Swiss involvement in particle physics experiments at frontier colliders

Olivier Schneider

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Prepared with the help of many CHIPP colleagues. Thanks.
What has happened since 2002?

- LHC construction phase: the long tunnel
  - All involved Swiss groups have successfully fulfilled their commitments towards the design, construction, assembly and commissioning of the ATLAS, CMS and LHCb detectors
  - Lots of Monte Carlo studies to assess physics performance
  - Real data from test beams, cosmic runs, LHC injection tests

- Reaching end of tunnel:
  - Ready to discover a new bright landscape!
What has happened since 2002?

- In the mean time, keep physics going …
  - Swiss groups building LHC experiments kept or took secondary involvements in other running experiments
  - Main motivation: maintain/develop expertise and offer PhD (master) students the possibility to operate a detector and analyze physics data
  - Nice physics results, opportunities to talk in conferences, …

- Experiments at (pre-LHC) frontier colliders with recent Swiss involvement:
  - H1 (ep frontier)
  - CDF and D0 (p̅p at energy frontier)
  - Belle (e⁺e⁻ at luminosity frontier)
### Switzerland @ LHC

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Institutes</th>
<th># PhD physicists</th>
<th># Doctoral students</th>
<th># Technical support (~)</th>
<th>Core detector construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATLAS</td>
<td>Uni Bern</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>23 MCHF</td>
</tr>
<tr>
<td></td>
<td>Uni Geneva</td>
<td>16</td>
<td>9</td>
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<tr>
<td>CMS</td>
<td>Uni Zurich</td>
<td>7</td>
<td>4+2 (PSI)</td>
<td>2</td>
<td>92 MCHF</td>
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<tr>
<td></td>
<td>ETH Zurich</td>
<td>21</td>
<td>9+2 (PSI)</td>
<td>21</td>
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<tr>
<td></td>
<td>PSI</td>
<td>12</td>
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<td>3</td>
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<tr>
<td>LHCb</td>
<td>Uni Zurich</td>
<td>7</td>
<td>3</td>
<td>2</td>
<td>8 MCHF</td>
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<tr>
<td></td>
<td>EPF Lausanne</td>
<td>10</td>
<td>9</td>
<td>8</td>
<td></td>
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<tr>
<td>Total</td>
<td></td>
<td>79</td>
<td>43</td>
<td>49</td>
<td>123 MCHF</td>
</tr>
</tbody>
</table>

In addition, through CHIPP:
- 9 post-docs financed by Swiss University Conference (2008–2012)
- 10 doctoral positions requested to Swiss National Science Foundation (2009–2012)
ATLAS members

Uni Bern

A. Ereditato
HP. Beck, M.S. Weber
E. Cogneras, S. Haug, K. Kordas
A. Battaglia, C. Borer, V. Gallo,
C. Topfel, N. Venturi

Uni Geneva

A. Blondel, A.G. Clark, M. Pohl
L. Rosselet, X. Wu,
D. Ferrere, S. Gadomski
W. Bell, J. Garcia Navarro, S. Gonzalez, A. Hamilton, M. Keil,
A. Lister, B. Martin dit Latour, G. Pastzor, P. Urquijo
A. Abdel-Alim, G. Alexandre, M. Backes, E. Berglund, F. Bucci,
V. Dao, T. Eifert, C. Mora Herrera, A. Robichaud-Veronneau

- 19 PhD theses as of 2008
  Blue = PhD physicist, Red = doctoral student
  Underlined members currently have a management or coordination responsibility in the ATLAS collaboration
ATLAS

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O. Schneider, Mar 6, 2009
Silicon tracker (SCT), Geneva:
- design, prototyping, testing (sensors + FE chip)
- 650 out of 2000 forward Si modules
- mechanical engineering, slow control

SCT commissioning:
- 0.3% dead channels (surface)
- alignment and performance with $> 10^6$ cosmics
ATLAS trigger and DAQ

Event Building Network
- Dataflow Manager
- Sub-Farm Input
- Event Builder
- Read-Out Buffers
- Event Filter Network
- Sub-Farm Output

Read-Out System
- Lvl1 acc = 75 kHz
- ~2 kHz
- Event Filter
- L2 Supervisor
- L2 Network

