Particle Physics Masterclasses: Sharing LHC Research and Discovery with High School Students

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Why LHC Masterclasses?

- HEP is a fascinating topic, but rarely covered at school
- Our duty:
  - Inform about findings, questions and discoveries
  - Inspire the next generation of physicists
  - Create an appreciation for basic research
- Masterclasses: high school students (16-19 y) learn about HEP in a one day course, with help of physicists

Key Features of LHC Masterclasses

High school students are scientists for one day

- Own hands-on activities
- Use the same methods and tools like scientists
- As close as possible to current research
- Direct contact with (young) physicists

LHC Masterclasses are organized within several programs

- International Masterclasses (global) www.physicsmasterclasses.org
- Netzwerk Teilchenwelt (German project) www.teilchenwelt.de
- Plus many more use cases

International Masterclasses

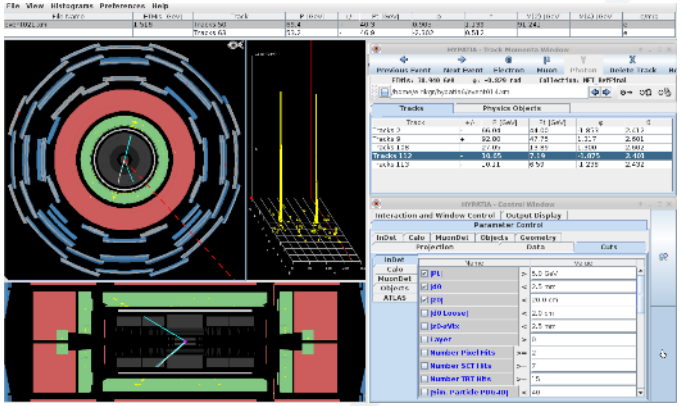
- At university or research lab
  - Introductory presentations
  - Taylor-made physics analysis with LHC data (all LHC experiments have designed measurements, translated in many languages)
  - International video conference (5 inst. + CERN/Fermilab)
- Run by IPPOG http://ippog.web.cern.ch/

International Masterclasses

- Every year in spring
- 52 countries involved
- 225 universities / research labs
- Reaching 14k high school students
- Coordination:
  TU Dresden / QuarkNet

ATLAS Z path

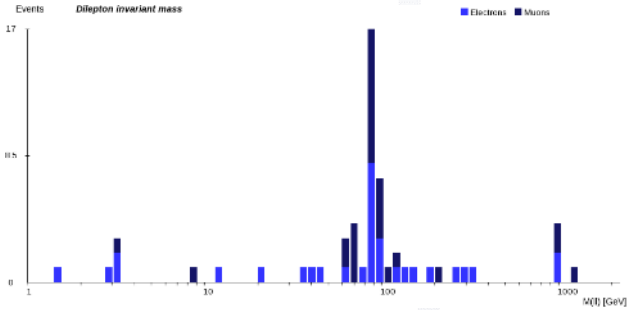
1) Identify events: ll, 4l, $\gamma\gamma$

