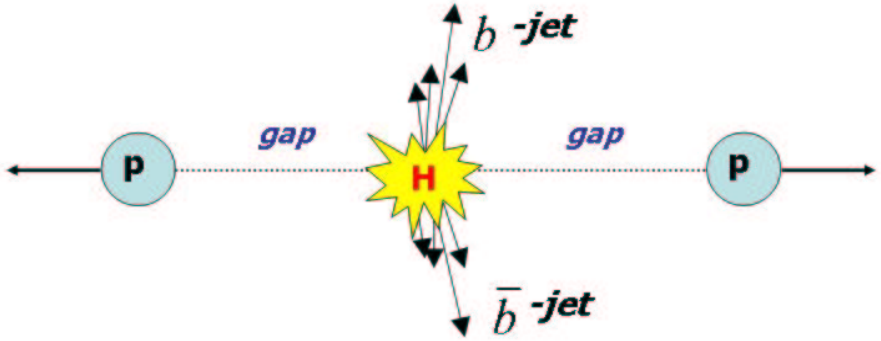
Exclusive χ_c at CDF

Angela Wyatt (UCL)

- Motivation
- Selection of J/ψ events
- Selection of double pomeron exchange
- Selection of exclusive events
- What are the events?
- Summary

Exclusive Higgs production

The Higgs boson has vacuum quantum numbers
⇒ could be produced exclusively: $pp \rightarrow pHp$



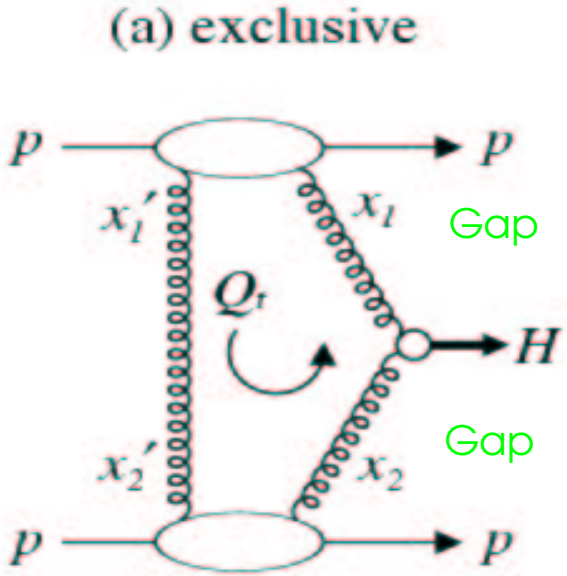
- Outgoing protons scattered by a small angle
- The Higgs decays centrally
- Large rapidity gaps between the protons and the Higgs

LO QCD: $gg \rightarrow H$ via a t-quark loop
plus an additional gluon exchange that cancels colour ⇒ colour singlet

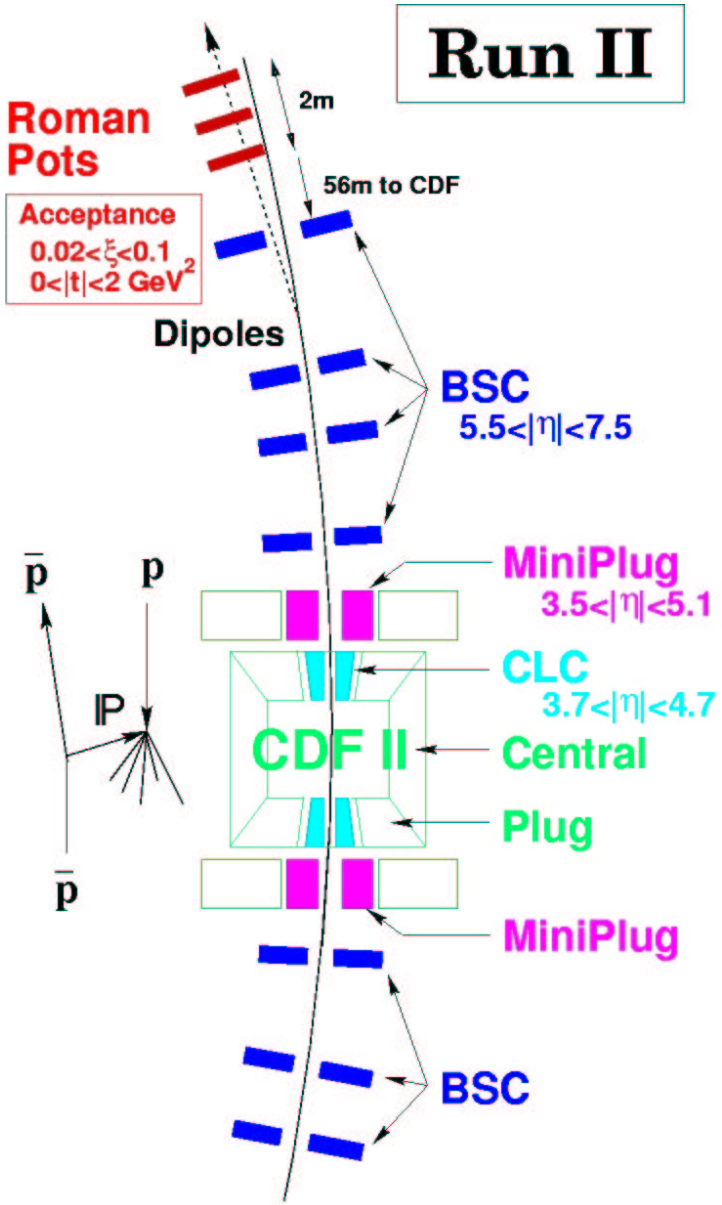
Colour singlet exchange (diffraction)
⇒ rapidity gap formed.

Reconstruct Higgs mass from tagging protons
⇒ S/B approx 3
(De Roeck, Khoze, Martin, Orava,Ryskin, Eur. Phys J. C25, 391(2002))

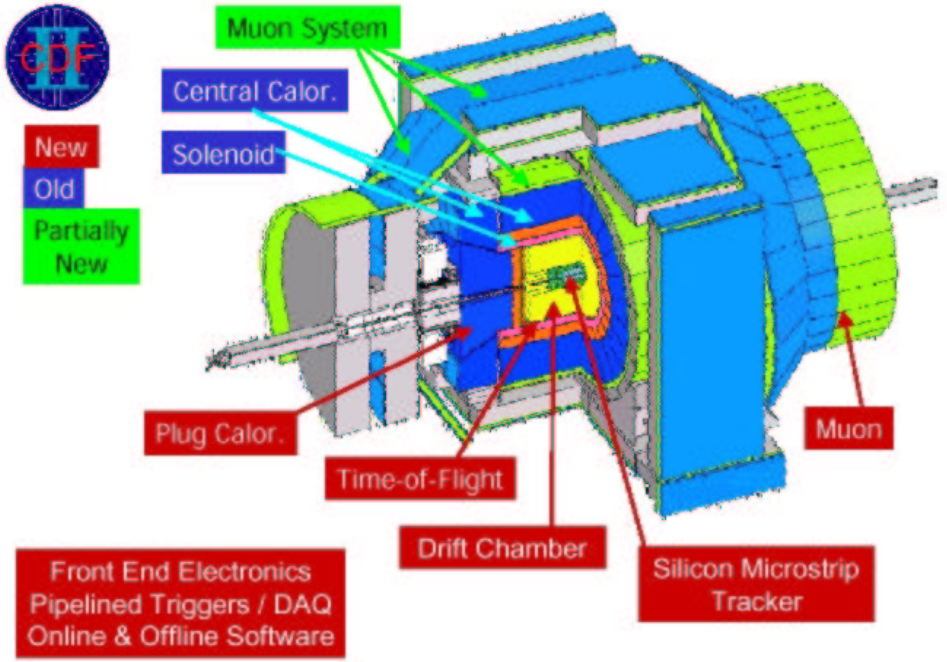
Test predictions with χ_c (same quantum nos)