Lvl2 acc = ~2 kHz
- Event Filter Processors
- ~10 ms

Read-Out System
- Lvl2 acc = ~10 ms
- ~4 GB/s

Event Filter Network
- DFM
- EBN
- EB
- Lvl2 acc = ~0.2 kHz

Read-Out System
- ROB
- ROB
- ROB
- ~120 GB/s

Event Filter Network
- EFP
- ~200 Hz
- ~2+4 GB/s

Read-Out System
- LVL2
- ~10 ms
- RoI Builder Requests

Event Filter Network
- EFacc = ~0.2 kHz

Read-Out System
- SFI
- ~4 GB/s

Dataflow Manager
- Event Building Network
- Event Filter Network

Read-Out System
- L2P
- ~2 kHz
- L2N

Event Filter Network
- L2SV
- ~ 10 ms

Read-Out System
- L2 Proc Unit

Event Filter Network
- ROIB
- L2P

Read-Out System
- ~ 10 ms
- Lvl2 acc = ~2 kHz

Event Filter Network
- ~2 kHz

Read-Out System
- ~ 10 ms

Event Filter Network
- ~2 kHz

Read-Out System
- ~2+4 GB/s

Event Filter Network
- EB
- Lvl2 acc = ~0.2 kHz

Read-Out System
- ~300 MB/s

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ATLAS physics (e.g. BSM)

- **Early data:**
  - understand and calibrate detector!
    - use SM processes (J/ψ, W, Z, …)
  - development/study of SUSY triggers
  - look for excess over SM
    (comb. of leptons, jets, photons, missing E_T)
    - key issue is estimation of SM bkg (tt, W/Z, QCD)

- **With > 1 fb⁻¹, if excess found:**
  - determination of new particle masses
    from end-point spectra, e.g. m(µµ)

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<table>
<thead>
<tr>
<th>Observable</th>
<th>SU3 m_{meas} [GeV/c²]</th>
<th>SU3 m_{MC} [GeV/c²]</th>
<th>SU4 m_{meas} [GeV/c²]</th>
<th>SU4 m_{MC} [GeV/c²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>m_{Z'}</td>
<td>88 ± 60 ± 2</td>
<td>118</td>
<td>62 ± 126 ± 0.4</td>
<td>60</td>
</tr>
<tr>
<td>m_{Z''}</td>
<td>189 ± 60 ± 2</td>
<td>219</td>
<td>115 ± 126 ± 0.4</td>
<td>114</td>
</tr>
<tr>
<td>m_{W}</td>
<td>614 ± 91 ± 11</td>
<td>634</td>
<td>406 ± 180 ± 9</td>
<td>416</td>
</tr>
<tr>
<td>m_{t}</td>
<td>122 ± 61 ± 2</td>
<td>155</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Observable</th>
<th>SU3 Δm_{meas} [GeV/c²]</th>
<th>SU3 Δm_{MC} [GeV/c²]</th>
<th>SU4 Δm_{meas} [GeV/c²]</th>
<th>SU4 Δm_{MC} [GeV/c²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>m_{Z'} - m_{Z''}</td>
<td>100.6 ± 1.9 ± 0.0</td>
<td>100.7</td>
<td>52.7 ± 2.4 ± 0.0</td>
<td>53.6</td>
</tr>
<tr>
<td>m_{W} - m_{Z'}</td>
<td>526 ± 34 ± 13</td>
<td>516.0</td>
<td>344 ± 53 ± 9</td>
<td>356</td>
</tr>
<tr>
<td>m_{t} - m_{Z''}</td>
<td>342 ± 3.8 ± 0.1</td>
<td>37.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Jet + E_T^{miss}

Events / 100 fb⁻¹

- SUSY(1 TeV)
- SU3 (~700 GeV)
- all BG
- tt
- W
- Z
- QCD

- Flavour-subtracted dilepton mass spectrum
  - SU3 benchmark
  - 1 fb⁻¹

arXiv:0901.0512 ; CERN-OPEN-2008-020
CMS members

<table>
<thead>
<tr>
<th>Uni Zurich</th>
<th>ETH Zurich</th>
<th>PSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. Amsler</td>
<td>G. Dissertori, F. Pauss</td>
<td>R. Horisberger</td>
</tr>
<tr>
<td>V. Chiochia</td>
<td>B. Betev, M.C. Casella, M. Dittmar, A. Hervé,</td>
<td>W. Bertl</td>
</tr>
<tr>
<td>C. Regenfus</td>
<td>D. Luckey, W. Lustermann, F. Moortgat, F. Nessi,</td>
<td>W. Erdmann</td>
</tr>
<tr>
<td>P. Robmann</td>
<td>L. Pape, F. Ronga, M.-C. Sawley, V. Sordini,</td>
<td>H.-C. Kästli</td>
</tr>
<tr>
<td>A. Schmidt</td>
<td>F. Stoeckli, A. Thea, D. Treille, J. Weng</td>
<td>D. Kotinski</td>
</tr>
<tr>
<td>E. Alagöz (also PSI)</td>
<td>Z. Chen, W. Hintz, C. Marchica (also PSI),</td>
<td>S. König</td>
</tr>
<tr>
<td>T. Rommerskirchen</td>
<td>A.-K. Sanchez, B. Stieger</td>
<td>A. Stradodumov</td>
</tr>
<tr>
<td>D. Tsirigkas</td>
<td>U. Langenegger</td>
<td>S. Tentindo</td>
</tr>
<tr>
<td>L. Wilke (also PSI)</td>
<td>C. Grab</td>
<td>Q. Ingram</td>
</tr>
<tr>
<td></td>
<td>A. Rizzi</td>
<td>K. Deiters</td>
</tr>
<tr>
<td></td>
<td>L. Caminada (also PSI), L. Wehrli</td>
<td>D. Renker</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(M. Spira, theory)</td>
</tr>
</tbody>
</table>

