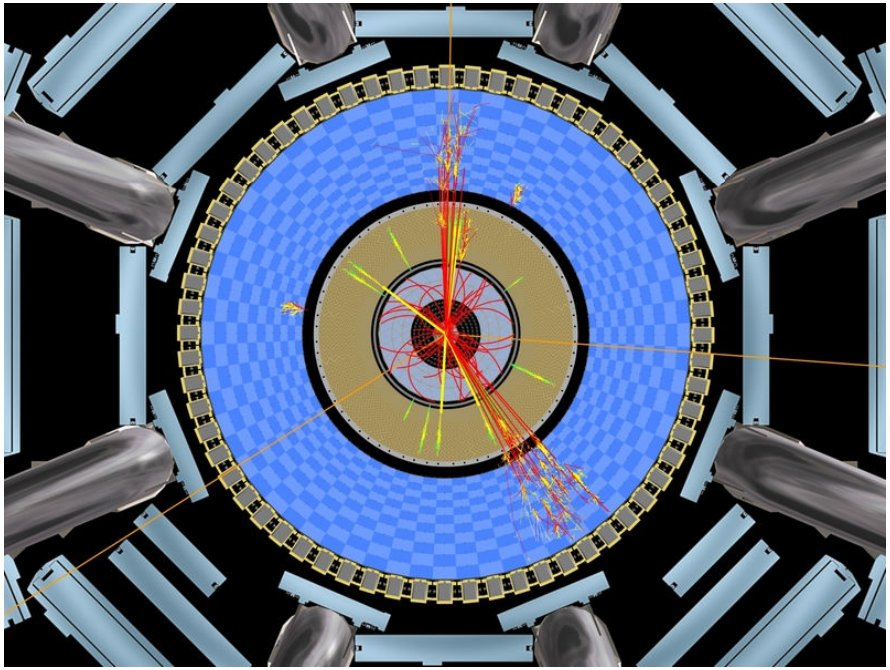
Planning for the 7. International Masterclasses "Hands on Particle Physics" 2011

A concept for the future LHC physics content of the International Masterclasses



EPPOG outreach meeting, CERN, 30.10.2009

Michael Kobel

Outline

- **Boundary Conditions**
  - **Authentic feeling**
  - **Practical Performance**
  - **Insights**
- **Proposed physics tasks**
  - **Start close to students**
  - **Step 1,2,3 from basic measurements to new physics**
- **Planning**
  - **Timeline**
  - **Personnel**
- Possible synergy: Netzwerk Teilchenwelt

Boundary conditions I : Authentic Feeling

- Work as much as possible with **real data**
  - Use real events from 7 TeV and 10 TeV running in 2010 (at least for all known “background” processes)
  - Add simulations for new physics (as long as nothing new is discovered in real data)

- Compare and discuss the measurements
  - Within the same data sample between different students
  - Compare and combine samples from different experiments
    - at least ATLAS+CMS
    - stay open for ALICE and LHC-b, to be discussed

- Discuss with scientists
  - Get insight into scientific process by
    - **thorough cross-checking of measurements**
    - **theoretical interpretation of measurement method(s)**
  - Get insight into sociologic working conditions (video conf: international team work, etc.)

Boundary conditions II: Practical Performance

- Start close to the knowledge of the students

- Make measurement feasible in given time
  - ***Concentrate on counting (check list)***
  - Preparation of dataset necessary (preselection, bias?)

- Avoid “black box” components as much as possible
  - ☹ Invariant mass is pretty remote for 16-year-olds
  - ☺ ***angles, energy are known to 16-year-olds***

- Miscellaneous
  - Leave enough room for student’s own thinking
  - **Plug and Play for ~ 80 institutes (not only for the authors of the packages)**
  - **Guarantee Flexibility for whatever the LHC will find**

Boundary conditions III: Insights

- Convey the aims and challenges
  - LHC as discovery machine (<-> LEP as precision machine)
    - Understand known processes
    - Find new phenomena beyond known processes
  - LHC challenges
    - Much more background than signal
    - Signal process embedded in complicated events
- Concepts to understand
  - Particle identification
  - Signal and background
- Fundamental insights via easy arguments are important
  - LEP: lepton universality and α_s from counting events
  - LHC: fundamental insights and potential discoveries

Proposal for measurement tasks:

- Do measurements by ***identifying and counting***
  - Number of **Leptons** (e and μ) in an events
  - Number of **Jets** in an event
- Further boundary conditions for events
  - missing transverse momentum (**missing Energy**)
    (preselected events w/ large missing E, readily reconstructed)
- Possible extension:
  - Angle between Leptons
- **3 Basic Quantities: Leptons, Jets, missing Energy**
- 2 possible extension: Angles

Authentic method, used by scientists

- Example: Supersymmetry at 10 TeV

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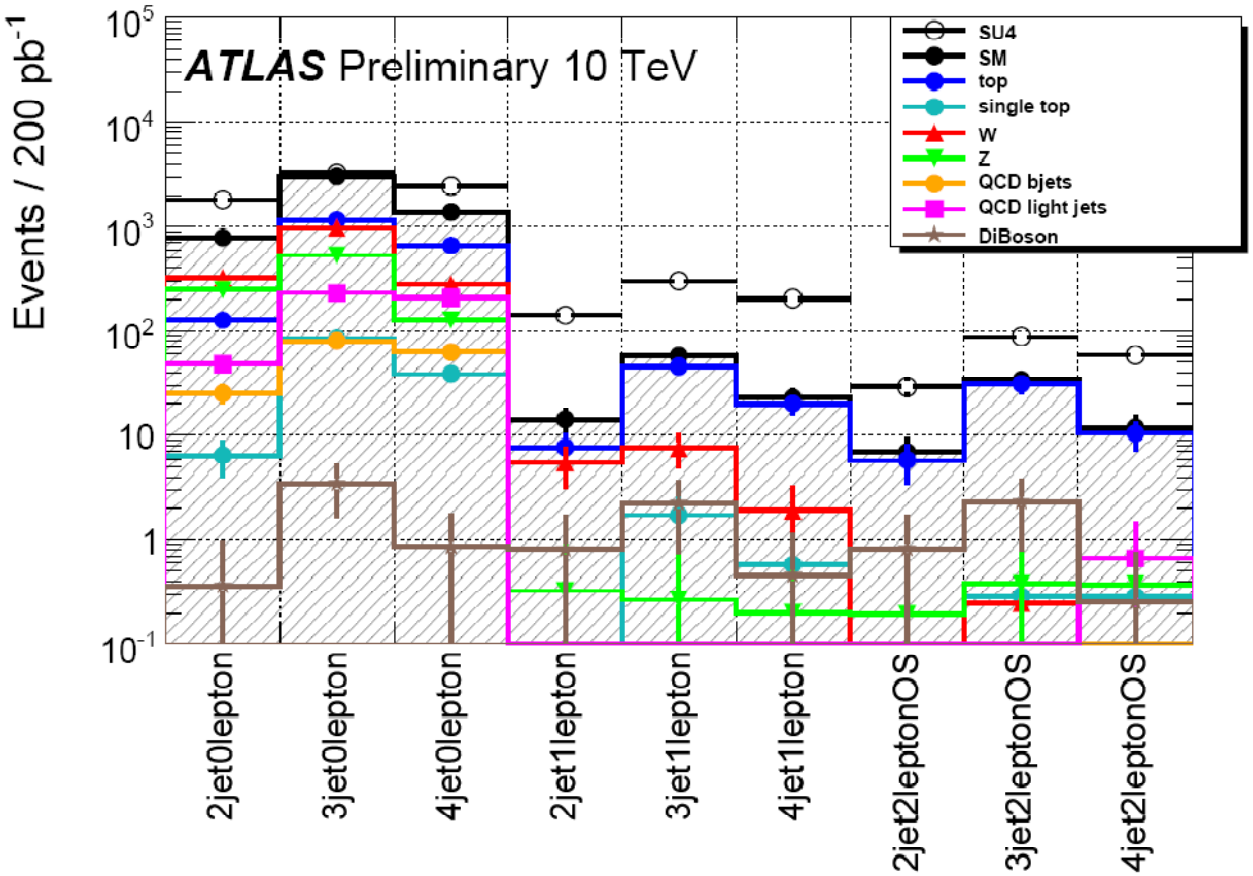


Figure 2: Number of events expected for 200 pb^{-1} in 0-lepton channels and multi-leptons channels after preselection for the main background processes and the SUSY signal SU4.