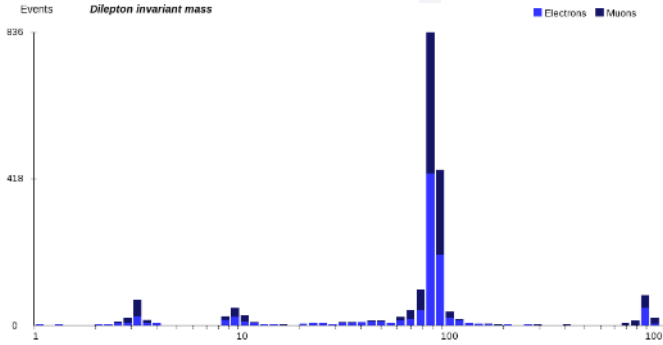


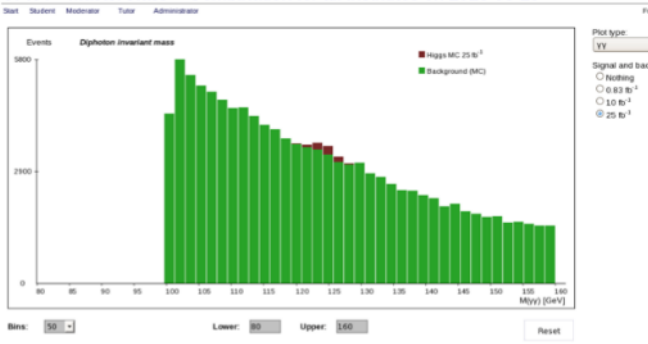
2) Calculate invariant mass

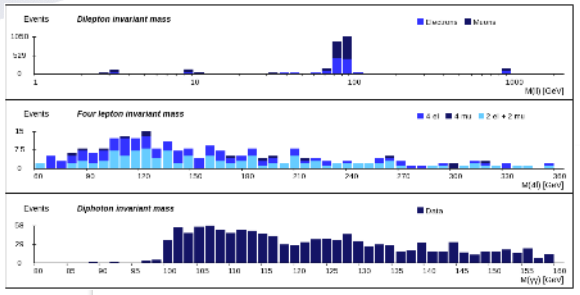
3) Upload results

4) Combine results, discuss, interpret









ll ➔ Measure mass and width of known particles: Z^0,J/ψ,Υ

➔ Search for new force / new gauge boson: Z‘

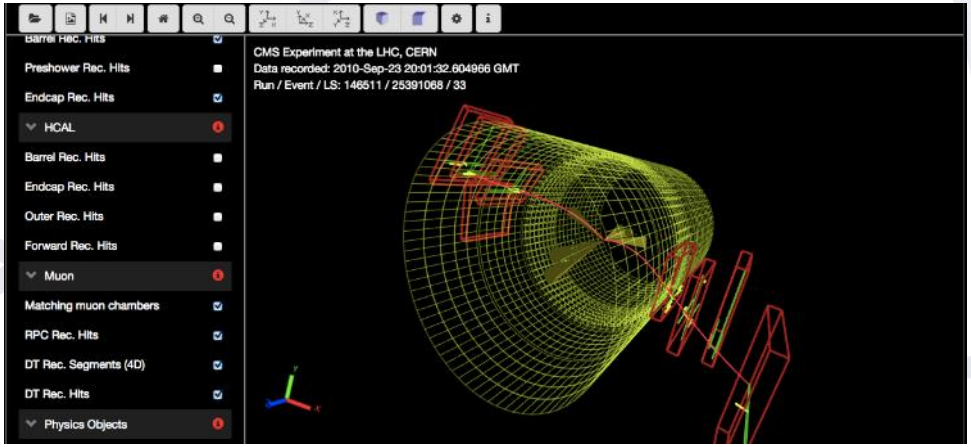
4l, $\gamma\gamma$ ➔ Provide insight into the process of discovering the Higgs at CERN

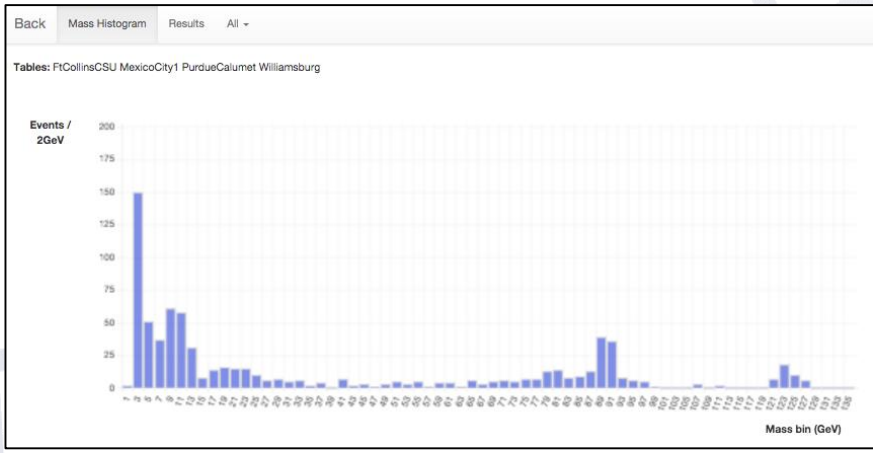
➔ Explain concepts of statistics, modeling, signal significance

