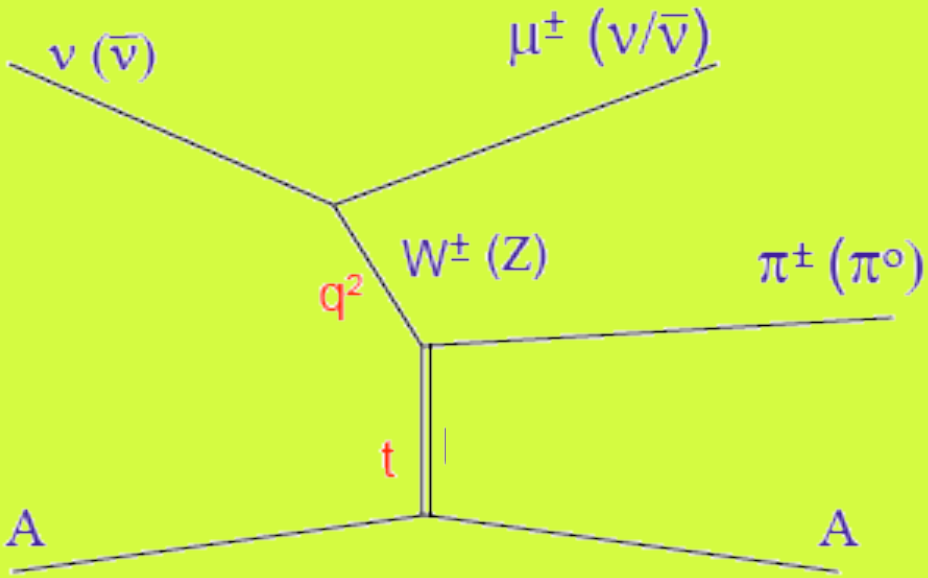
Coherent Pion Production Measurements in Minerva



Hugh Gallagher, Tufts University
for the Minerva Collaboration
NuINT 2007, Fermilab

Outline of Talk

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1. Motivation
2. Minerva measurement capabilities
3. CC Coherent:
   - Event selection and sensitivity
   - Experimental resolution
   - Systematic Uncertainties
4. NC Coherent
   - Event selection and sensitivity

Coherent Production: Theory

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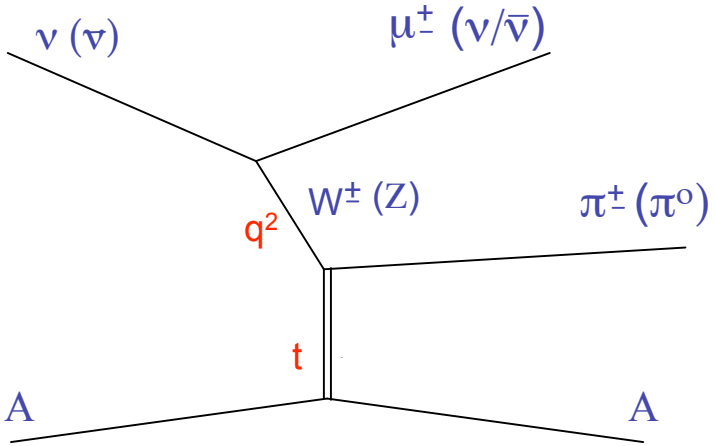
Coherence requires:
$t = (q - p_\pi)^2 < 1/R^2$
Where R is the size of the nucleus

From the Rein-Sehgal model:
1. Purely axial
2. $d\sigma(CC) = 2\, d\sigma(NC)$
3. $\sigma(A) \sim A^{1/3}$



Characterized by a small energy transfer to the nucleus, forward going π.

Piketty and Stodolosky, Nucl. Phys B15 (1970) 571.
Rein and Sehgal, Nucl. Phys **B223** (1983) 29.
Belkov and Kopeliovich, Sovt. J Nucl Phys 46 (1987) 499.
Singh et al., Phys Rev. Lett. 96:241801 (2006).
Paschos and Kartavtsev, Phys. Rev **D74**:054007 (2006).
Alvarez-Ruso et al., Phys. Rev **C75**:05501 (2007).