Searching for exclusive χ_c at CDF

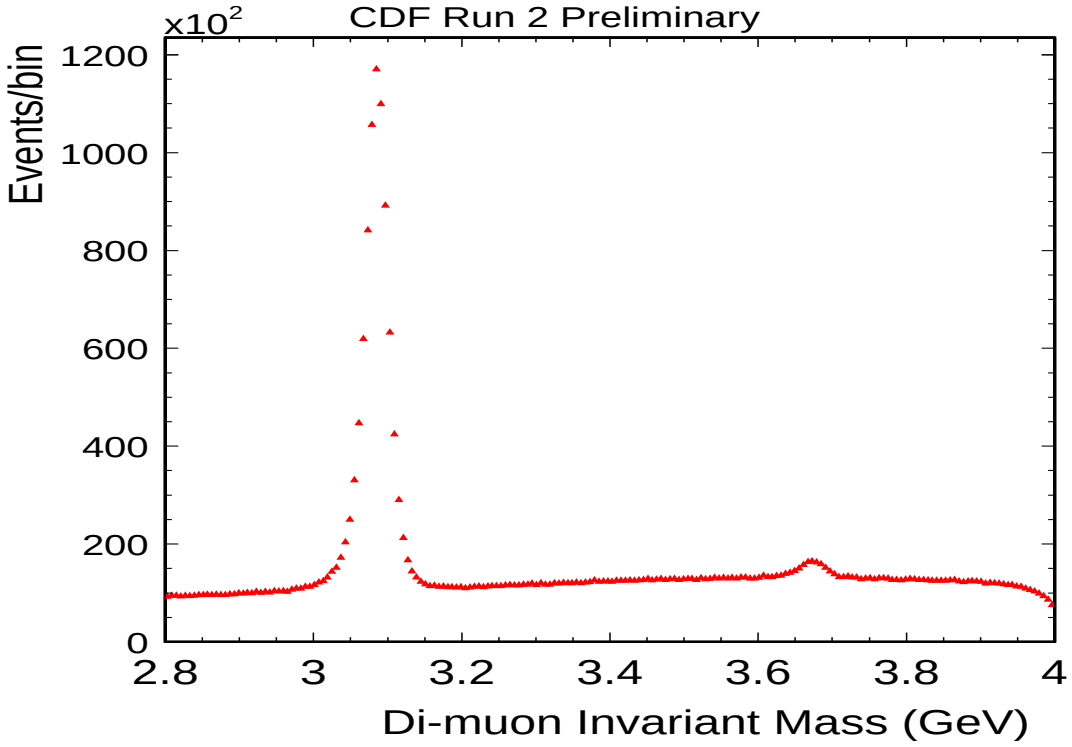


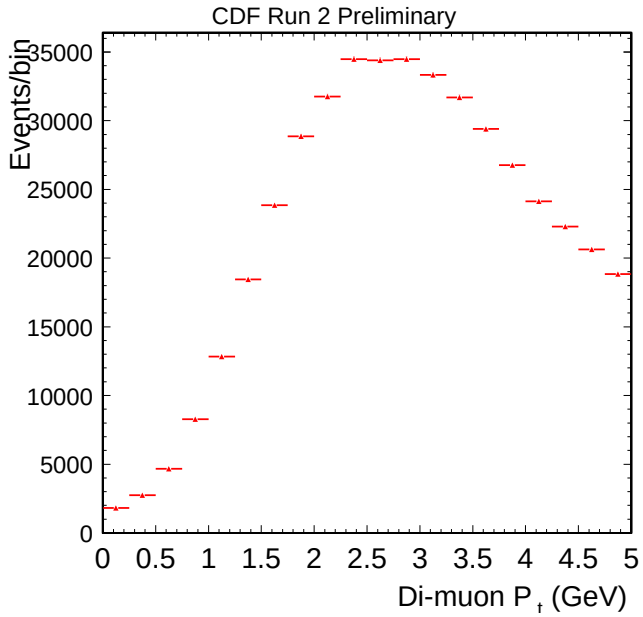
- Use the decays: $\chi_c \rightarrow J/\psi\,\gamma \rightarrow \mu\mu\gamma$
- Roman pots won't tag $\bar{p}$ for this low mass.
- Use the beam shower counters (BSC) and MiniPlug (MP) to tag diffractive events.
- Search for exclusive events using in addition the main CDF detectors: calorimeters, muon detectors, trackers.

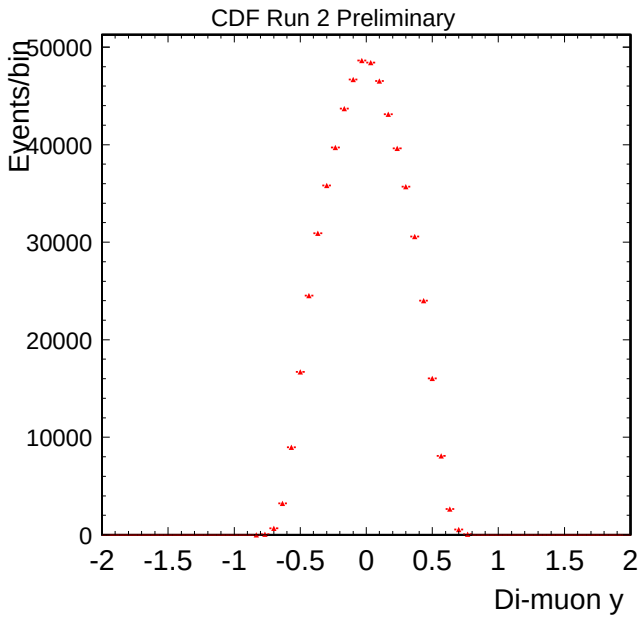


Selection of an inclusive J/ψ sample

- Events are triggered on by a di-muon trigger
- Muons have $P_t > 1.5$ GeV, $|\eta| < 0.6$
- Reject cosmic rays with time of flight info.
- Select events in J/ψ mass window.







Rapidity gap selection at CDF

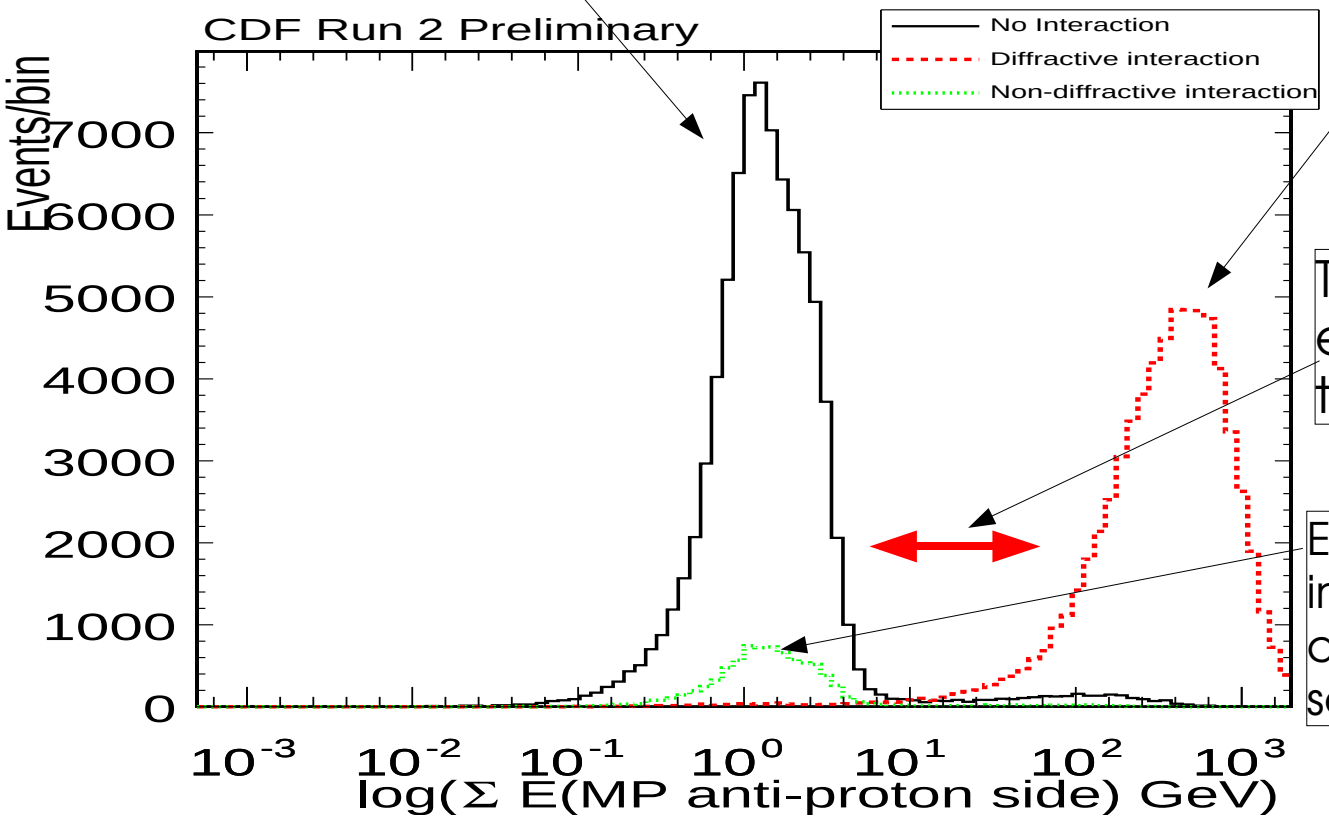
Beam/electronic noise means that exclusive isn't zero signal

⇒ define rapidity gap by a cut at low energy

Used trigger unbiased data to study this choice.

