A general search for new phenomena

HERA- LHC WORKSHOP
Oktober 2004

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- Idea and motivation
- A general search at H1 (and the LHC?)
- Important ingredients for a SM prediction
- Summary

Why is this interesting for the workshop?

- LHC physics may also profit from data analysis techniques used at HERA
- HERA data is well understood and could better be used for model tuning
- Do usual LO+PS Monte Carlos work within this approach?

Idea and Motivation

Question: Are there any new phenomena hidden in the data?

Solutions:

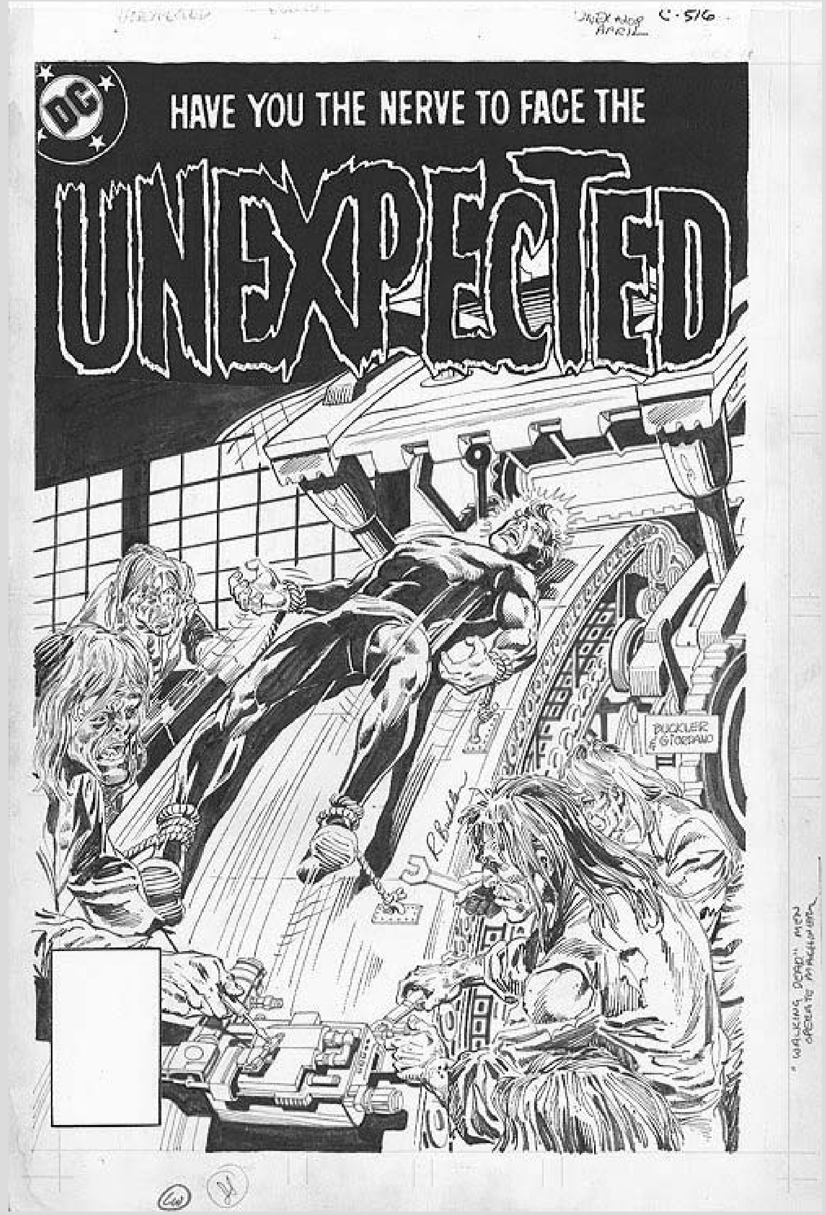
Check if the data is described by the SM prediction
(or search for deviations between data and SM prediction)

- Test of (BSM) models by searching for deviations in many specific data sub-sets
- (Global) fits to the data to check if the picture is consistent
- Measure final states and compare with the SM expectation
- Search systematically for deviations, e.g. with a search algorithm

How can we optimize the discovery potential?

Do we know what we want to look for?

Are we sensitive to the unexpected?



In how many final states do we search at the LHC?

Number of final states per BSM model:

(numbers are derived by counting on an afternoon and should not be taken too seriously)

Excited Fermions: about 20, e.g. ph-j, j-j, e-ph-jet,

4th generation and compositeness: about 10-15

Leptoquarks: about 20

W' Z', new gauge bosons etc. : 20-40 ?

Heavy quarks and leptons: 10? e.g. e-e-e-e-e-e, l-l-j-j-j-j

Dynamical symmetry breaking: 50? e.g. W-W, ZZ, toptop, bbjj, lllv,bjll, Ztop, Wb, Htop, …

Extra Dimensions and Black Holes: 20 + very high pt final states

+ many more + SUSY + …

= approx 100-500 final states

We measure at about 10 particles ($e^{\pm}$, $\mu^{\pm}$, $\tau^{\pm}$, jet, b-jet, photon, neutrino)

about 6000-40000 Final States!!

(depends if you distinguish charge etc.)