Motivation - Experiment

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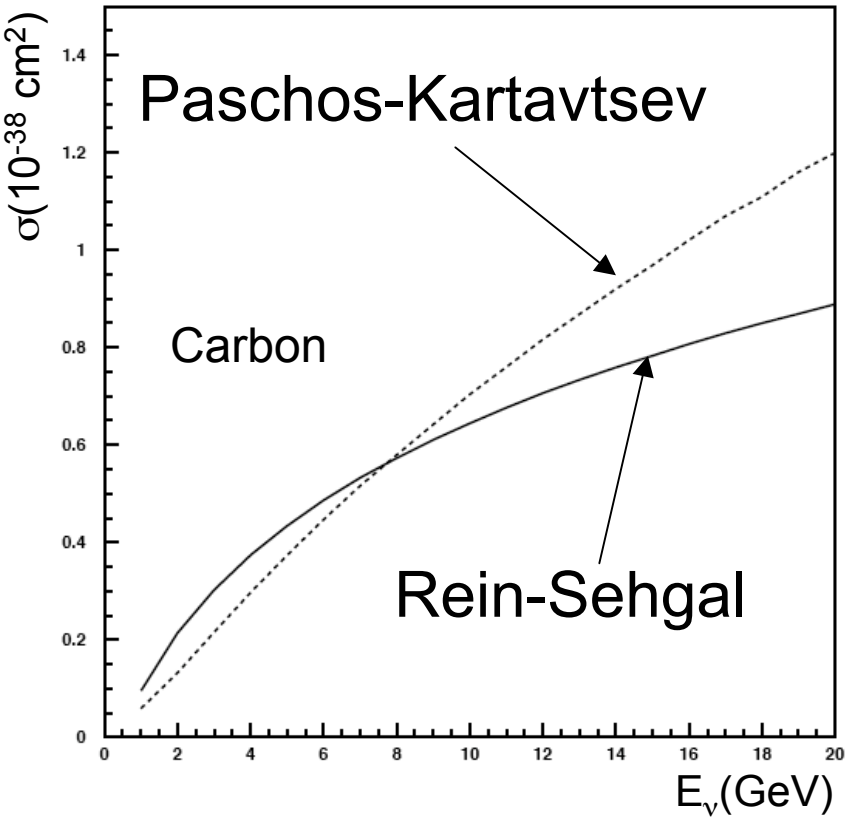

Oscillations: NC channel a main background to subdominant ν_μ–ν_e appearance searches!

Data to date has not been precise enough to discriminate between several very different model predictions.

Experiment	CC/NC	E	<A>	Signal
Aachen-Padova	NC	2	27	360
Gargamelle	NC	2	30	101
CHARM	NC	20-30	20	715
CHARM II	CC	20-30	20	1379
BEBC	CC	5-100	20	158
SKAT	CC(NC)	3-20	30	71(14)
FNAL 15’	NC	2-100	20	28
FNAL E180	CC	10-100	20	61
FNAL E632	CC	10-100	20	52

Coherent σ at E_ν~ 1 GeV

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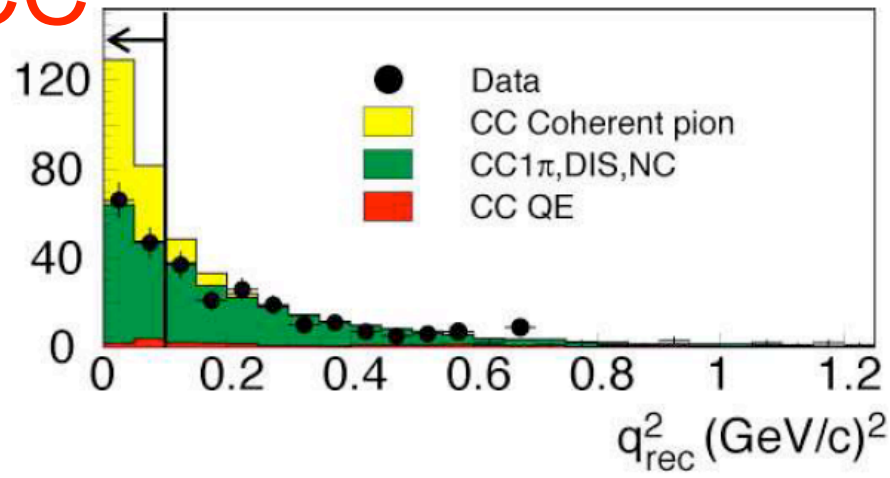
CC



K2K: "Our result is consistent with non-existence of CC coherent pion production…"

F. Sanchez *et al.*
Nucl.Phys.Proc.Suppl.
155:239-241,2006.:

$$\frac{\sigma(\text{CC coherent } \pi)}{\sigma(\nu_\mu CC)} < 0.60 \times 10^{-2}\ (90\%\text{CL})$$