Events with no central interaction have little energy in the detector

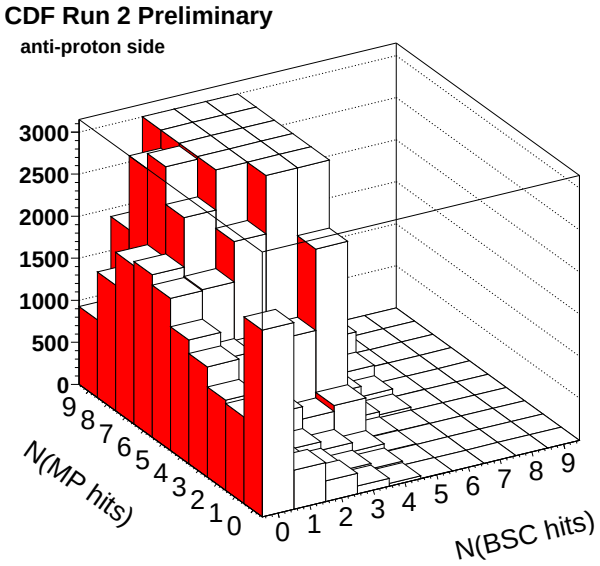
Events with a central interaction typically have energy in the detector.

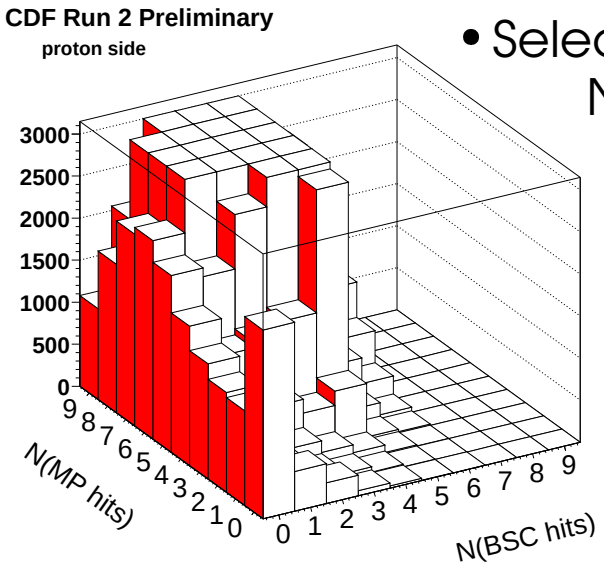


The tagging of diffractive events is not very sensitive to the exact cuts.

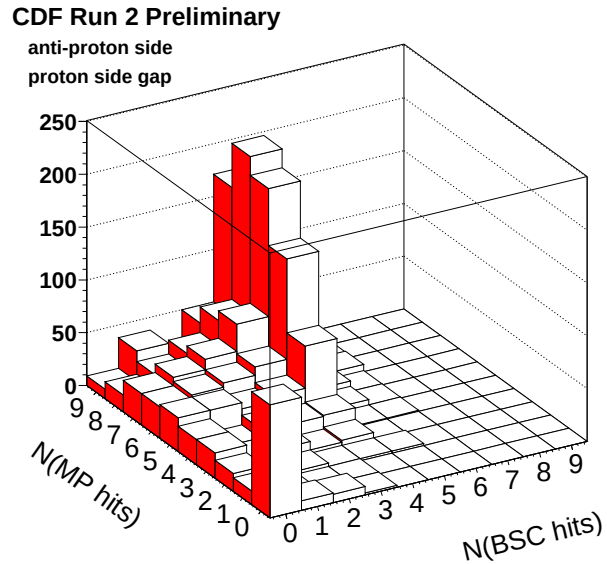
Events with a central interaction that are tagged as diffractive are also well separated.