A Strategy

Search for deviations in all final states

(H1 General Search)

- They are all interesting
  Either as a background or as a signal
- Helps to find the origin of a deviation
  (experimental, Monte Carlo prediction or new physics?)
- Needs reliable prediction for all final states (or check if predictions are globally consistent)

Need to explore more (sophisticated) data analysis techniques

- Why not do the search with a search algorithm ?
  (DØ Sleuth: Idea to automatise a search ,
  H1 General Search: Develop a simple and powerful strategy)

General Search for new phenomena at HERA

- HERA1 data (1994-2000, L = 117 pb^{-1})
  HERA2 analysis is used as a watchdog

- Investigate all final state topologies in ep collisions (in 1 coherent analysis)
  Data is classified into exclusive channels (e.g. e-j)

- Considered particles:
  electron, muon, photon, jet (inv KT), neutrino

- Common phase space for all particles:
  $P_T > 20$ GeV and $10^o < \theta < 140^o$

What is the SM?

- The SM:
  Set of leading order ME + Parton shower Monte Carlos + assigned theoretical uncertainties + NLO K factors

Used are standard MC parameter settings (and pparp(64)=4) which are almost independent of the data

- Photoproduction: Pythia6.1 (k=1.2 for > 1jet production)
- NC DIS: Rapgap (k=1.2 for > 1jet production)
- CC DIS: Django-Ariadne (k=1.2 for > 1jet production)
- QED Compton: Wabgen
- EW dilepton: Grape
- W production: EPVEC (reweighted to NLO calculation)

Theoretical uncertainties assigned to the generator level process (e.g. 15% for photoproduction of jets and 10% for DIS)

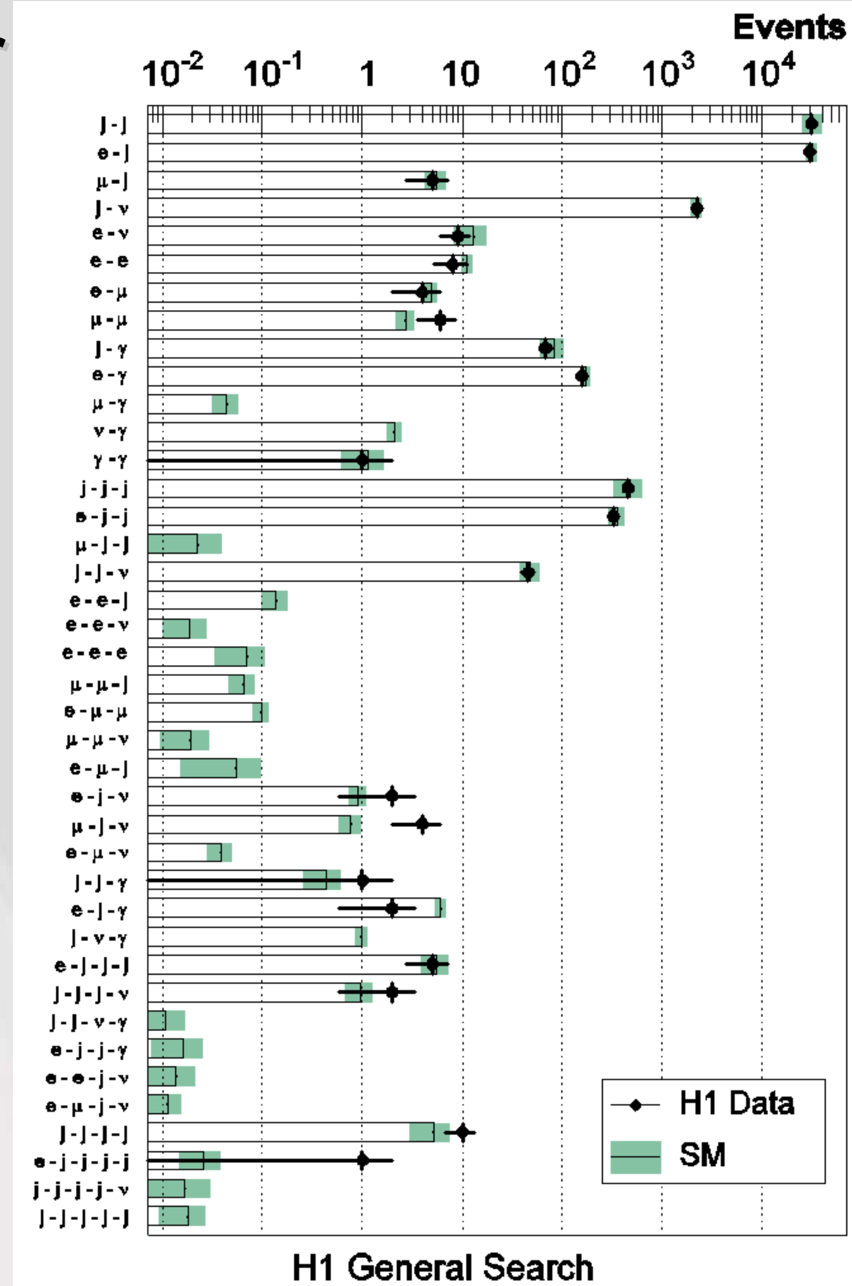
Additional uncertainty of 20% added for each jet produced by parton showers (checked with low P_T data)