Most interesting categories

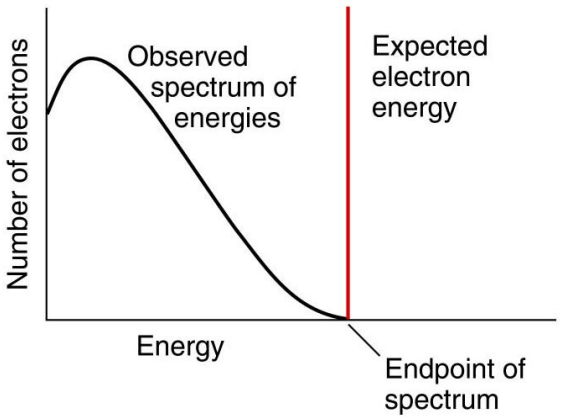
- *very* rough sketch (all with missing energy)

Leptons	0	1					2, opposite sign					2, same sign				
Jets	**x**	**0**	**1**	**2**	**3**	**4**	**0**	**1**	**2**	**3**	**4**	**0**	**1**	**2**	**3**	**4**
Eweak		$\bar{q}q \rightarrow W$	**$gq \rightarrow Wq$**				**$\bar{q}q \rightarrow WW$**		$qq \rightarrow qqWW$					$qq \rightarrow qqWW$		
Top						**$gg \rightarrow tt$**			**$gg \rightarrow tt$**							
Higgs							**$gg \rightarrow H \rightarrow WW$**		$qq \rightarrow qqH \rightarrow qqWW$							
SUSY																**$gg \rightarrow g\,g \rightarrow qqqq\chi^0\chi^0WW$**

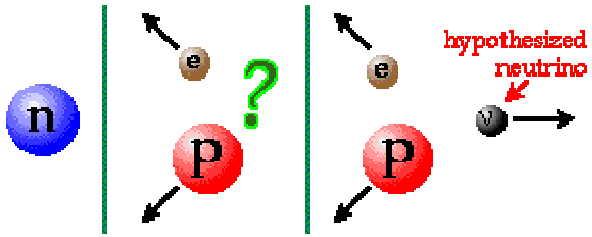
- Examples for
  - Standard Model processes (basic measurements)
  - Higgs search (new, large background)
  - SUSY search (new, smaller background)

Physics Proposal step 0: start close to students

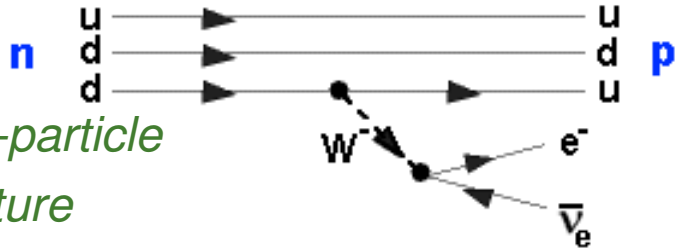
- Beta-Decay of Neutron
  - 1914 Chadwick β-Zerfall: n → p + e- unexpected energy distribution



  - Pauli (1930) postulates new particle: Neutrino ν

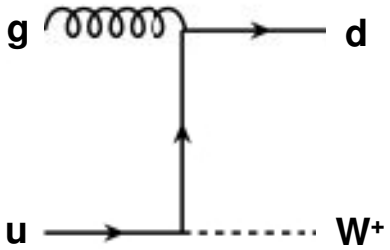


  - Today's view:
    - Process goes via intermediate *W-particle*
    - *missing Energy = Neutrino Signature*

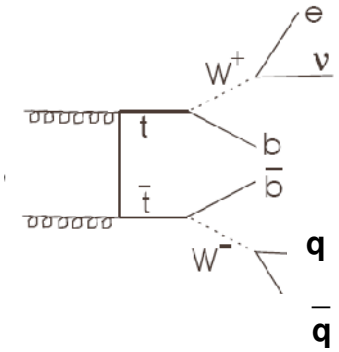


Physics Proposal step I: single W

- Look for 1 Lepton and 1 Jet
  - $g + u \rightarrow W^+ + d \rightarrow \ell^+ + \nu + d$
  - $g + d \rightarrow W^- + u \rightarrow \ell^- + \nu + u$



