ZPath - past, present and future and putting it all together with J/Ψ

Maiken Pedersen, Farid Ould-Saada

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# Outline

- Invariant mass technique
- Z path procedure
- Technical comments, improvements
- Concepts comments, suggestions
- Webpage

Invariant mass technique I

LHC is all about discovery

- ▶ Invariant mass technique to rediscover the known and to discover the new

- ▶ Technique used on short-lived particles (Z boson and J/Ψ meson) in detector
  - ▶ decay products e+e- /$\mu^+ \mu^-$ measured
  - ▶ identify electrons and muons in collision events recorded by ATLAS and CMS at LHC
- ▶ add energies and momenta of decay products to form energy and momenta of hypothetical decaying particle's invariant mass with usual Energy-momenta equation

$$m_0 c^2 = \sqrt{E^2 - \vec{p}^2 c^2}$$
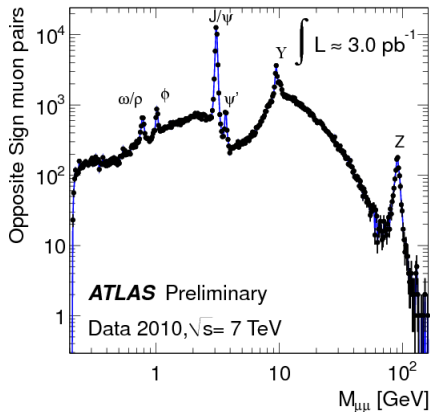
Invariant mass technique II
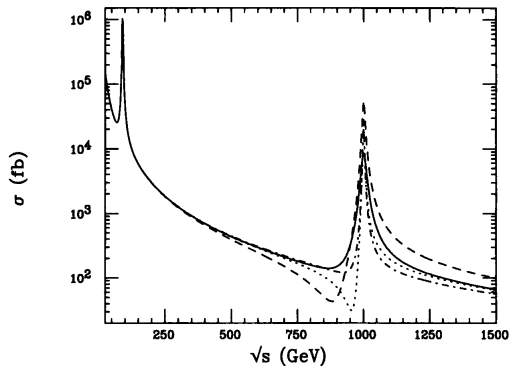
- method is general, applies to different particle kinds
- Z: elementary, mediator of weak interactions
- J/Ψ : composite, made of quarks
- $Z^{'}$: predicted beyond Standard Model, not yet discovered!

Zpath MasterClass - positive feedback

- In general Masterclasses are exiting and fun for students.
- They really liked to work with real data
- Students (most) thought it was fun to "discover" the Zprime

Wish from students:

- To feel they are working as close to how scientists do as possible

Current procedure

Students

(a) Identify particles

(b) Identify events

(c) Analyse 50 Z$\to \mu\mu$, *ee* events in HYPATIA, and combine objects in HYPATIA for inv mass calc

(d) Enter invariant mass in another tool (used excel sheet)

Institute responsible

1. Institute combines students results
   - Pick up students results either from google-docs or from memory-stick
   - Open a semi-automatic combination excel sheet

2. Snapshot of result, extraction of mass, width

3. Upload results for moderators

For moderators

(A) J/Ψ and Z results combined in one presentation for moderators

Obviously way too many steps

Comments on todays procedure

Technical

- ▶ HYPATIA too slow, due to bug-workaround
    - ▶ Expect this not to be an issue in future - expect fix instead of workaround
- ▶ Excel sheets was a choice for combining results per institute due to lacking feature in HYPATIA
- ▶ "Everyone" has Excel/OpenOffice
- ▶ Combination of results was far too complicated - too many steps until final result could be presented
- ▶ Too late preparing/thinking about how the results of both the Z and the J/Ψ measurements should be presented together at the videoconference.
- ▶ The final versions of the excel sheets were ready too late