NC

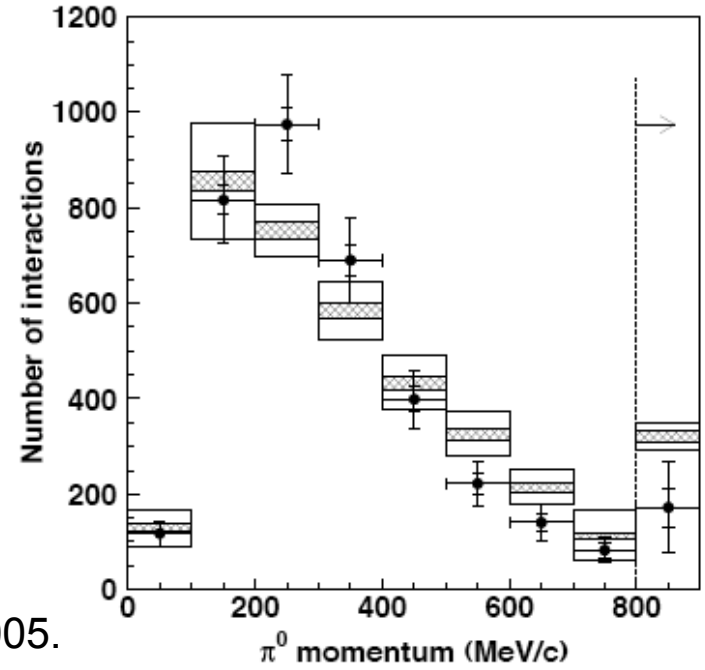
miniBoone, K2K
data and MC agree

$$\frac{\sigma(NC1\pi^0)}{\sigma(CC_{total})} =$$

$$0.064 \pm 0.001(stat.) \pm 0.007(syst.)$$

MC=0.065

S. Nakayama *et al.*
Phys.Lett.B619:255-262,2005.



Experimental Signatures

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Charged Current:

- μ and π tracks with no extra vertex activity
- low t $\quad -|t| = -(q - p_\pi)^2 = (\Sigma_i(E_i - p_i^{||}))^2 - (\Sigma_i(p_i^{\perp}))^2$
- different kinematics from topologically similar backgrounds

Neutral Current:

- single π^0 with no additional detector activity
- closer to the beam direction than resonance and DIS contributions

These signatures are well matched to Minerva's strengths:

- particle ID
- track resolution (0.5^o track pointing resolution)
- energy resolution
  - 10% muon energy
  - 18%/sqrt(E) for charged pions