A general Search for new phenomena

- Event yields for HERA 1 data
  (all channels with SM exp. > 0.01 event)

- Good agreement for (almost) all channels

  even Multi-jet channels



Search for deviations

Search for deviations between data and SM prediction in 1 dim. Distributions (M_{all} and ΣP_T)

- Check all connected regions with a size ≥ resolution in a histogram, i.e. calculate the probability p that data agrees with the SM

$$p = \begin{cases} A \int_0^\infty db\, G(b; N_{SM}, \delta N_{SM}) \sum_{i=N_{obs}}^{\infty} \frac{e^{-b} b^i}{i!} & \text{if } N_{obs} \geq N_{SM} \\ A \int_0^\infty db\, G(b; N_{SM}, \delta N_{SM}) \sum_{i=0}^{N_{obs}} \frac{e^{-b} b^i}{i!} & \text{if } N_{obs} < N_{SM} \end{cases}$$

$$\text{with} \quad A = 1 / \left[\int_0^\infty db\, G(b; N_{SM}, \delta N_{SM}) \sum_{i=0}^{\infty} \frac{e^{-b} b^i}{i!} \right].$$

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Search for deviations between data and SM prediction in 1 dim. Distributions (M_{all} and ΣP_T)

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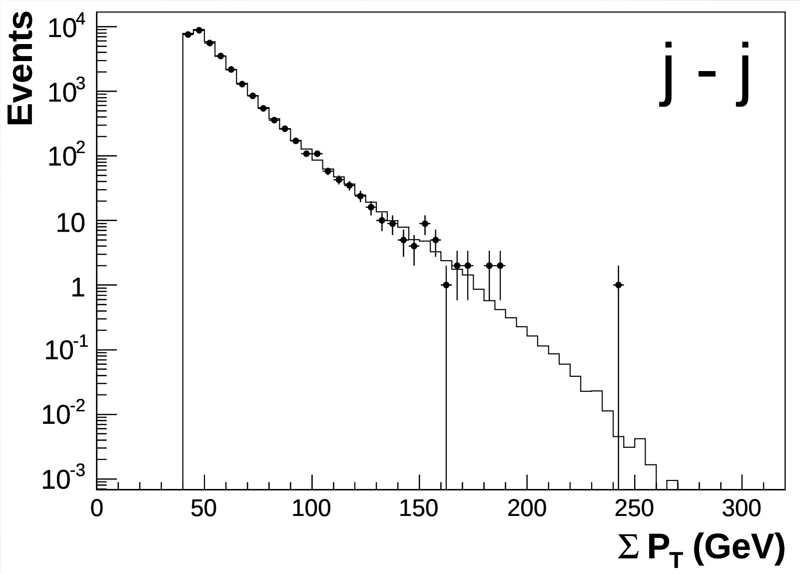
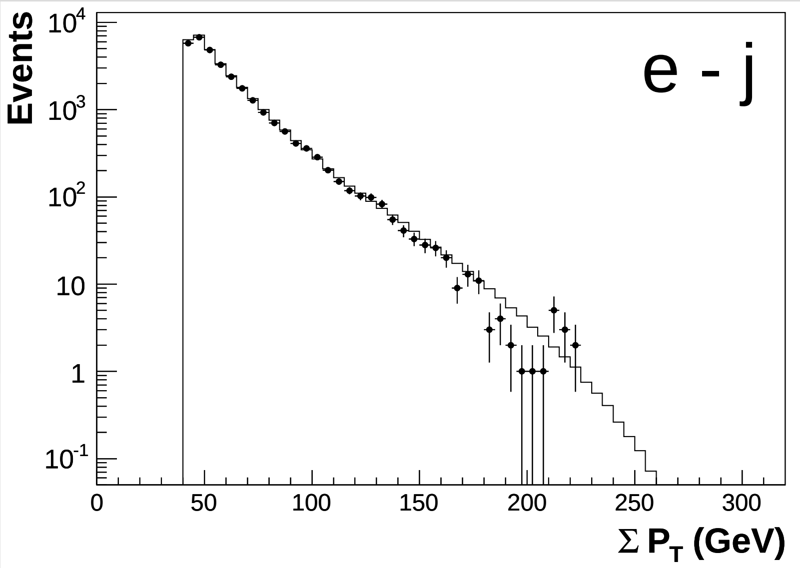
- Region of greatest interest is the one with the smallest p





