The LHCb experiment

- Spectrometer
- Physics Program
- Trigger, Data, Computing
Pythia: B meson production at a 14 TeV pp collider => need forward detector

$p_T$ vs $\eta$ for detected B hadrons

Momentum distribution of B decay products in LHCb:

example $B_s \rightarrow D_s K$

high average $|p| = 30$ 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 $L \sim 2 \times 10^{32} \text{ cm}^{-2}\text{s}^{-1}$ 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
\[ \int B \, dl = 4 \, \text{Tm} \]
Detector hit position resolution 30-100 \( \mu \text{m} \)
Amount of dead material: ca. 15% \( X_0 \) ...
... + 25% from vertex det. + RICH1
Momentum resolution 0.4%

TT: silicon strips

T1, T2, T3:
inner part: silicon strips
outer part: straw tubes
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

Silicon sensors
- (2nd sensor not shown)
IT station being built at Lausanne
Level-1 trigger / tracking upstream of magnet:

- 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

**CMS-OB2 sensors (HPK):**
- p-on-n, 500 µm thick
- 91.57 mm long strips
- 512 readout strips
- 183 µm pitch
- 46 µm wide implants

TT station (Zurich)
final ladder production for TT station in Zurich
Swiss contributions to the LHCb experiment:

- Silicon tracking stations: TT, IT: about 12 m² 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):
- $r\phi$ geometry
- 21 stations
- approaching 8 mm to beam

proper time resolution $\sim 40$ fs
Simulation of $\Delta m_s$ using $B_s \rightarrow D_s^- \pi^+$ decays

$\Delta m_s = 25 \text{ ps}^{-1}$

$\Rightarrow 5\sigma$ observation of $B_s$ oscillation

for $\Delta m_s < 68 \text{ ps}^{-1}$ (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 $2.5 \times 2.5$ mm$^2$
What to measure?

A wealth of interesting B meson decay channels!

- Precise measurement of $B^0_s$-$\bar{B}^0_s$ mixing: $\Delta m_s$, $\Delta \Gamma_s$ and phase $\phi_s$. 
  
  $B_s \rightarrow D_s \pi$, ...
  $B_s \rightarrow J/\psi \phi$, $B_s \rightarrow J/\psi \eta(\prime)$

- Precise $\gamma$ determinations, including from processes at tree-level, in order to disentangle possible NP contributions
  
  $B_s \rightarrow D_s K$, $B^0 \rightarrow D^0 K^{*0}$,
  $B^0 \rightarrow \pi \pi$ & $B_s \rightarrow K K$, ...

- Several other measurements of CP phases in different channels for over-constraining the Unitarity Triangles
  
  $B^0 \rightarrow \phi K_s$, $B_s \rightarrow \phi \phi$, ...
  $B^0 \rightarrow \rho \pi$, $B \rightarrow \rho \rho$, ...

- Search for effects of NP appearing in rare exclusive and inclusive B decays
  
  $B^0 \rightarrow K^* \gamma$, $B^0 \rightarrow K^{*0} l^+ l^-$,
  $b \rightarrow s l^+ l^-$, $B_s \rightarrow \mu^+ \mu^-$...

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!

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 $J/\psi$)
- 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 $B_s \rightarrow D_s \pi$

• Rare decays, sensitive to new physics: $B_s \rightarrow \mu \mu$
  $B_s \rightarrow X_s \mu \mu$

• Measure time dependant CP violation of $B_s \rightarrow J/\psi \eta(')$
  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.
Event rate
40 MHz
Level-0: high $p_T(\mu, e, \gamma, h)$ + pile-up veto
FPGA based, data stored on detector
1 MHz
Level-1: high IP, high $p_T$ tracks (Vtx, TT)
processor farm, data stored in local buffers
40 kHz
HLT: use complete event data
processor farm
200 Hz + 1.8 kHz

Latency:
4 $\mu$s
1 ms
10 ms

<table>
<thead>
<tr>
<th>HLT rate</th>
<th>Event type</th>
<th>Physics</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 Hz</td>
<td>Exclusive B candidates</td>
<td>B (core program)</td>
</tr>
<tr>
<td>600 Hz</td>
<td>High mass di-muons</td>
<td>$J/\psi, b \rightarrow J/\psi X$ (unbiased)</td>
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<tr>
<td>300 Hz</td>
<td>$D^*$ candidates</td>
<td>Charm (mixing&amp;CPV)</td>
</tr>
<tr>
<td>900 Hz</td>
<td>Inclusive $b$ (e.g. $b \rightarrow \mu$)</td>
<td>B (data mining)</td>
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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
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)
LHCb on 1. June 2005