MC Evaluation of Minerva Capabilities

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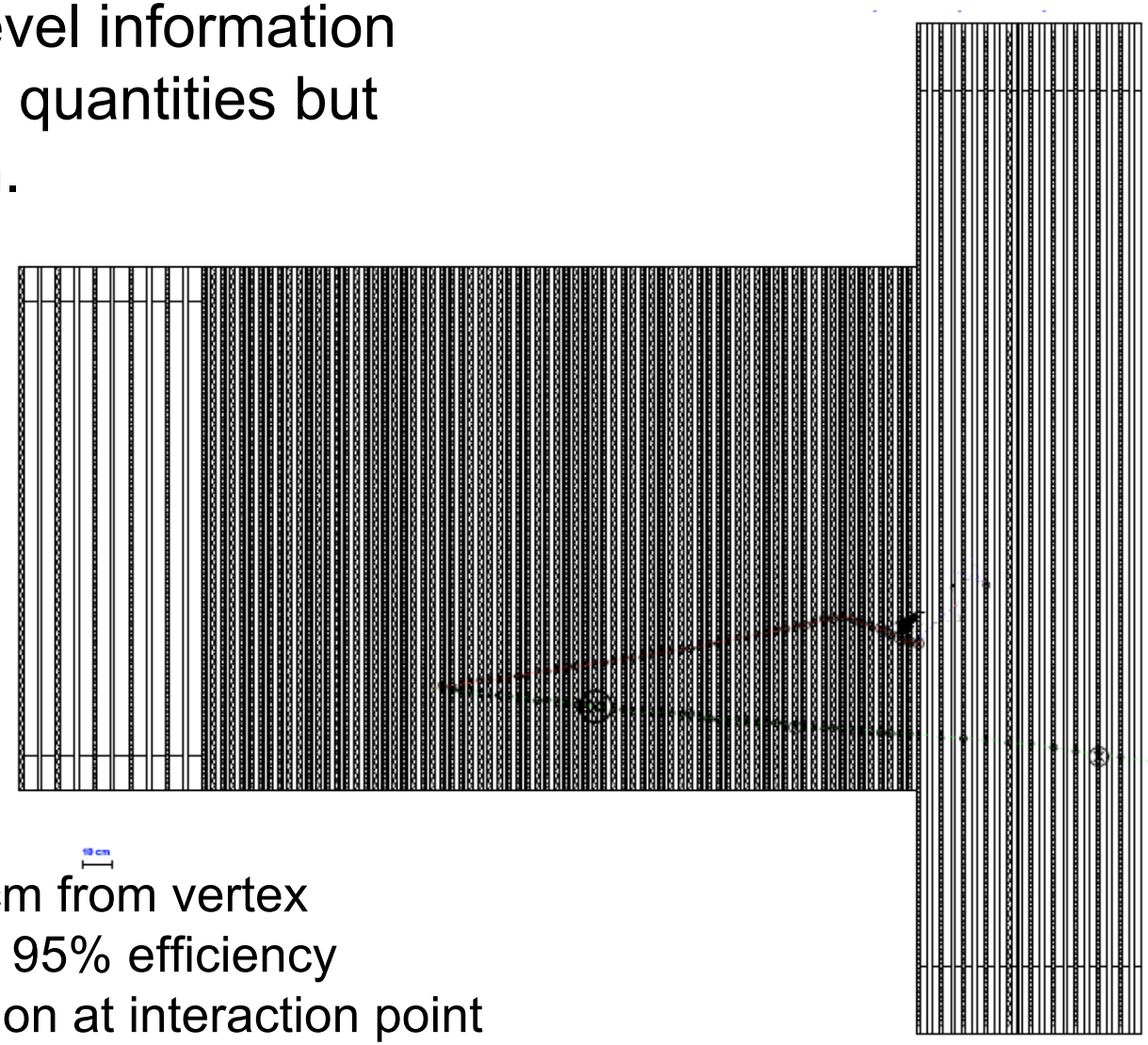
MC Studies use hit-level information and smearing of truth quantities but not full reconstruction.



Topological Cuts:

- 2 “visible” tracks (>7 hits on each)
- muon candidate
- pi candidate (interaction)
- less than 500 MeV from neutrals
- Interaction point > 30 cm from vertex
- Protons identified with 95% efficiency
- At least 4 strip separation at interaction point

Event Selection

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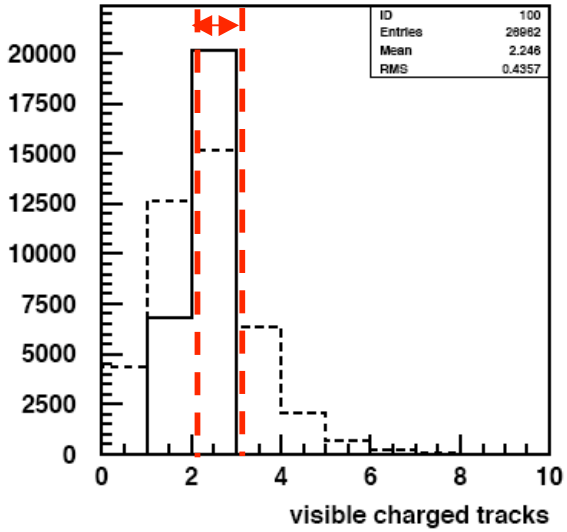
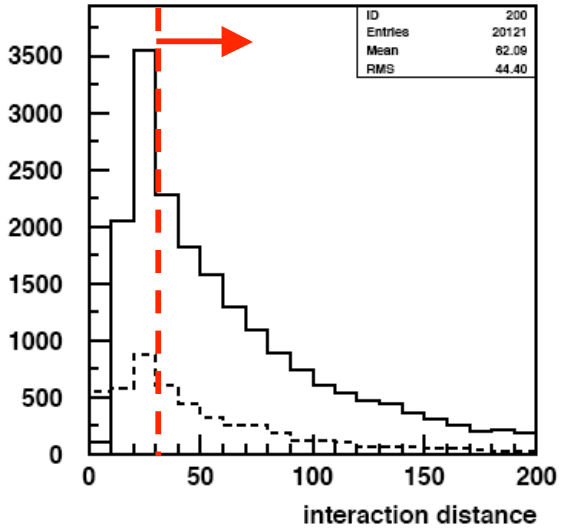
Measured quantities are estimated by smearing truth quantities by the expected measurement resolution.