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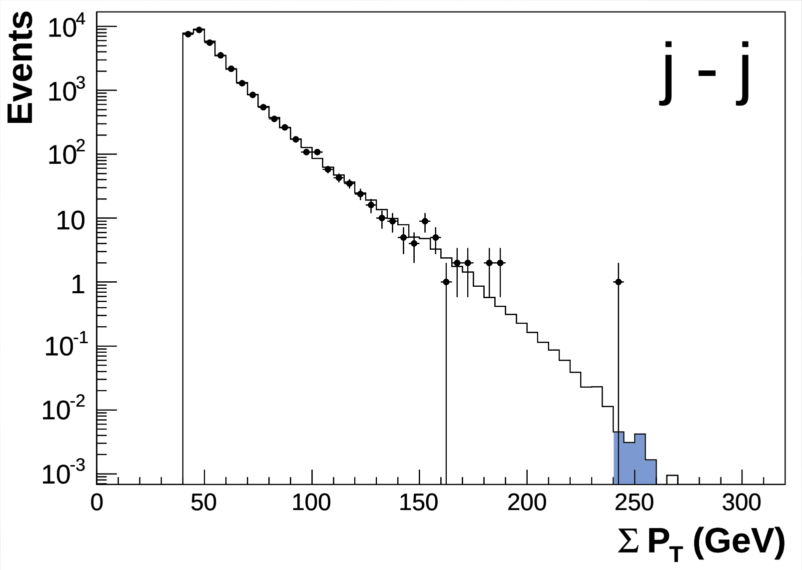
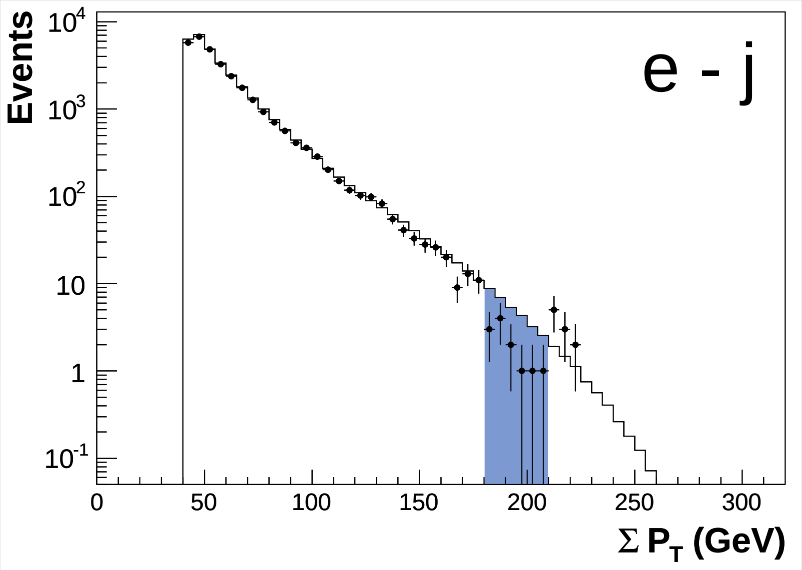
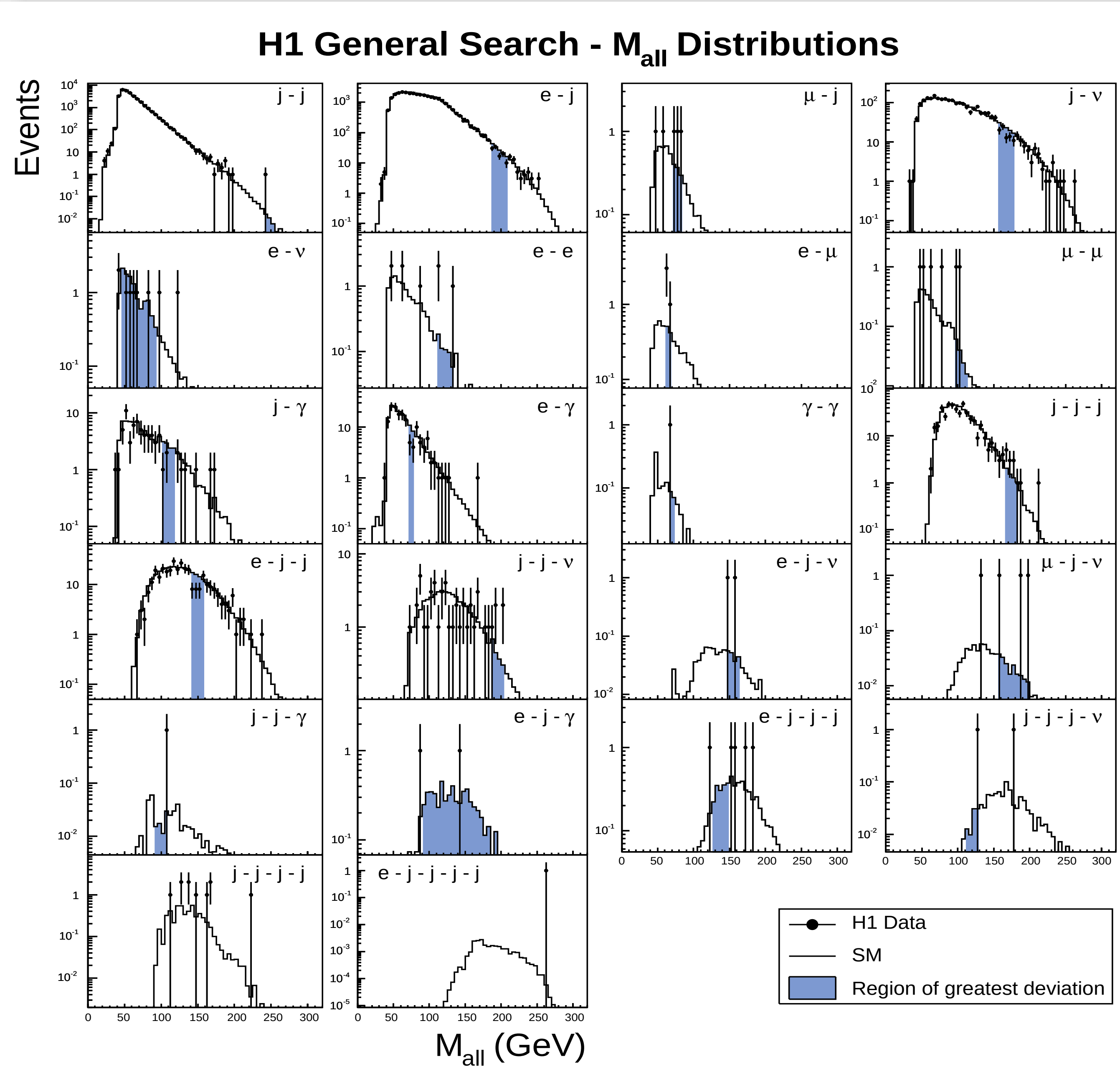