http://atlas.physicsmasterclasses.org/en/zpath.htm

CMS WZH measurement

- WebGL 3D event display
- Students characterize W, Z, and Higgs candidates
- Create mass plot of standard model particles that decay into 2 leptons, plus Higgs
- Ratios W+/W-, e/μ





http://cms.physicsmasterclasses.org/cms.html

Int. Day of Women and Girls in Science

- Declared by UN: Feb 11th www.un.org/en/events/women-and-girls-in-science-day/
- To support and promote the access of women and girls to science education and research activities
  - Since 2017: MCs for girls http://physicsmasterclasses.org/index.php?cat=women_in_science
  - Female lecturers and tutors (as much as possible)
  - Videoconferences with female moderators
  - Presentation on situation/numbers of women in physics

Netzwerk Teilchenwelt

- 30 univ./labs in Germany + CERN
- Central organization: TU Dresden
- Multi-level program for high school students
- At schools, school labs, science centers, museums…
  - 140 Masterclasses per year
  - In addition: Astroparticle Physics activities (detectors, web experiments)

NTW goes beyond Masterclasses

Workshops at CERN

- 60 s. in two annual CERN workshops (4 d)
- 10 s. at CERN for project weeks

own research projects, e.g. Medipix, CLOUD, ATLAS trigger system, LHC beam steering, ASACUSA, track finding…

www.teilchenwelt.de/mitmachen/jugendliche/projekt-fach-und-forschungsarbeiten/

Fellow Program

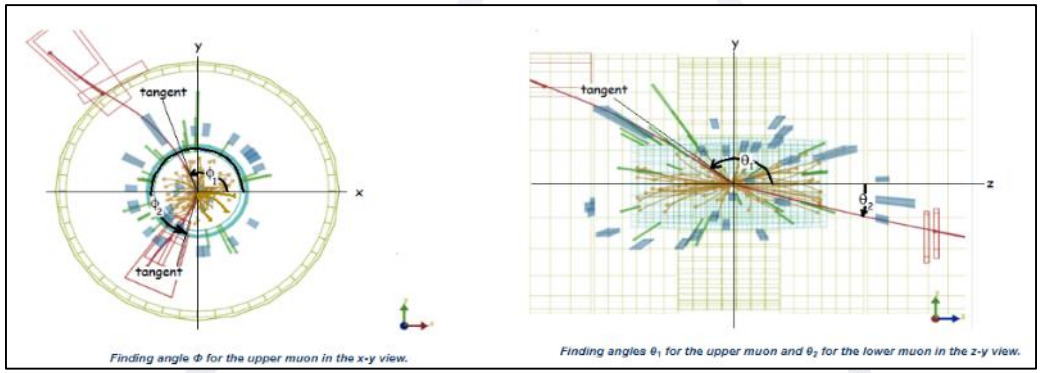
- Started in 2017
- Tighten links to research groups (mutual benefit)
- 120 Fellows (Alumni)

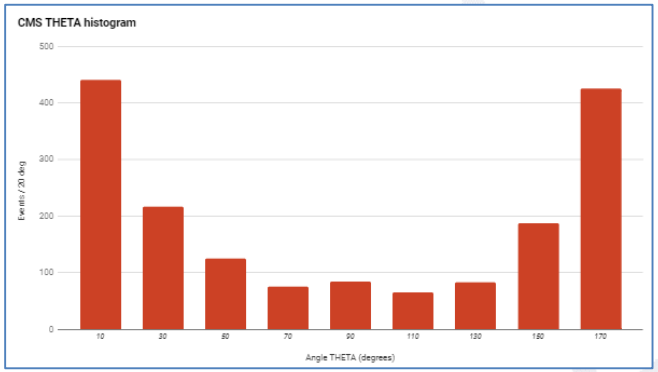
www.teilchenwelt.de/mitmachen/fellows/

„NTW helped me a lot in deciding to study physics. I learned how exciting physics can be, outside of school.“

World Wide Data Day

- Masterclass with “simple” measurement
- Students measure theta and phi for dimuon events





- Data analysis at school
- Physics discussion in Videoconf.
- Organized by QuarkNet
- Each year in Nov/Dec

http://tiny.cc/w2d2-17

Summary

- Masterclasses are a successful tool to engage young people with particle physics
- A variety of measurements from all LHC experiments is available
- Masterclasses can be organized in various settings
- You can contribute:
  - Organize an event / help as a tutor at your research lab
  - Moderate IMC videoconferences at CERN or Fermilab