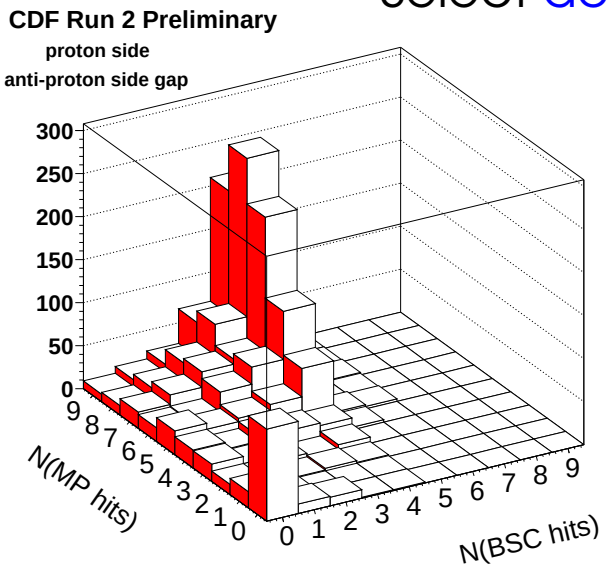
Selection of double pomeron exchange





- Select single diffractive sample
  N(BSC hits) = N(MP hits) = 0

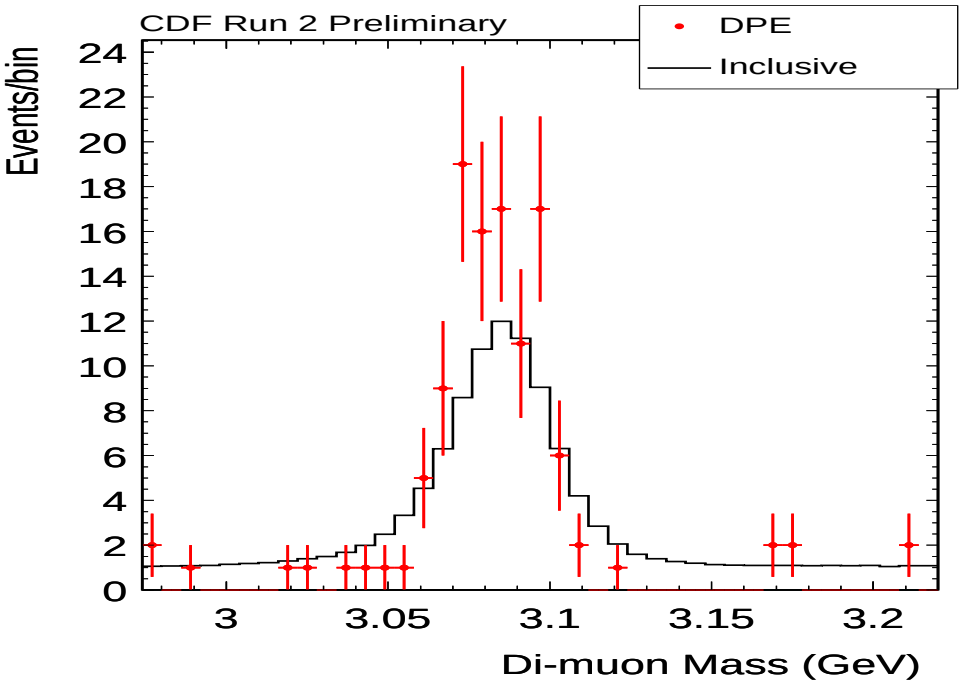


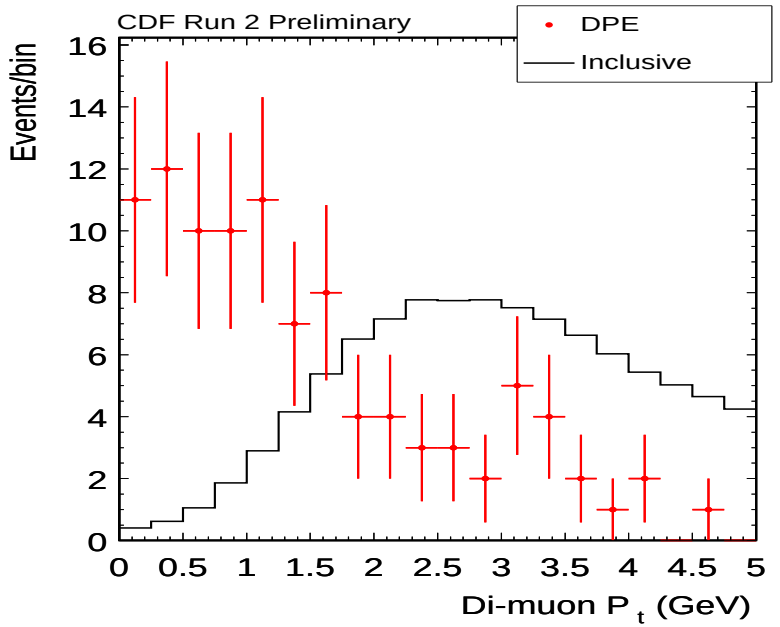


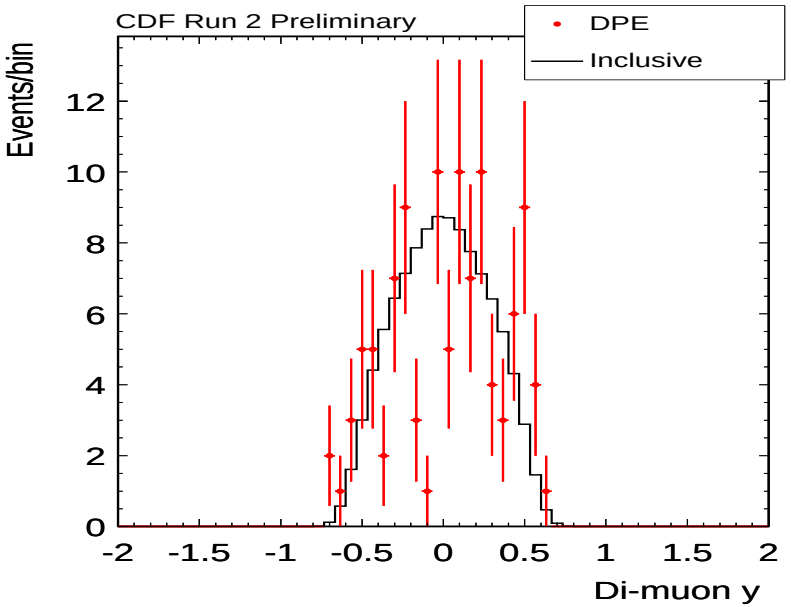
- Select double pomeron exchange
  N(BSC $\bar{p}$) = N(MP $\bar{p}$) =
  N(BSC p) = N(MP p) = 0

Kinematics of the J/ψ in DPE

- Selected double pomeron exchange (DPE)
- DPE events have a lower J/ψ P_t
- Otherwise, very similar to inclusive sample.







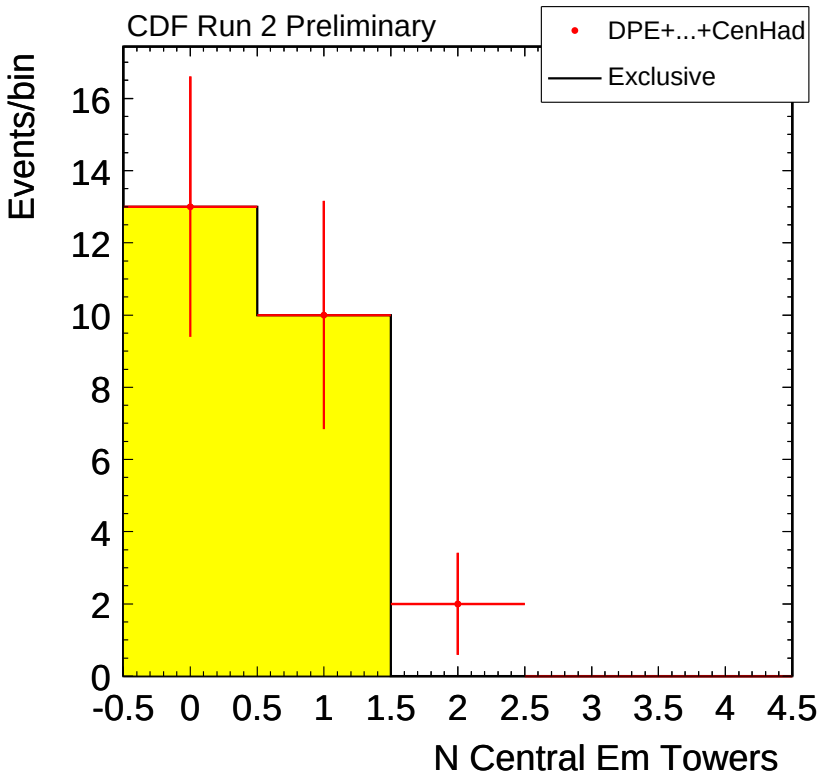
Selection of exclusive events

- Start from the DPE sample.
- Ignore the tracks and calorimeter towers of the J/ψ.
- Define events as exclusive if they contain:
  - no muon stubs.
  - no towers Et > 0.1 GeV
  - no tracks
- Allow 1 EM tower in the event.

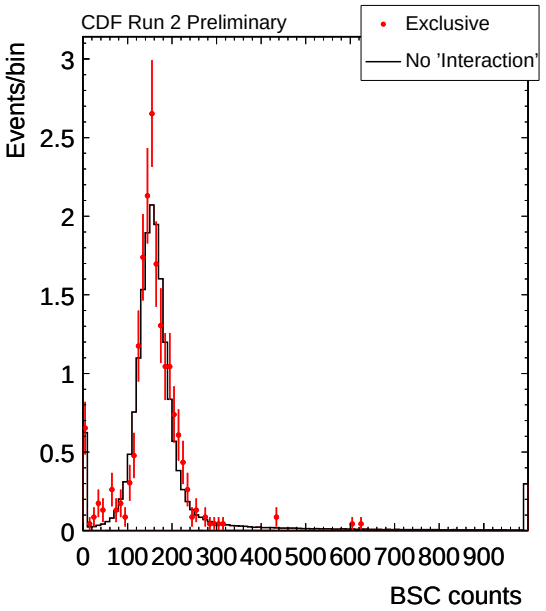
From 107 DPE events:
13 events just J/ψ
10 events just J/ψ + γ
and nothing else
OBSERVABLE

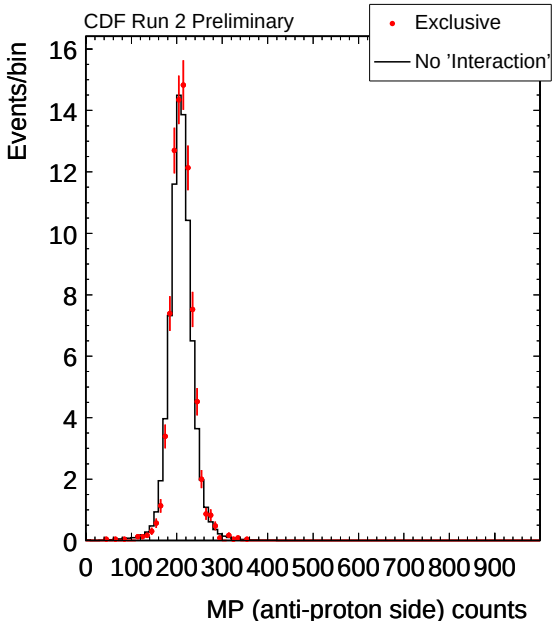
These 23 events are DEFINED
as the exclusive sample.
They may not all be truly exclusive.