Investigate M_{all} and ΣP_T distributions

Find in each channel the region with the greatest deviation



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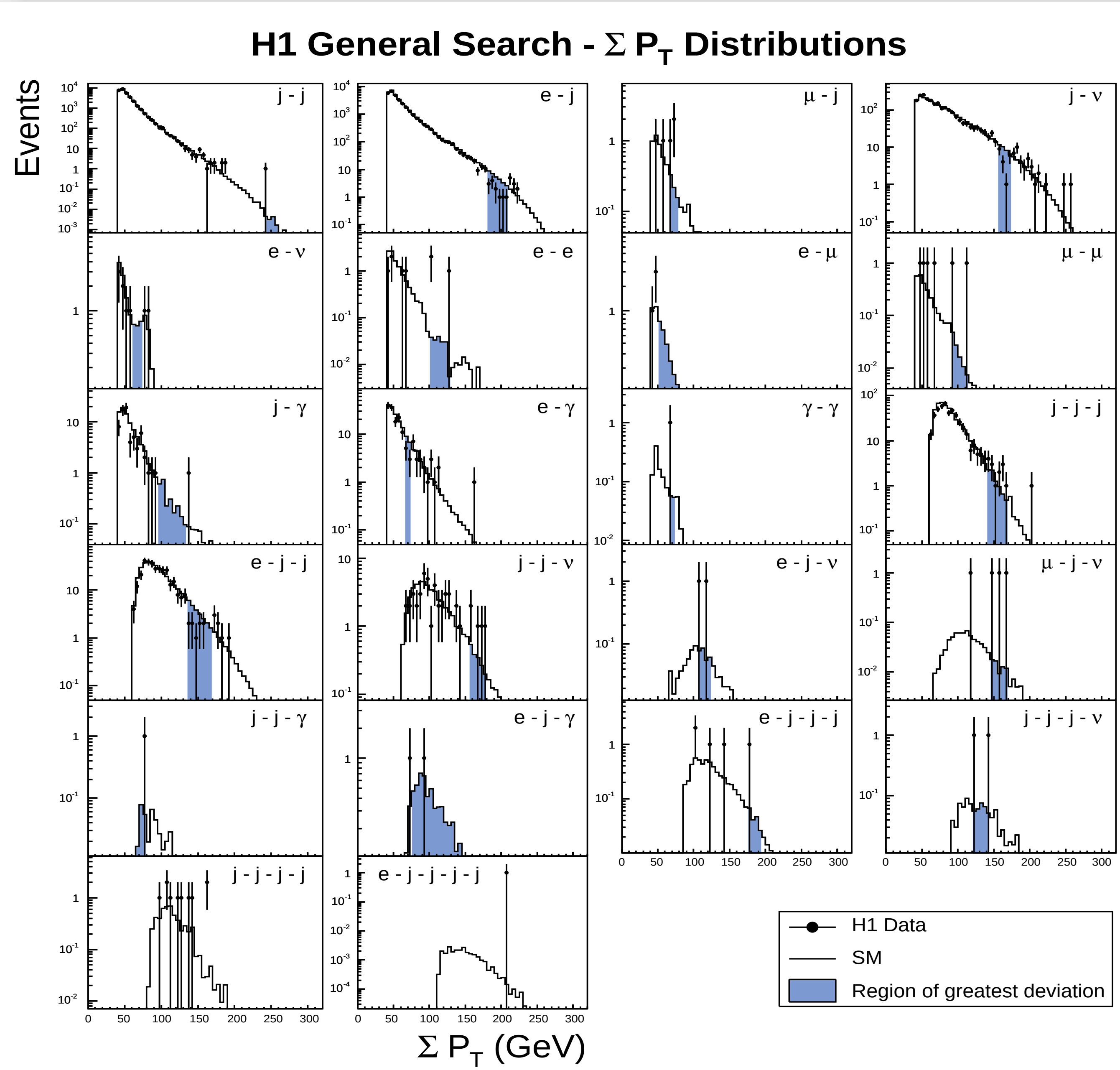


Quantify the deviations

Derive for each event class the probability $\hat{P}$ to observe a deviation anywhere in the spectrum as large as found in the data