- 19 PhD theses as of 2008
- Blue = PhD physicist, Red = doctoral student
- Underlined members currently have a management or coordination responsibility in the CMS collaboration

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O. Schneider, Mar 6, 2009
CMS

Weight: 12’500 t
Diameter: 15 m
Length: 21.6 m
Magnetic field: 4 T

Crystal calorimeter ETHZ
Electronics ETHZ, PSI

Software & Physics
ETHZ, PSI, UniZh

Silicon strips ETHZ
Pixel detector
PSI, ETHZ, UniZh

Superconductor for magnet ETHZ

Magnet design and procurement ETHZ

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CMS pixel barrel detector

- **PSI and ETHZ:**
  - design and construction of pixels modules (sensors and readout chip)

- **Uni Zurich:**
  - sensor and readout developments
  - construction of support structure including cooling and supply tube (containing optical links for control and readout, power, …)

Complete barrel pixel detector half shell (all three layers)

Complete supply tube half shell
CMS crystal calorimeter

- ETHZ:
  - PbWO$_4$ crystals (procurement and tests)
  - Electronics and electronics integration
  - Detector control system

- PSI:
  - Photodetectors for barrel (APDs)

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CMS physics (example)

- SM Higgs search in decay channel $H \rightarrow WW \rightarrow \ell\nu\ell\nu$:
  - most promising channel for Higgs mass close to $160 \text{ GeV}/c^2$
  - detailed simulation in CMS detector ... and first NNLO calculation of this process

Anastasiou, Dissertori, Stoeckli, JHEP 0709:018,2007

O. Schneider, Mar 6, 2009

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LHCb members

Uni Zurich

U. Straumann
R. Bernet, A. Vollhardt, O. Steinkamp
J. Anderson, J. van Tilburg, M. Tobin
A. Buechler-Germann, M. De Cian,
C. Salzmann

EPF Lausanne

A. Bay, T. Nakada, O. Schneider
F. Blanc, G. Haefeli, M.T. Tran
A. Hicheur, R. Muresan,
M. Needham, P. Szczypka
M.-O. Bettler, G. Conti, V. Fave,
N. Gueissaz, A. Keune, M. Knecht,
J. Luisier, L. Nicolas, C. Potterat

20 PhD theses

Blue = PhD physicist, Red = doctoral student
Underlined members currently have a management or
coordination responsibility in the LHCb collaboration
- Common readout board (EPFL):
  - adopted by most sub-detectors
  - ~300 boards in LHCb

- Vertex detector (EPFL):
  - analogue transmission line (drivers, repeaters, …)
  - power supplies, grounding

- Silicon tracker (design, development, construction):
  - Trigger tracker (Uni Zurich)
  - Inner track (EPFL)
LHCb silicon tracker

Station 3, 2, 1

Trigger Tracker

Inner tracker

2–3% dead channels in Sep 2008
(being fixed, aim 99% working)
LHCb commissioning

- Commissioning with real tracks:
  - LHC synchronization tests (TED data, Sep 2008)
  - rare cosmics events

First TT pulse height signal
S/N ~ 12–13 (most prob.)

TT residuals for extrapolated IT tracks
(width dominated by MS)

TED data

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Search for $B_s \rightarrow \mu\mu$:
- highly sensitive to new physics
- 90% CL upper limit can
  - pass final Tevatron limit with 0.1 fb$^{-1}$ of data
  - go down to SM value with 2 fb$^{-1}$
- SM signal can be observed (5σ) with 10 fb$^{-1}$

Other analysis topics for the near future:
- $\Lambda$ production, $J/\psi$ production
- PDFs with $Z \rightarrow \mu\mu$ and $\gamma^* \rightarrow \mu\mu$
- $B_s$ mixing and CP violation $B_s \rightarrow J/\psi\phi$ decay
- Observables in $B^0 \rightarrow K^{*0}\mu\mu$ decays
- New Physics with displaced vertexes
Swiss participation since 1984. Current members:
- UniZh: U. Straumann, P. Truol, K. Müller, P. Robmann, K. Nowak
- ETHZ: C. Grab, M. Sauter
- PSI: S. Egli, M. Hildebrandt, R. Horisberger

Hardware:
- Central Si Tracker (ETHZ+PSI+UniZh)
- Fast Tracking Trigger (ETHZ)
- Central Inner Prop. chamber (UniZh+ETHZ)
- z vertex trigger (UniZh)
- ...