Number of EM towers before cut:

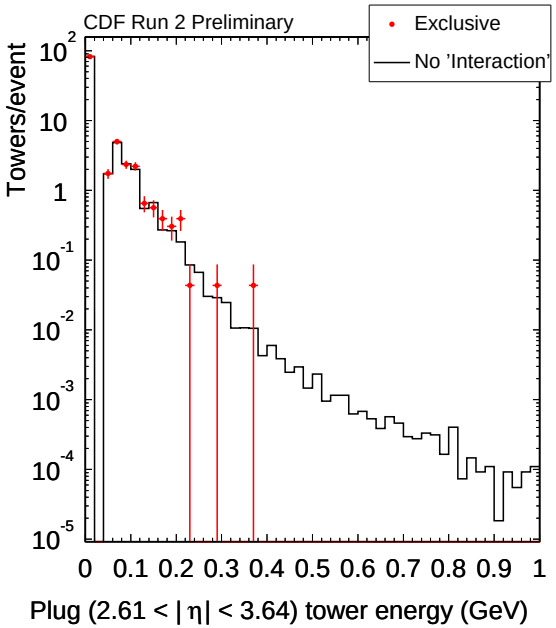


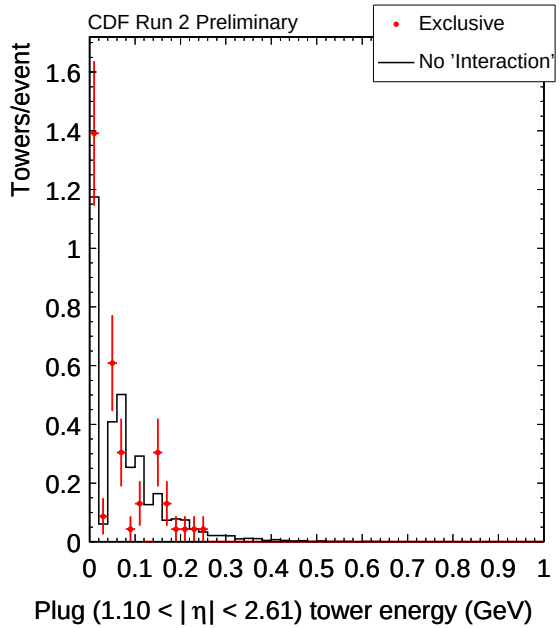
Exclusive energy distributions

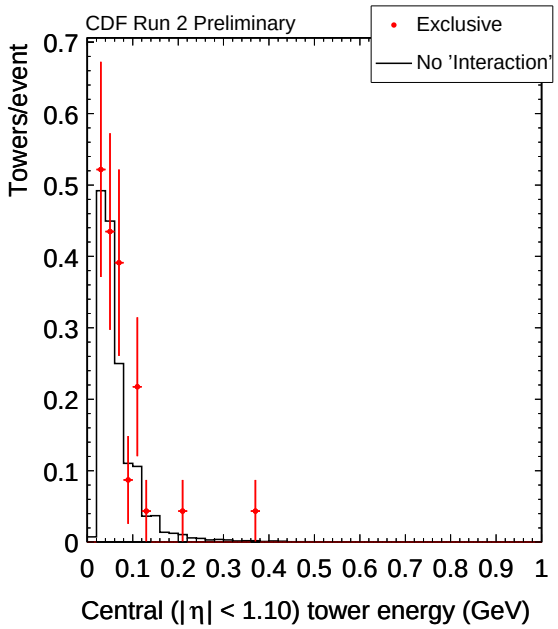




- Compare the 'signal' rejected by the noise cuts in exclusive events to non-interaction events in zero bias data
  - good agreement.

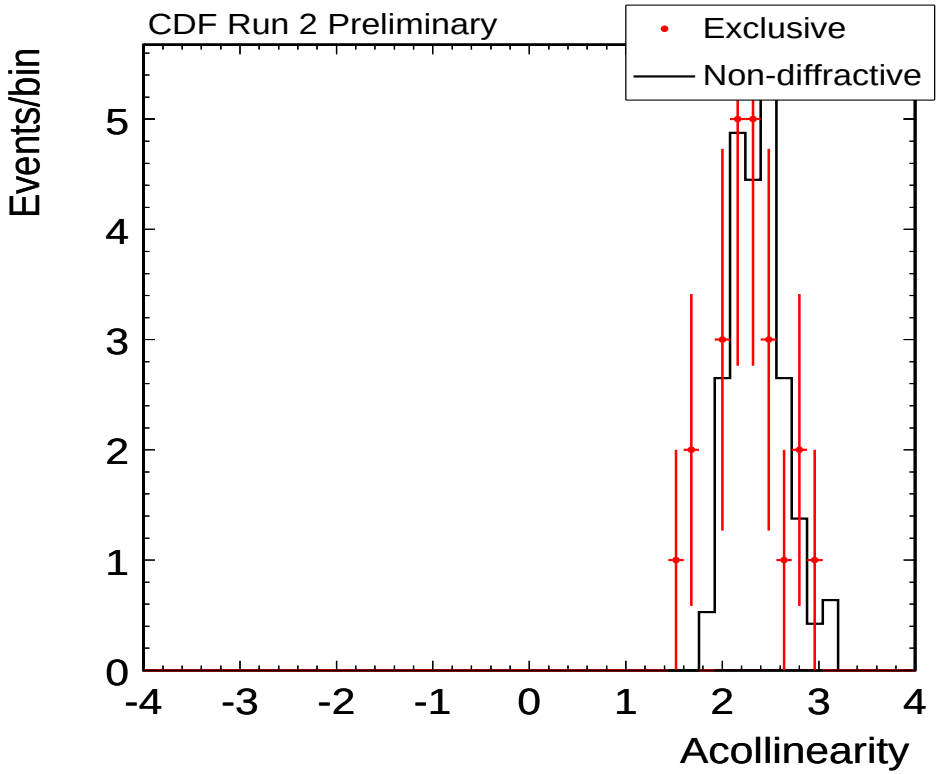


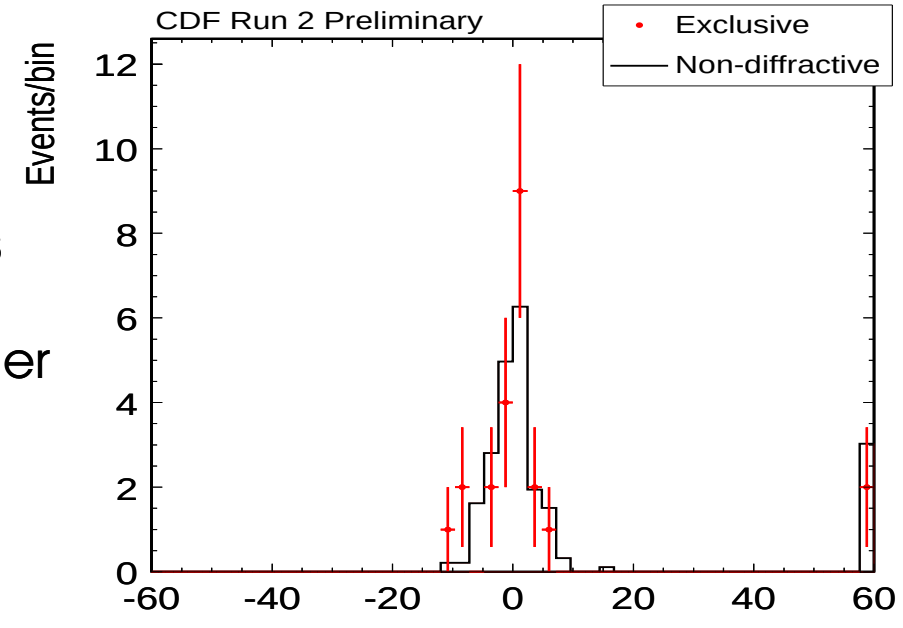


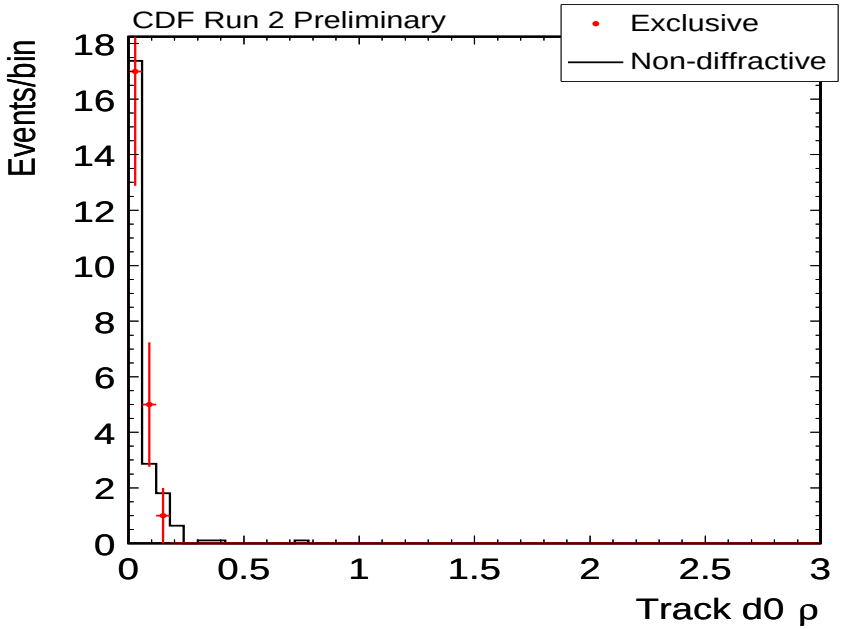


Cosmic background rejection

- Cosmic ray rejection was chosen to reject 100% of cosmic rays.
- Can be a significant background, so we check many variables that no event looks like a cosmic ray.
- Examples are: track opening angle, further timing information, track correlations.