Dice pseudo Histograms H according to probability density function of the expectations

$$\hat{P} = \frac{\text{number of pseudo H with } p_{min} < p_{min} \text{ in data}}{\text{number of pseudo H}}$$

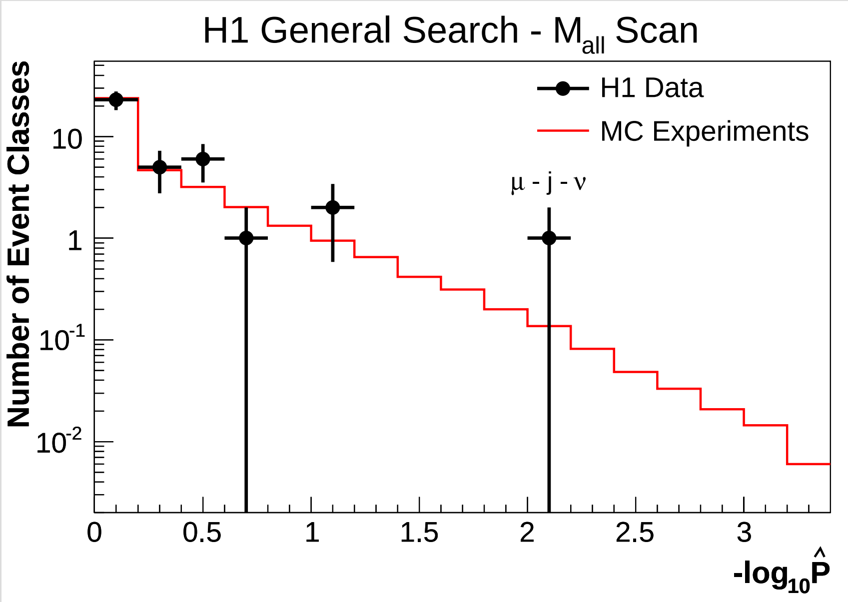
Quantify the deviations

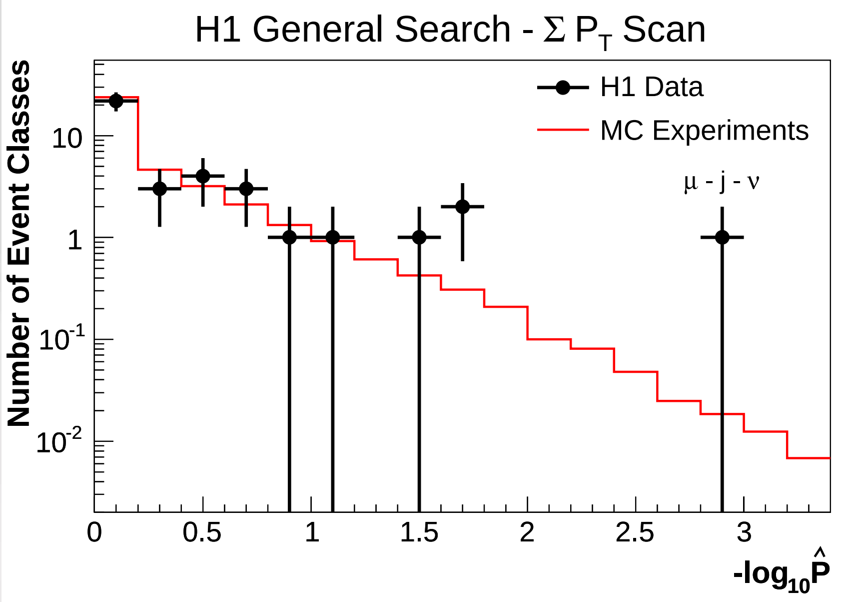
Derive for each event class the probability $\hat{P}$ to observe a deviation anywhere in the spectrum as large as found in the data

→ Smallest $\hat{P}$ found in μ-jet-ν, e-jet and e-e channels

Repeat the whole analysis with many MC (pseudo data) experiments each with the H1 luminosity

About 3% (ΣP_T) and 25% (M_{all}) of MC experiments have a deviation larger than that of μ-j-ν final state