Next International Masterclasses: March/April 2019

Interested? Contact: uta.bilow@tu-dresden.de

INTERNATIONAL MASTERCLASSES
hands on particle physics

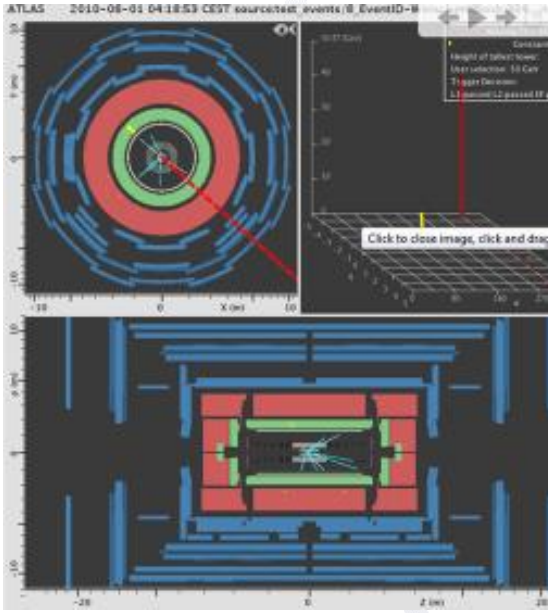
Backup slides

ATLAS W path

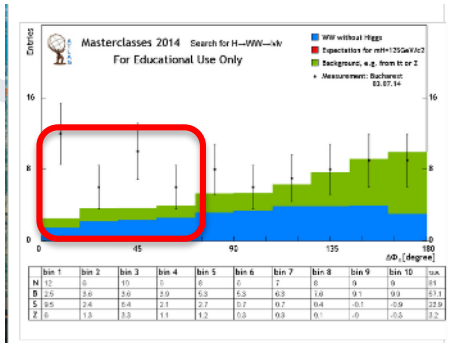
http://atlas.physicsmasterclasses.org/en/wpath.htm

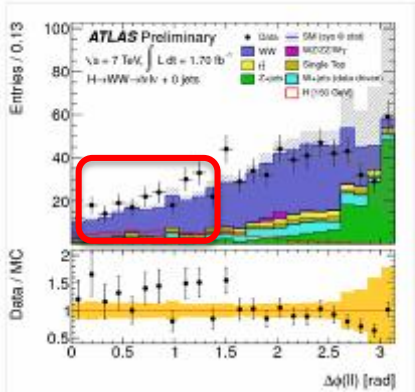
Each pair of students goes through 50 collision events

- Identify W bosons, count leptons and determine charge
- Resulting W+/W- is used to reveal the inner structure of the proton
- Ø 2015: 1.48 ± 0.02
- Identify W pairs and measure opening angle
- Resulting histogram is used to provide insight into Higgs discovery process at CERN



Total #	W → ... + ν				Backgro
532	e^+	e^-	μ^+	μ^-	
group A	9	4	10	1	24
group B	11	12	13	10	19
group C	5	3	1	1	19
group D	7	4	11	5	21
group E	11	10	3	2	31
group F	15	3	3	1	26
group G	6	4	3	5	27
group H	15	10	3	2	13
group I	5	3	3	4	5
group J	4	0	1	0	21
group K	5	1	5	3	18
group L	4	7	4	2	31

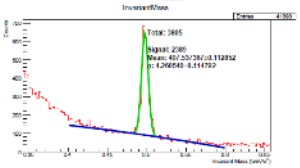




ALICE : Looking for strange particles

Search for strange particles from their V0-decays
Visual identification of V0s from their decay pattern
Invariant mass calculation

$K^0_s \rightarrow \pi^+\pi^-$ $\Lambda \rightarrow \pi^-p^+$ anti $\Lambda \rightarrow p^-\square^+$