PhD theses:
- UniZh: 16 completed, 1 ongoing, 1 to come
- ETHZ: 18 completed, 1 ongoing

HERA stopped mid-2007

- Heavy flavour measurements (s, c, b)
- Strangeness production (K_S and Λ)
- Pentaquark search
- q and φ production
- bb → ee production
- charm production in charged current events

Δ production in DIS vs p_T and η
(M. Del Degan, C. Grab)

2 < Q^2 < 100 GeV^2, 50 pb^{-1}
preliminary 2008 result, submitted to EPJ

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Production of isolated photons in association with hadrons:
- sensitive to proton and photon PDFs
- possible signature for New Physics
- important to understand background in $H \rightarrow \gamma\gamma$ search at LHC

Recent analyses:
- isolated photons in DIS (C. Schmitz)
- isolated photons in photo-production (K. Novak)
- close collab. with theory group (Th. Gehrmann)

Full 2004–2007 sample, 340 pb$^{-1}$
preliminary result shown at DIS2008 & ICHEP08
Uni Geneva participates since 1990
- Current members: A. Clark, X. Wu, A. Lister, J. Garcia Navarro

- Construction contribution:
  - SVT offset track trigger for CDF2 (with Pisa, Rome, Chicago)

  - 11 PhD theses completed, of which 9 are ATLAS+CDF
  - 3 additional PhD theses from ETHZ (CMS group) as visitors through Geneva
Geneva @ CDF

Involvement in many analyses:

- **High p_T physics**
  - Diboson production
  - W helicity

- **QCD measurements**
  - bbγ
  - bb cross section
  - bγ
  - γγ
  - Inclusive b-jets cross section
  - …

- **Low p_T physics**
  - B_s → hh lifetime
  - B_s and B_d rare decays
  - …

γγ production (Y. Liu)

bb production (S. Vallecorsa)

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UniZh @ D0

- Uni Zurich participation (2001–2008)
  — U. Straumann, F. Lehner, R. Bernhard, A. Wenger

- Hardware:
  — contributions to design and commissioning of Layer 0 (vertex detector)

- B physics analysis
  (as training ground for LHCb)
  — PhD thesis (R. Bernhard, 2005) on search for $B_s \rightarrow \mu \mu$
  — PhD thesis (A. Wenger, 2008) on search for $B^+ \rightarrow K^+ \mu \mu$ and $B^0 \rightarrow K^{*0} \mu \mu$
  — + habilitation (F. Lehner, 2006)
Lausanne participates since 2001

- Current members:
  A. Bay, O. Schneider, A. Aushev, R. Louvot, N. Zwahlen

Service tasks:
- lepton ID systematics (till 2007)
- MC production at EPFL
- convenership of “Indirect CP violation” analysis group

Data analysis:
- 5 PhD theses completed, of which 4 are LHCb+Belle
- + 2 other analyses completed
- 1 ongoing PhD thesis
Topics using $\Upsilon$(4S) data:
- $B$ mixing + tests of quantum mechanics (BB-pair quantum entanglement)
- Search for $B^0 \rightarrow \gamma \gamma$
- $B \rightarrow \phi K \gamma$, $B \rightarrow \omega K \gamma$, resonant $B^+ \rightarrow K^+\gamma \gamma$
- Evidence for CP violation in $B^0 \rightarrow D^{*+}D^{*-}$
- $X(3872) \rightarrow D^{*0}\overline{D}^0$ mass and width

Topics using $\Upsilon$(5S) data:
- $B_s$ and $B_s^*$ masses
- $B_s \rightarrow D_s \pi$ branching fraction
- Search for $B_s \rightarrow \gamma \gamma$
- First observation of $B_s \rightarrow \phi \gamma$

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Old collider frontiers:

- Swiss groups maintained physics analysis activities at the major frontiers: HERA, Tevatron and B factory
- Good for PhD students, and good for preparation in view of LHC
- Will now phase out with LHC startup

New LHC frontier (ATLAS, CMS, LHCb):

- Large involvement of Swiss groups, including leadership at all levels
- Large construction effort over many years, successfully completed
- Strong involvement in commissioning
- Ready to start physics program and search for new phenomena
- Also preparing in view of future detector upgrades