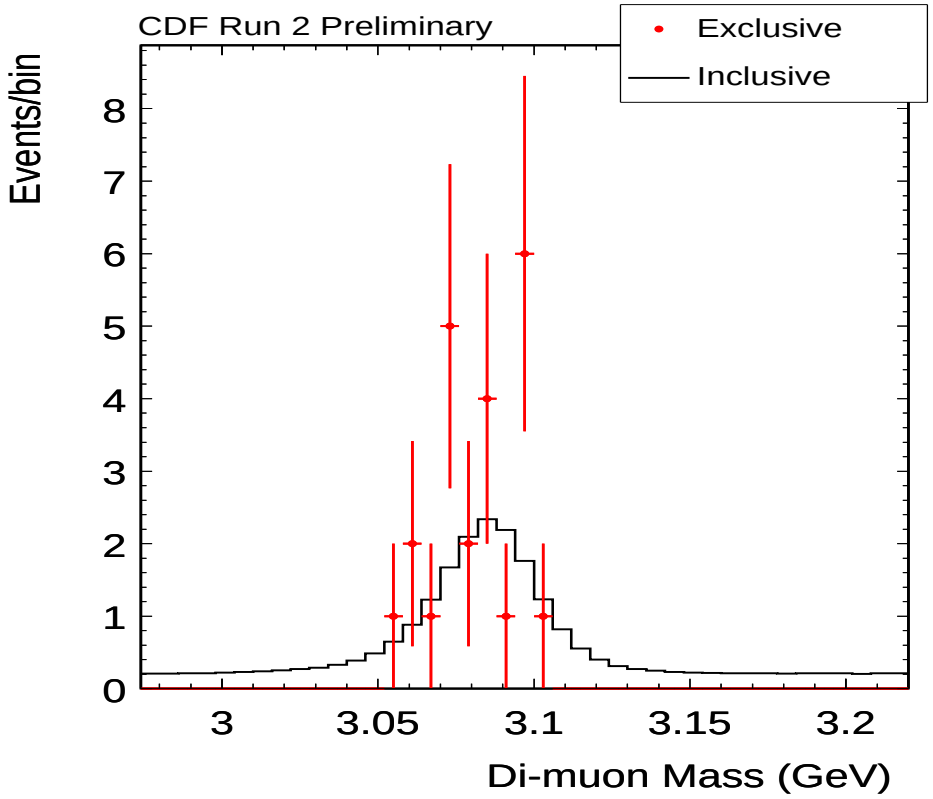


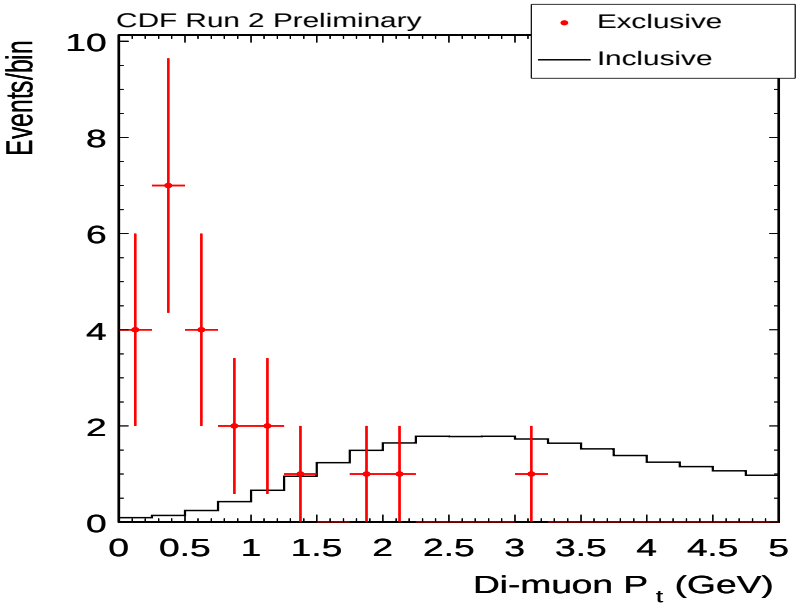


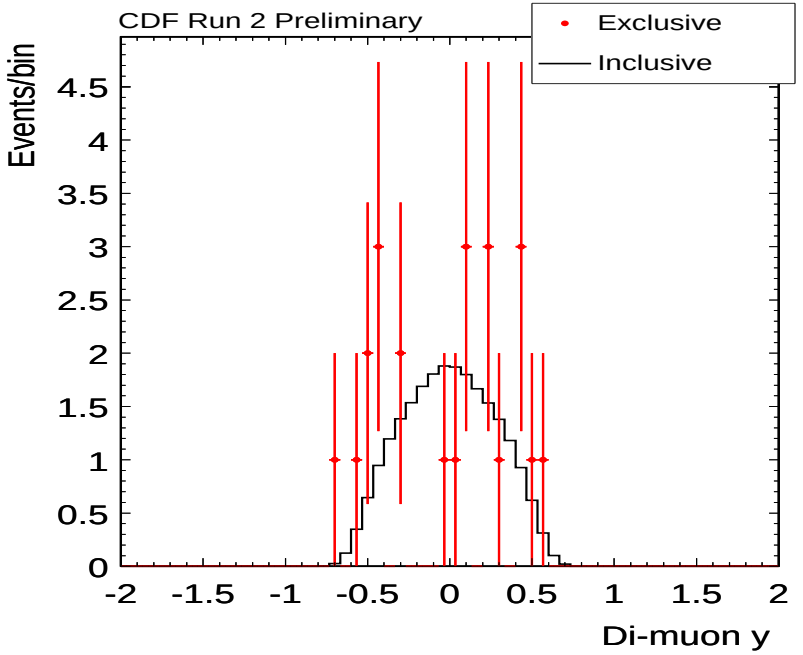


Kinematics of the J/ψ in exclusive events

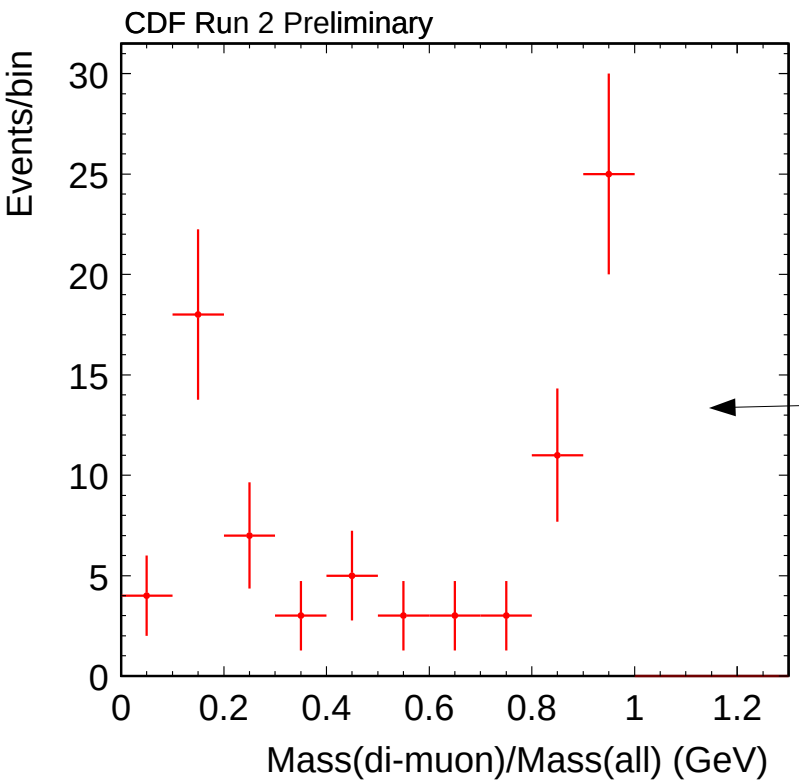
- 23 events: J/ψ or $J/\psi + \gamma$
- The J/ψ has even lower P_t than in DPE, but not zero P_t - recoils against outgoing pp
- Again, the other variables look similar.
- Very little continuum background.