Suggestions for improving technical part

- Points (d), 1-3 and (A) for improvement
- Students enter invariant masses in common tool
- Combination of students belonging to one institute is done automatically through same tool
- Both J/Ψ and Z path use same tool
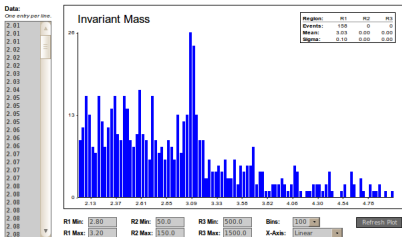- All J/Ψ and Z measurements automatically shown in one presentation page for moderators

Huge improvement

- No need for institutes to combine, prepare, upload results
- Work finished when students have entered their results

Suggestion - new upload/combination procedure
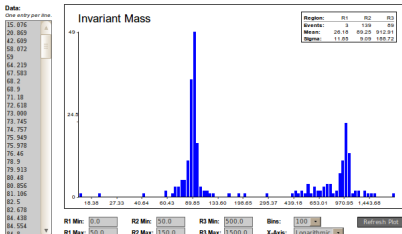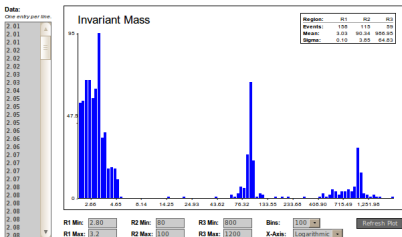
Tool prepared by Frank Olsen
Link to tool: http://folk.uio.no/frankol/masterclass/

Showing results - moderators
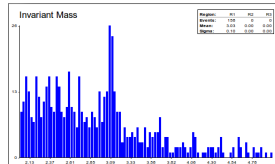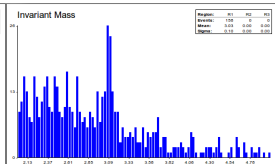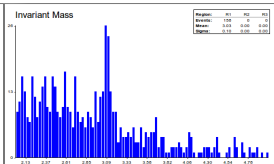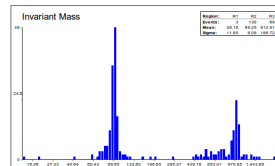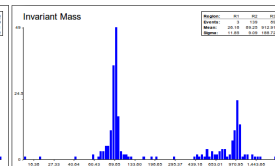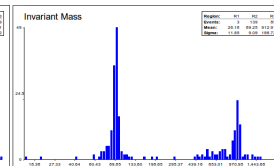
How to make the Zpath even more interesting for students?

- ► Students found the event-display part easy (or too easy)
- ► Too repetetive to go through event-displays in current version of the exercise
    - ► Could be due to a not perfect data sample
    - ► Would like to include more relevant Z background data
    - ► this could make the event-display part more challenging and interesting
    - ► Or should we move away from this repetetive exercise?
- ► Lectures
    - ► Students want to go more in detail of chosen topic: E.g. Zprime, Higgs, extra dimensions
- ► The Zprime - points to remember
    - ► Important to elaborate on the simulation technique
    - ► Emphasize that this is exactly the way we work - by creating a theory that extends our current understanding of nature and modelling it all through simulation
    - ► Then use our analysis techniques to see if we really could discover particles predicted by such a new theory

Future - improvements idea I

Analysis idea

- Go through a set of event displays in detail, maybe 20 per student group
- In order to find common features in event - signal cuts
- Use a tool to loop over the full selection - input/cut on some key properties of the Z events
    - Opposite sign
    - Same flavour
    - Energy
    - Phi
- Each group runs through the full set

- Pro
    - This would really enable students to work as we do!
- Con
    - Requires rather a large amount of development / manpower.

Future - improvement idea II. Video conference

- ▶ Finding some good base questions to discuss and highlight at the video conference is rather difficult
- ▶ Maybe this year it was extra bad because everything was new
- ▶ Really would like that the videoconference in a nice way tries to summarize what the students have found and what they have learned

Suggestion: Create a set of questions - each institute is given one to answer, but everyone knows about them all, then in videoconference we rather base the discussion on these questions?

Finally some words on the Zpath on web (or dvd)

A lot already done, but still needs quite a bit of work....

- Zpath - titles of pages dont necessarily correspond to whats inside
- Complicated navigation - non-intuitive, bad overview
  - Metro map idea - Marge?
- Too much text some places