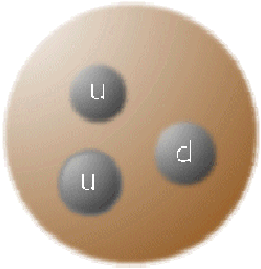
- **Build ratio of**
  - Number of positively charged leptons
  - Number of negatively charged leptons
  - Result from diagram above, if no background: 2:1 (2 u-quarks and 1 d-quark in proton)
  - Washed out e.g. by tt background (1:1) (usually much more than just 1 Jet)



Insights I

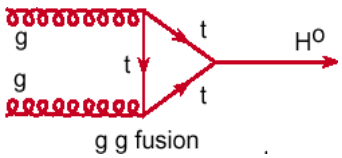
- Fundamental insight just by counting charges!
  - Proton has more u-quarks than d-quarks

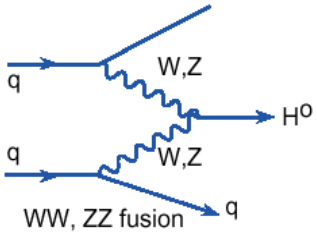
Proton



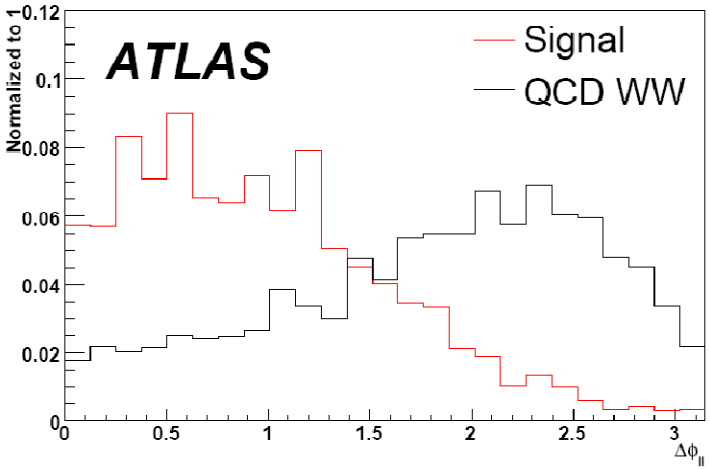
Physics Physics Proposal step II: WW pairs

- Identified via **2 Leptons**: $W^+ W^- \rightarrow \ell^+ \nu \ell^- \nu$
- Produced via
  - Eweak/QCD: $\bar{q}q \rightarrow WW$, **$qq \rightarrow qqWW$**
  - Higgs: **$gg \rightarrow H \rightarrow WW$, $qq \rightarrow qqH \rightarrow qqWW$**
  - Top: **$gg \rightarrow tt \rightarrow bbWW$**





- **Task: Search for excess over known Eweak process**
  - Reduce top by **requiring 0 jets**
  - Compare remaining number with expectation from WW (Excess maybe Higgs?)
  - Check via additional information: angle $\Delta\phi_{\ell\ell}$ between leptons Higgs would have low values



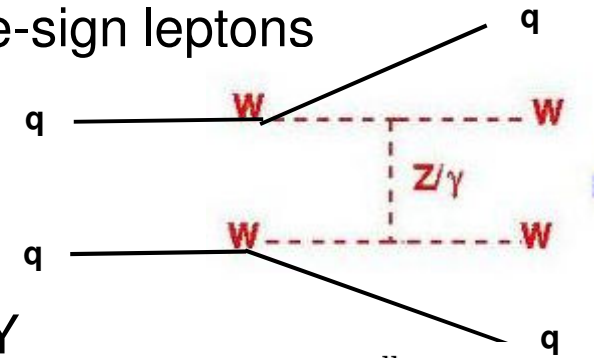
- *CERN-OPEN-2008-020*
  (ATLAS, Higgs Boson in Gluon Fusion
  Higgs Signal not to scale!)

Insights II

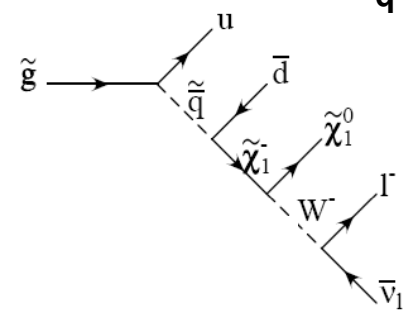
- **Concept of signal and much larger background**
- **Let students find the separation concept (0 Jets)**
  - Background still larger than signal
    → signal not event by event, but with statistical methods
  - have to be well understood
- **Larger statistics of data helps**
  - Build up $\Delta\phi_{\ell\ell}$ peak combining many data
    - from several groups
    - from several experiments ATLAS+CMS
    - maybe even over several years?