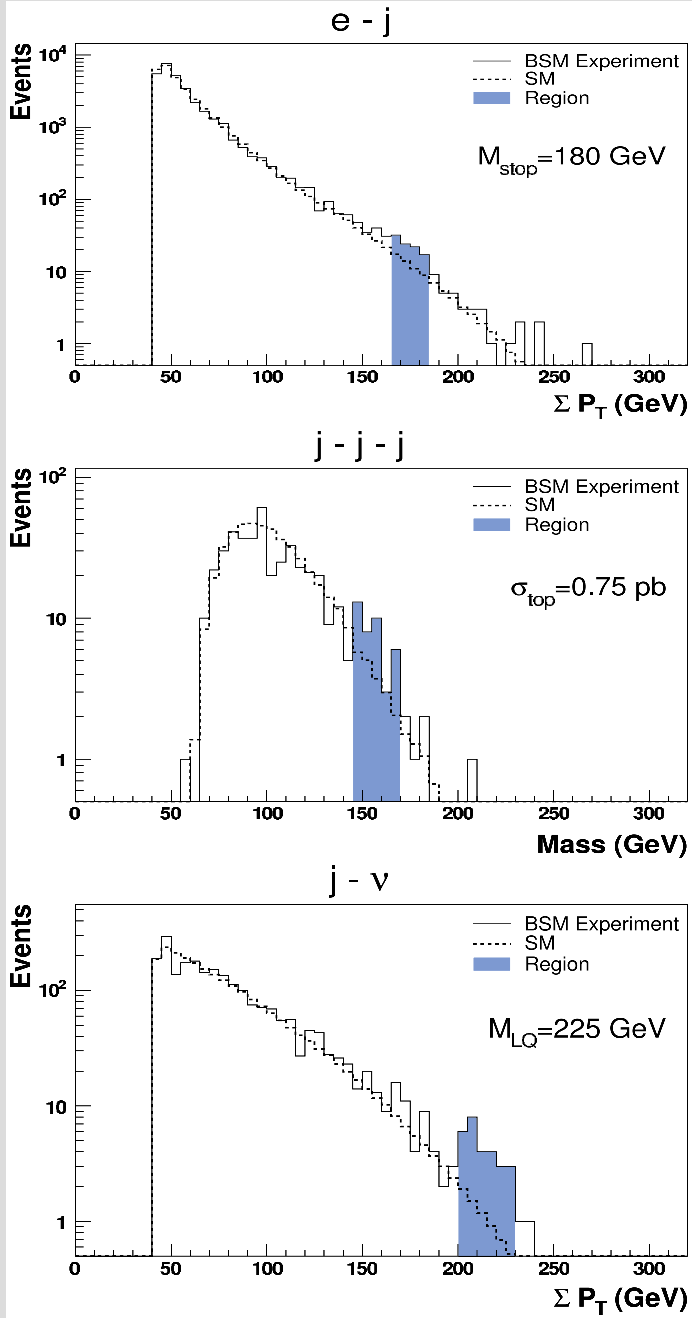
Does this make any sense?

Test sensitivity of the analysis by generating pseudo data using BSM predictions

Dice a data set and run the algorithm

Signals are found where they should be

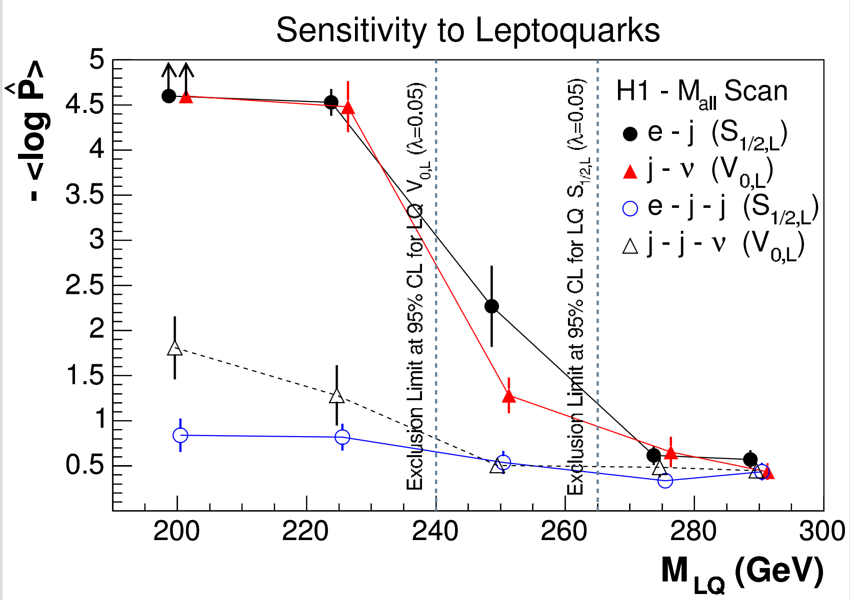
(plots from M. Wessels Ph. D. thesis)