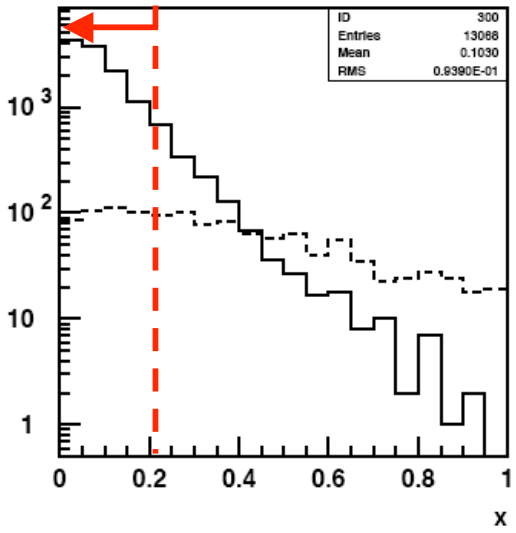
Topological Cuts
(previous slide)

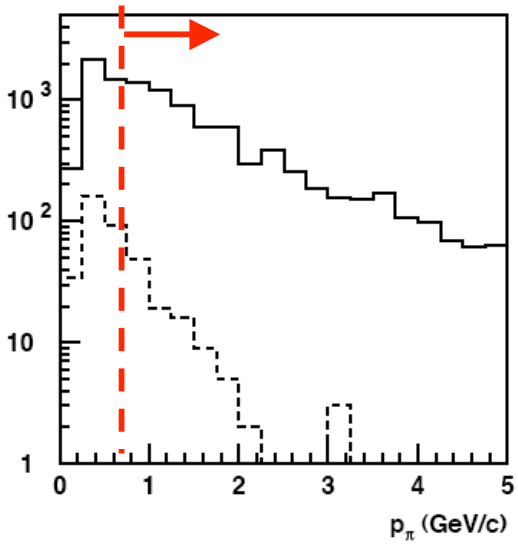
Kinematic Cuts:
x<0.2
t<0.2 GeV^2

Energy Cut:
p_π> 600 MeV/c









Sensitivity

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Applying cuts to full signal sample (85 k events)

25.5k pass all cuts

Overall efficiency is 30%

Purity of sample is $67 \pm 3\%$ (error bar is MC statistics)

Other variables like near-vertex activity were not used.

Error Budget on σ Measurement

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Statistical errors: 20 energy bins with equal statistics (1275 events signal, 628 events background). σ_{stat}=3.4%

Systematic Errors:

Source	Systematic uncertainty
Flux uncertainty	5%
Background Subtraction	2%
μ energy scale (2%)	-
π energy scale (3%)	1%
efficiency correction	5%
Total systematic (non-beam)	5.5%

Expected CC Results

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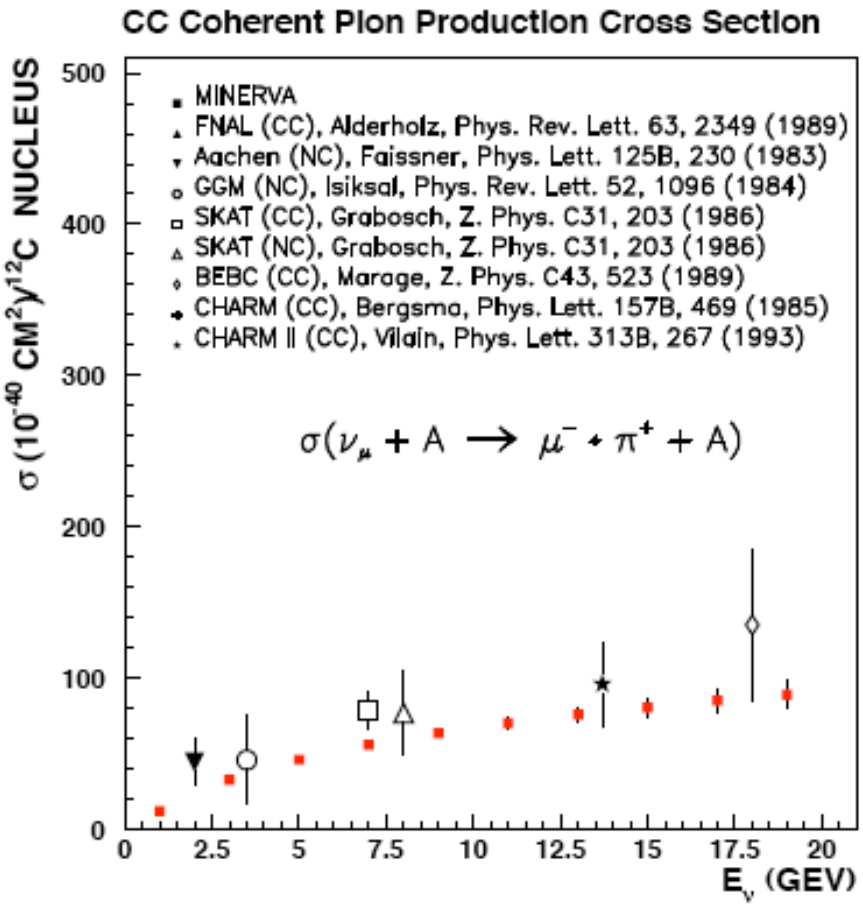

