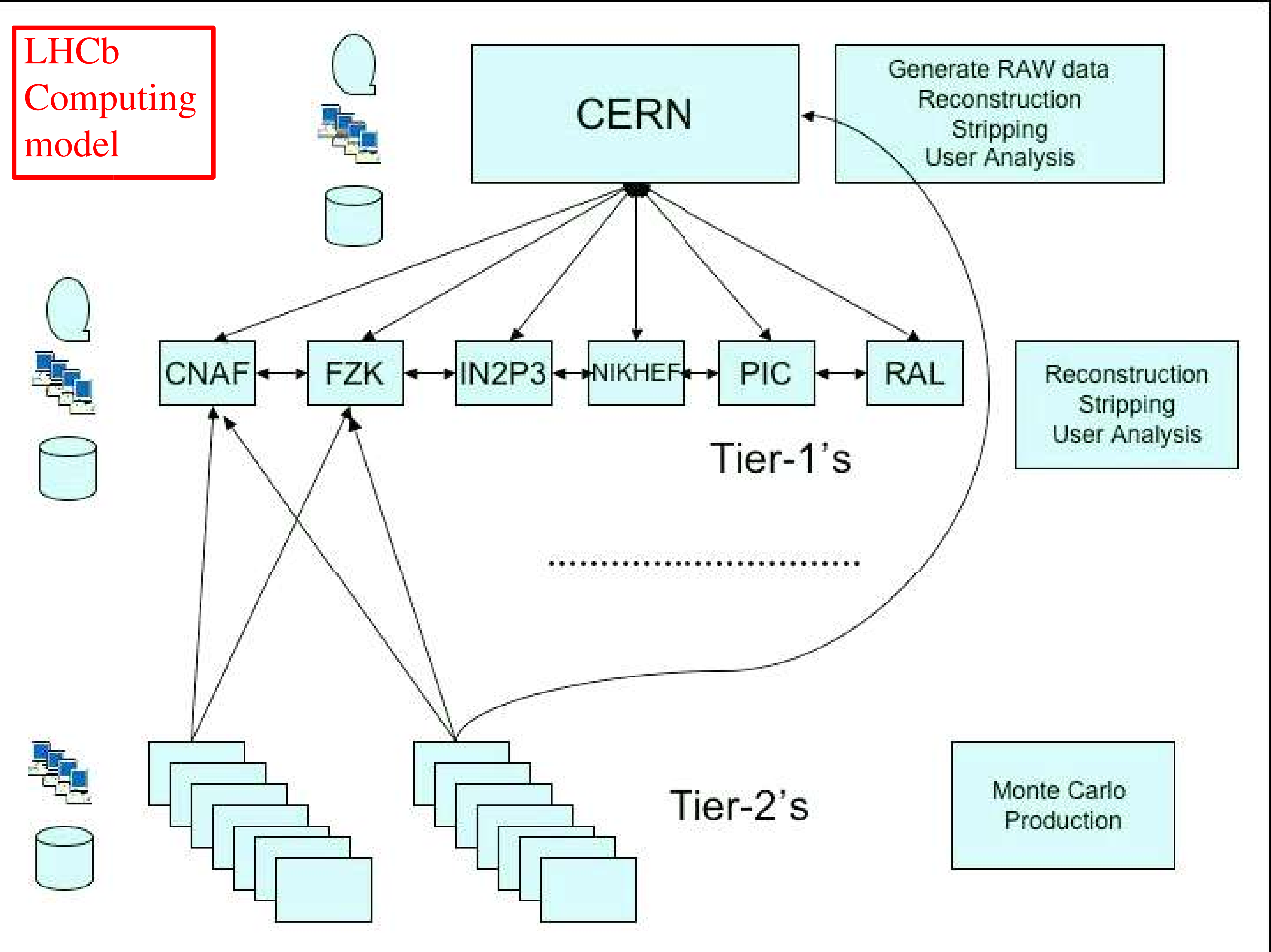




NEW!
Computing TDR, 20. Juni 2005

Event Size	**kB**
RAW	25
rDST	25
DST	75

Event processing	**kSI2k.s**
Reconstruction	2.4
Stripping	0.2
Analysis	0.3



LHCb Computing model
CERN
Generate RAW data
Reconstruction
Stripping
User Analysis
CNAF
FZK
IN2P3
NIKHEF
PIC
RAL
Reconstruction
Stripping
User Analysis
Tier-1's
Tier-2's
Monte Carlo Production

However, Switzerland does not have its own Tier–1

Therefore, we would like to do some user analysis on the Tier-2 in Manno

Details see presentations of Roland Bernet and Stefano Villa

Total LHCb computing requirements for 2008
(Switzerland is 4.7% of LHCb)