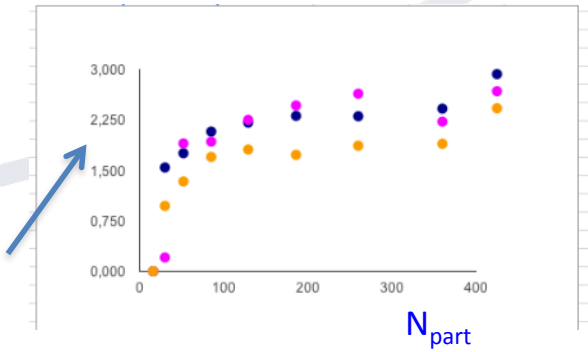
First part : visual analysis of ~ 15 events per group
Merging of results

Second part:
Calculation of numbers of Ks, Λ , anti Λ from invariant mass distributions (fit gaussian/polynomial to peak/background; subtract background) for different centrality regions in lead-lead collisions

Concepts conveyed : invariant mass; centrality of PbPb collisions; background

results : observe strangeness enhancement in Pb-Pb collisions comparing with pp collisions

Use ROOT-based simplified ALICE event display

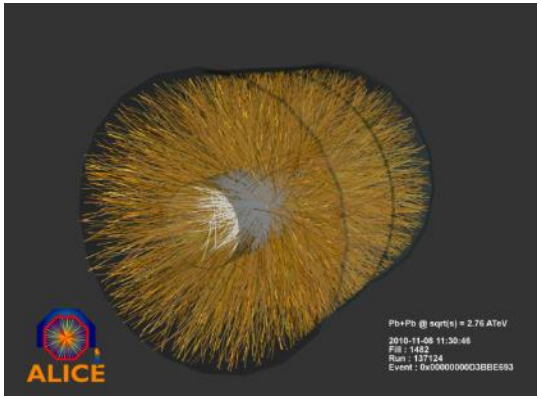


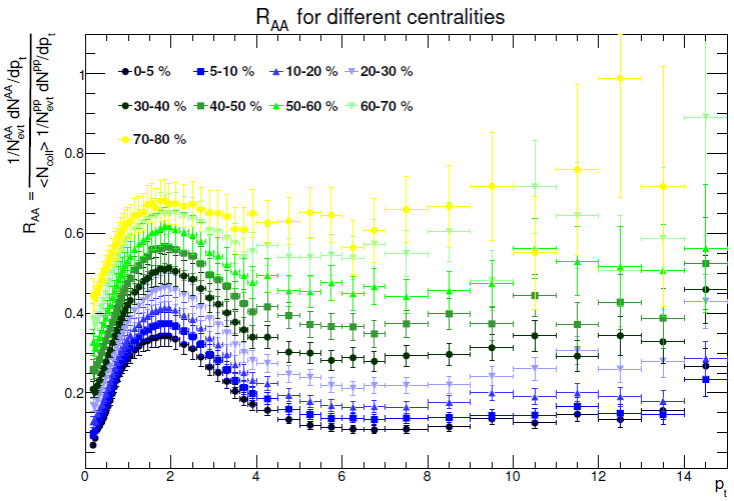
Strangeness enhancement: the particle yield normalised by the number of participating nucleons in the collision N_{part}, and divided by the yield in proton-proton collisions

http://alice.physicsmasterclasses.org/MasterClassWebpage.html

ALICE: nuclear modification factor

- ALICE: heavy-ion experiment at the LHC
  - study properties of deconfined matter: the Quark-Gluon Plasma
  - Pb-Pb collision ≠ independent pp collisions
- nuclear modification factor $R_{AA} = \frac{yield\ (Pb-Pb)}{\langle N_{coll} \rangle\ yield\ (pp)}$
  - ratio of transverse-momentum distributions of charged particles in Pb-Pb and pp collisions, taking into account the collision geometry
  - R_{AA}<1 implies jet suppression in the QGP
- students‘ measurement
  - necessary concepts: measurement of
    - charged particle momentum
    - collision centrality
  - event-display based visual analysis
    → R_{AA} simply via counting of tracks
  - ROOT based large scale analysis
    → R_{AA} as a function of momentum in various Pb-Pb centrality classes
    → students discover jet suppression!





http://www-alice.gsi.de/masterclass/

LHCb

See presentation from Luca Pescatore

“Status of outreach activities at LHCb”

https://indico.cern.ch/event/686555/contributions/2971029/