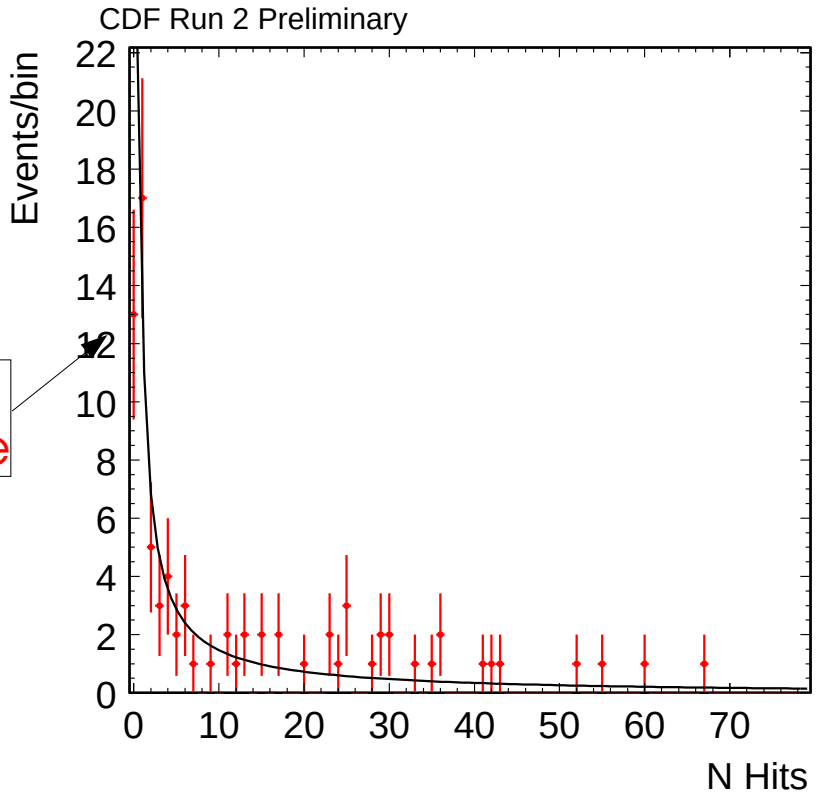




Are the events from exclusive production?



All DPE Sample



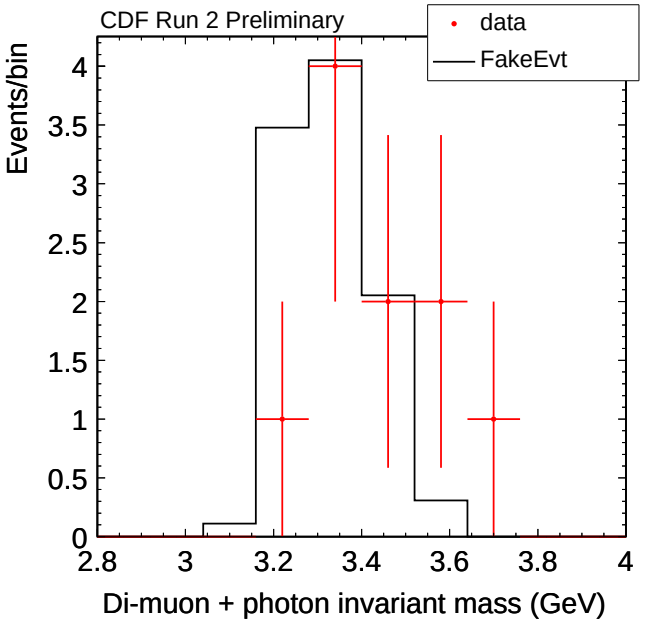
- Plot $M_{J/\psi}/M_x$

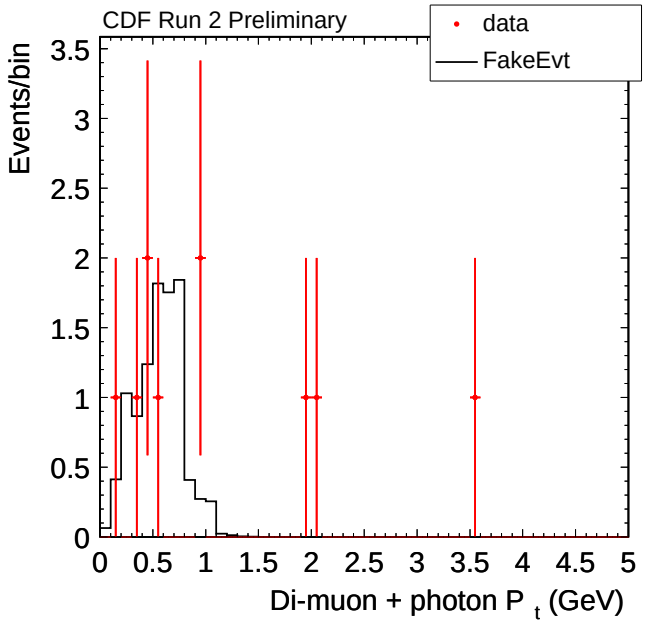
M_x = Mass of all tracks,towers

- You do see a peak, BUT, this mainly shows that the distribution has a low multiplicty.
- Plotting the multiplicity distribution may be less mis-leading.

- N Hits is the total number of tracks+towers.
- Not possible to distinguish between
  - -low multiplicity distribution
  - - higher multiplicity distribution + additional exclusive events

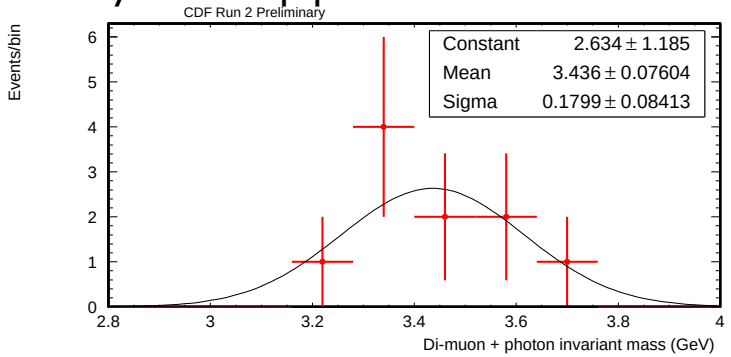
Are the photons from χ_c decay?

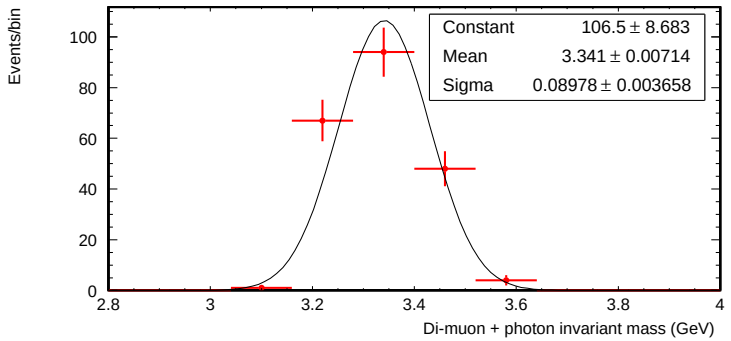




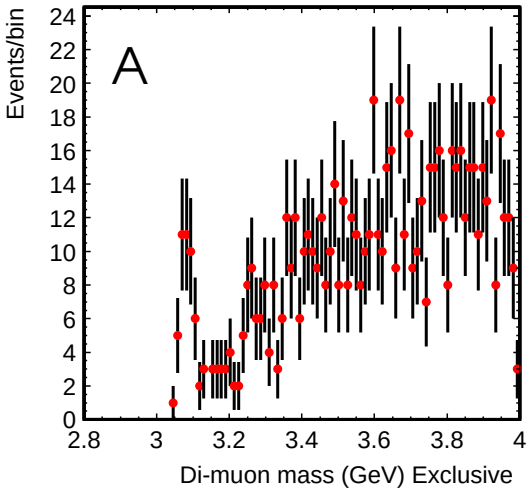
- This is very hard to tell.
- The photon E_t is so low in χ_c production that its distribution is very similar to the background.
- The data distribution is similar to that expected from χ_{c0} after detector simulation.
- With 10 events cannot tell the difference between a falling distribution and a mass peak.
- The mass resolution is worse in data. Other χ_c are possible, but may be suppressed.