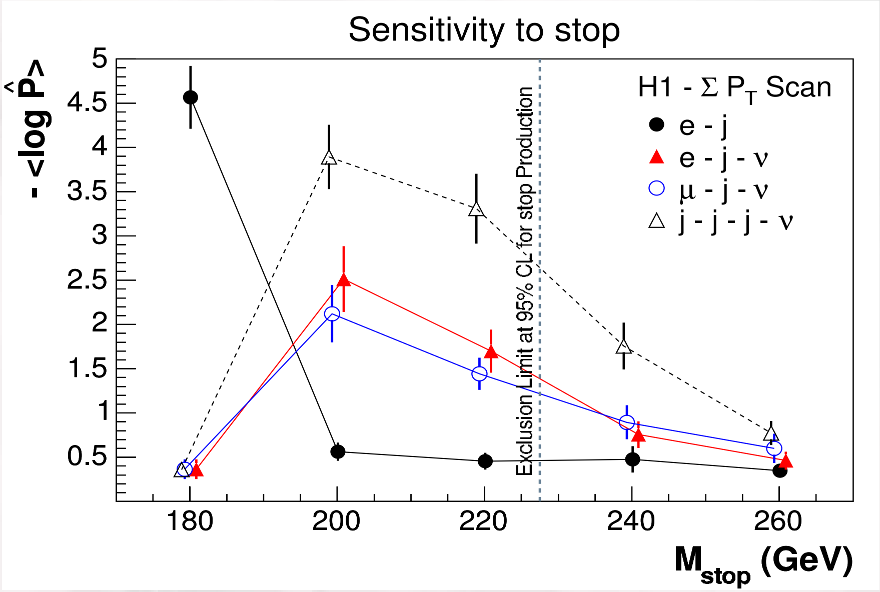


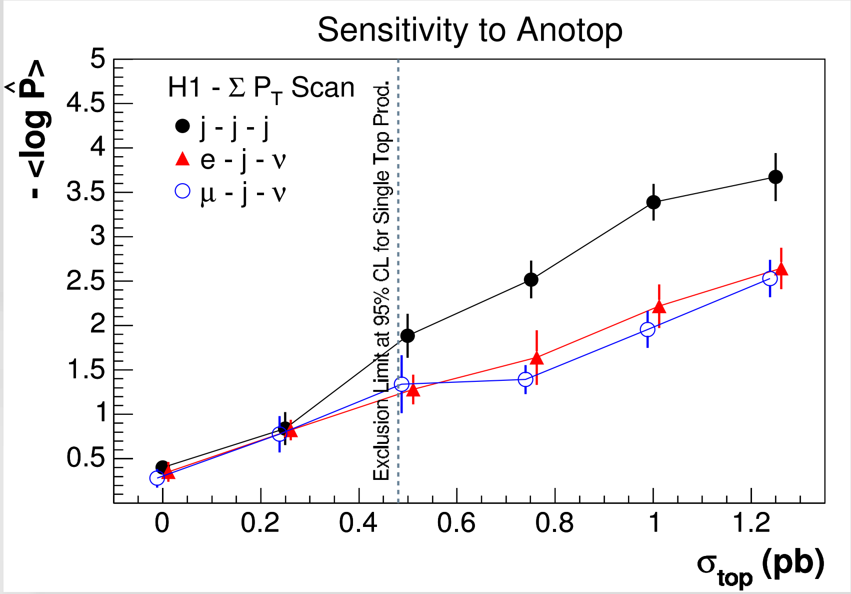
Sensitivity

Make BSM pseudo data sets and derive average P values

Found sensitivity comparable to that of dedicated searches

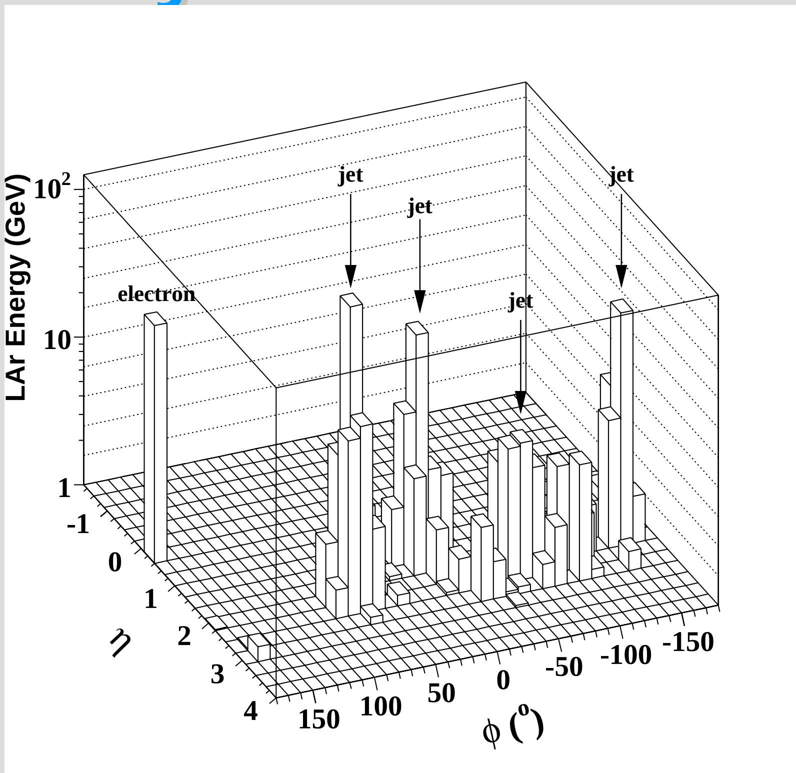






Summary

- A general search might be a good solution to exploit the discovery potential at LHC
- Unexpected physics may be found
- The analysis of many final states helps to find the origin of effects
- A MC mixture can do a good job to represent the SM in this case



A H1 event found in the ejjjj channel with a invariant mass of 260 GeV The NC DIS expectation in this region is ≈ 9* 10^{-5}. Rare SM processes (e.g. WW production) may dominate in this region and could not be considered.

References

A general search for new phenomena, H1 Collaboration, A. Aktas et al. , accepted by Phys. Lett. B 08/04 (hep-ex 0408044),

M. Wessels (Aachen), M. Peez (Marseille) , G. Frising (Aachen) Ph.D. theses

Search for new physics in e mu X data using Sleuth: A quasi-model Indendent search strategy for new physics, D0 Collaboration, Phys.Rev. D62, 2000.