Physics Physics Proposal step III: Same-sign Leptons

- Only very rare SM processes have same-sign leptons



- Prominent new physics possibility: SUSY
  g g → → qqqq$\chi^0\chi^0$WW
  (Searching for SUSY w/ same-sign leptons)



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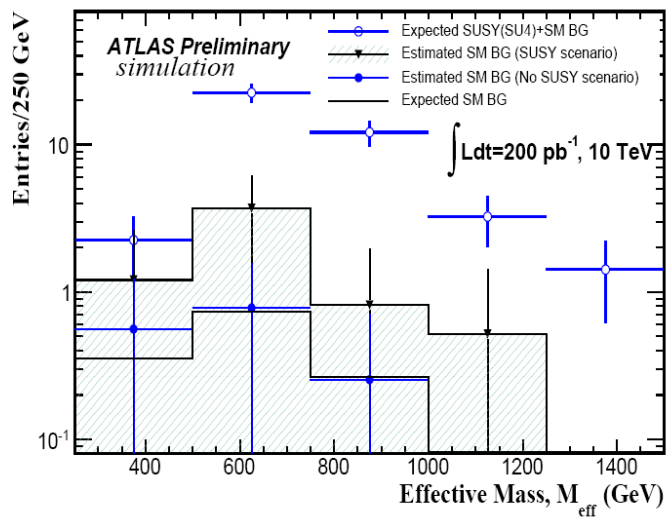

Figure 3: Effective mass distribution for same-sign dileptons in the inclusive two-jet and missing-energy final state. The events are for 200 pb^{-1} integrated luminosity at 10 TeV CM energy. SU4 SUSY signal events are considered for this figure.

Insights III

- **Let students again find separation concept: e.g. 4 Jets(?)**
- **Experience very rare events**
  - Just a handful (0,1,2,..) events in a whole year of data
    - Main example: Same-sign leptons
    - mention also: 3 Leptons + Jets , etc.
  - Background is now often experimental misidentification
    - has to be well understood
- **Dark Matter (Neutralinos) also causes missing Energy**
  - Not to distinguishable from neutrinos
  - Increases total amount of missing energy

Timeline

- Finish developing concept ~ by January 2010
  - Didactical
  - Physics content
- Get both ATLAS and CMS on board
- Check requirements to user interfaces
  - HYPATIA, MINERVA, AMELIA, etc.
  - Anything new? Globe?
- Build first testing package in spring 2010
  - Test with high school students in summer 2010
  - → Beta Version for broader use in Masterclasses 2011

Personnel

- Professional Didactics
  - Prof. Gesche Pospiech (Didactics, Dresden)
  - Gentner Program Ph.D. student Konrad Jende (since 08/09)
- Physics event sample
  - ATLAS: Dipl. Päd. René Schulz (student teacher, Dresden) (from 02/10) with the help of
    - Dresden group
    - Oslo group, …
  - CMS: ???
- Organisatorial effort
  - Uta Bilow, Michael Kobel
  - Student assistants for technical work
- Any help from EPPOG highly welcome! (and needed)

Related Future Prospect: National „Netzwerk Teilchenwelt“ in Germany

- Application for a **national network of young people, project leaders, and scientists** for particle physics and cosmic ray physics submitted this month **(inlcuding teachers and high school students, but broader than that)**
- 4 branches (nationwide coverage)
  - Local **National Masterclasses** (schools, museums, etc.)
  - Development of **material for preparation and wrap-up**, plus further studies
  - **Workshops at CERN** (including project weeks, hands on: Cosmics, OGRE?, …)
  - **Professional evaluation**, also w.r.t. sustainability (Didactics)
- Hierarchical program for project leaders and young people:
  4 levels with decreasing number of participants
  - **Basic program**: 400 project leaders + 6000 young people / year
  - **Qualification program** 50 project leaders + 100 yound people / year
  - **Active „Teilchenwelt“ Members**
    - 200 project leaders for 5 years or longer
    - 200 Students for typically 2 years
  - **Work in research goups**: 5 project leaders + 10 young people / year
- (Hopefully) going to be realized from 2010 onwards
- **Would build ideal basis for tests of new LHC material**