CPU requirements

	CERN	Tier1's	Tier2's	Total
Stripping	0.17	1.03	0.0	1.20
Full reconstruction	0.40	2.42	0.0	2.82
Monte Carlo	0.0	0.0	7.6	7.6
Analysis	0.32	0.97	0.0	1.29
Total	0.90	4.42	7.65	12.97

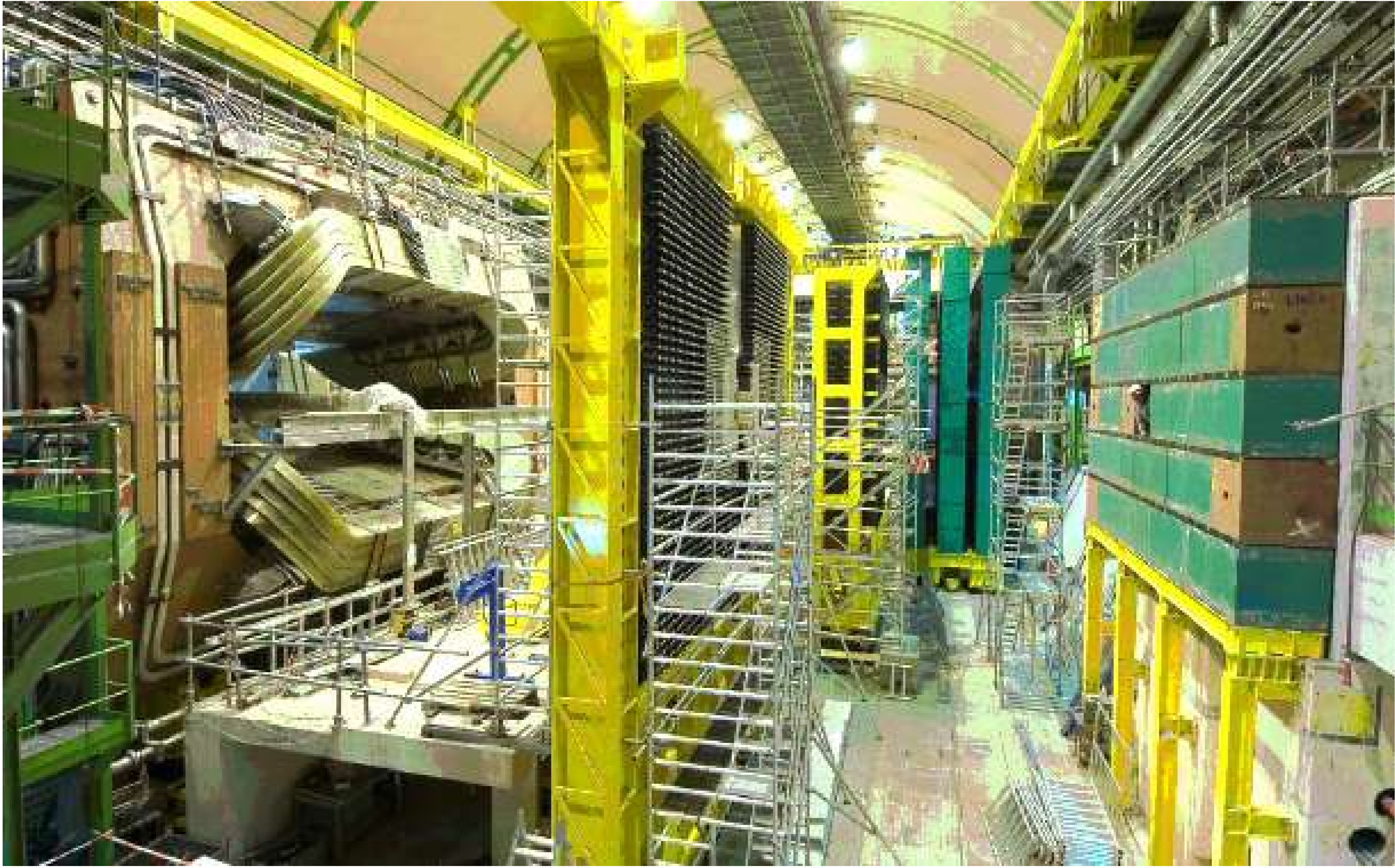
Table 4-13: 2008 CPU requirements in MSI2k.years

Disk storage requirements

	CERN	Tier-1's	Tier-2's	Total
RAW	136	0	0	136
rDST	136	0	0	136
Stripped DST	440	1954	23	2417
TAG	45	267	0	312
Analysis	70	210	0	280
Total	826	2432	23	3281

Table 4-14: 2008 disk requirements in TB

See LHCb Computing TDR, 20. June 2005



LHCb on 1. June 2005