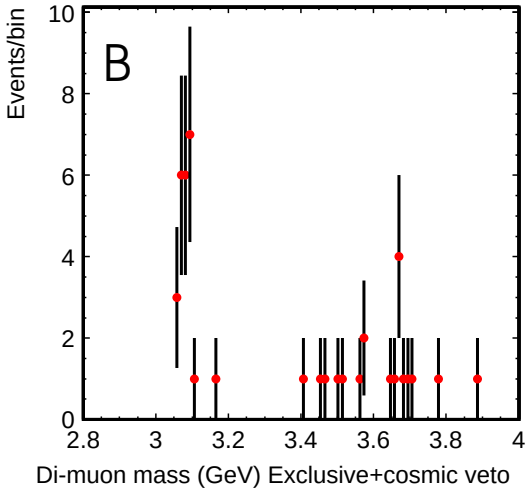
10 events
$J/\psi + \gamma$

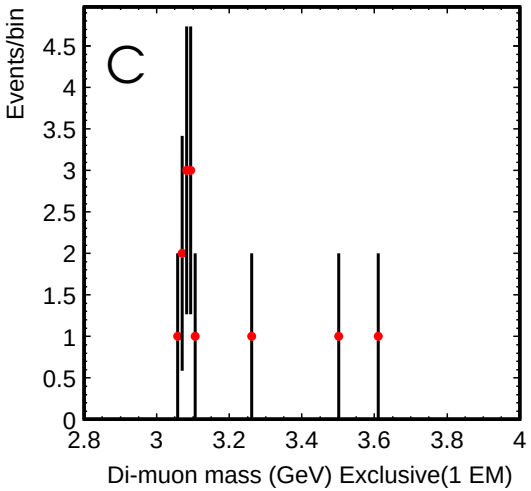


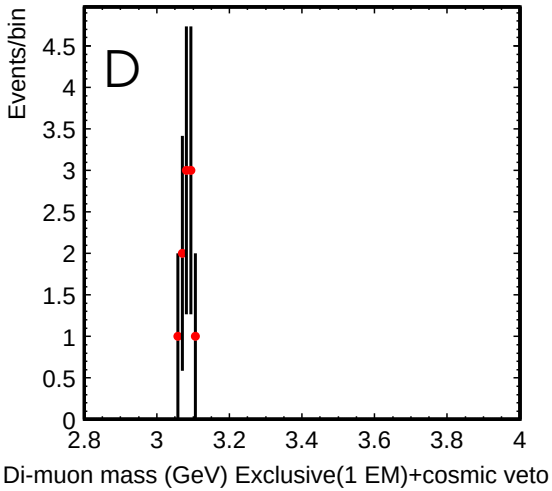


Invariant mass of all 'exclusive' events









The cosmic background rate is large.
There are exclusive dimuon events that are not J/ψ.

- Compare A and C
  - photons occur more often in J/ψ events than cosmic events
  - not noise?

- Compare B and D
  - photons occur more often in J/ψ mass peak than continuum
  - some are really χ_c??

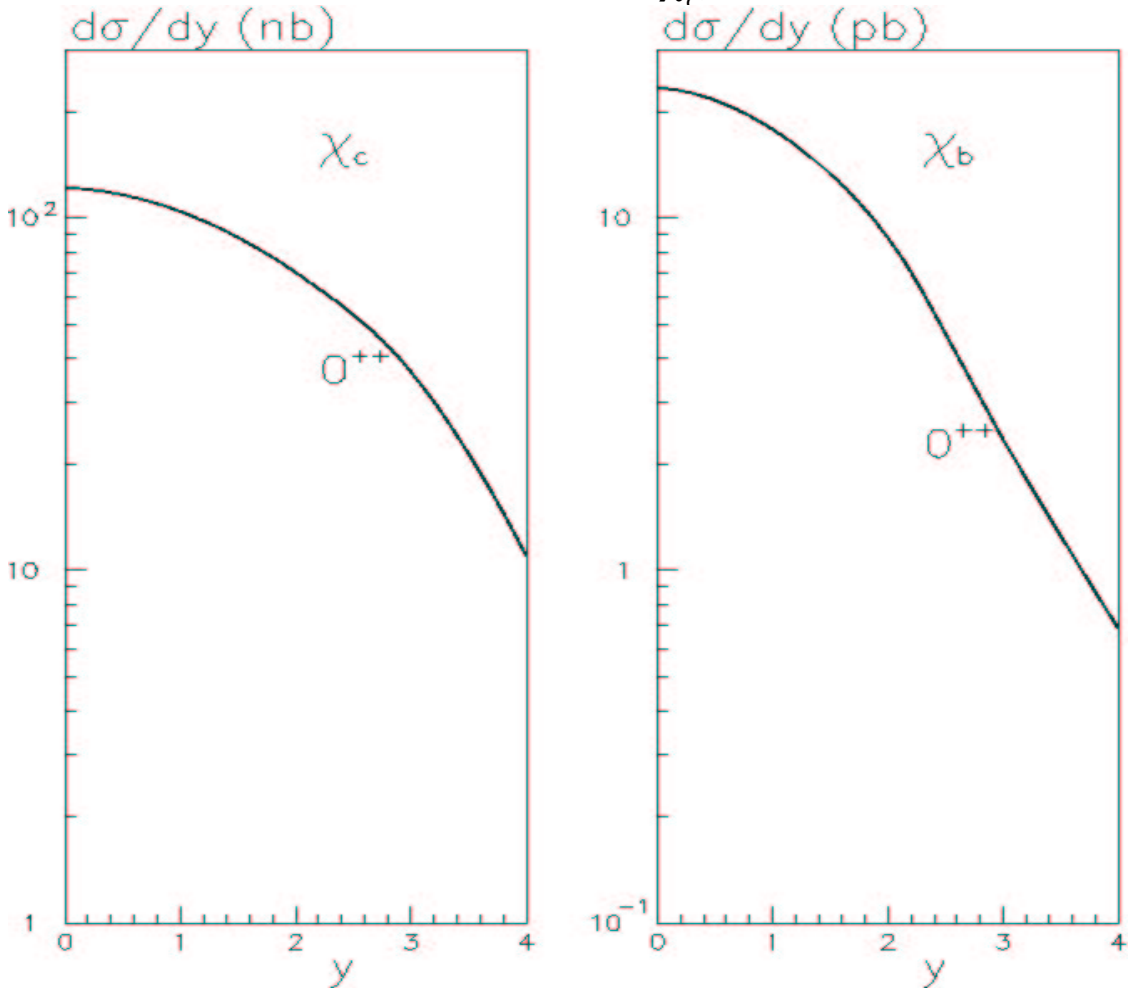
A: No cosmic veto. B: Cosmic veto added
C: Require 1 EM tower D: Cosmic veto+1 EM tower

Upper Limit on the Cross section

- If ASSUME 10 events are all χ_c^0
- From $\sigma = \frac{N_{evt}}{(L\,\epsilon_S\,\epsilon_H\,A_{J/\psi}\,\epsilon_{J/\psi}\,A_\gamma\,\epsilon_{cosmic})}$

$\Rightarrow$ upper limit of 49 $\pm$ 18 (stat) $\pm$ 39 (syst) pb for exclusive χ_c production, with $|y| < 0.6$.

- Estimate from
Khoze, Martin, Ryskin
Eur Phys J. C19, 477(2001)
$\sigma \approx 600$ nb
(uncertainty factor 2-5)
$\sigma\ J/\psi + \gamma \approx 350$ pb
$|y| < 0.6 \approx$ 70 pb



Summary

- We observe DPE events in which there is a J/ψ or a J/ψ+ γ and nothing else OBSERVABLE in the detector (defined as exclusive events).

- All of these events may be explained by standard DPE models, IF the multiplicity in DPE is low.

- Currently, the statistics/detector understanding don't allow us to make a serious estimate of the DPE contribution to the exclusive events (it could be 0-100%) or of the background contribution to the photons.

- There are 10 events which are compatible with exclusive χ_c production and we use these to give an upper limit and hope to improve this later when we have a better handle on the multiplicity and backgrounds.

- While the results are currently ambiguous, with more data and better understanding of the detector and Monte Carlo models we will be able to learn more.