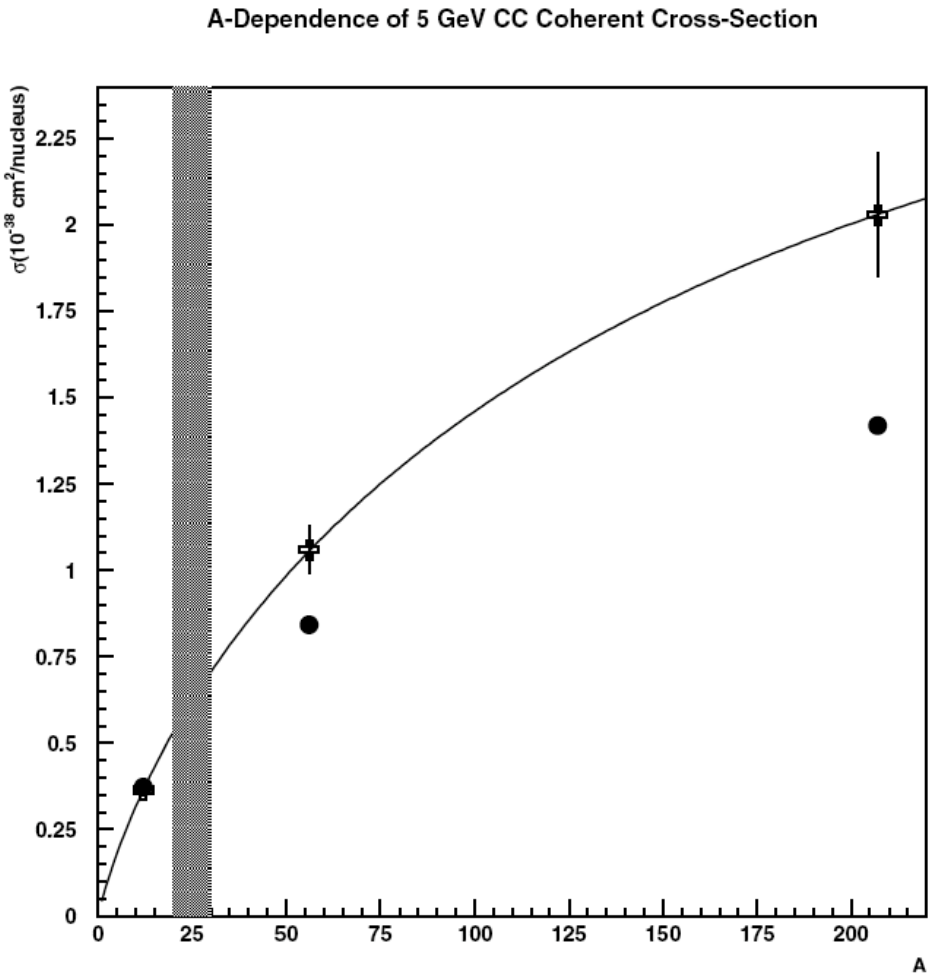

statistical errors only

Physics Goals

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High statistics will make possible:

1. Detailed studies of the kinematic distributions
2. Separation of nucleus-coherent and nucleon-diffractive components based on different t-dependence
3. Comparison of neutrinos and antineutrinos with high statistics.
4. Probes the polarization of the W-boson through study of the distribution of $\cos\phi$ (the azimuthal angle between the hadron and – lepton scattering plane).
5. With several thousand events each on lead and iron, can study the A dependence of the cross section

NC coherent production

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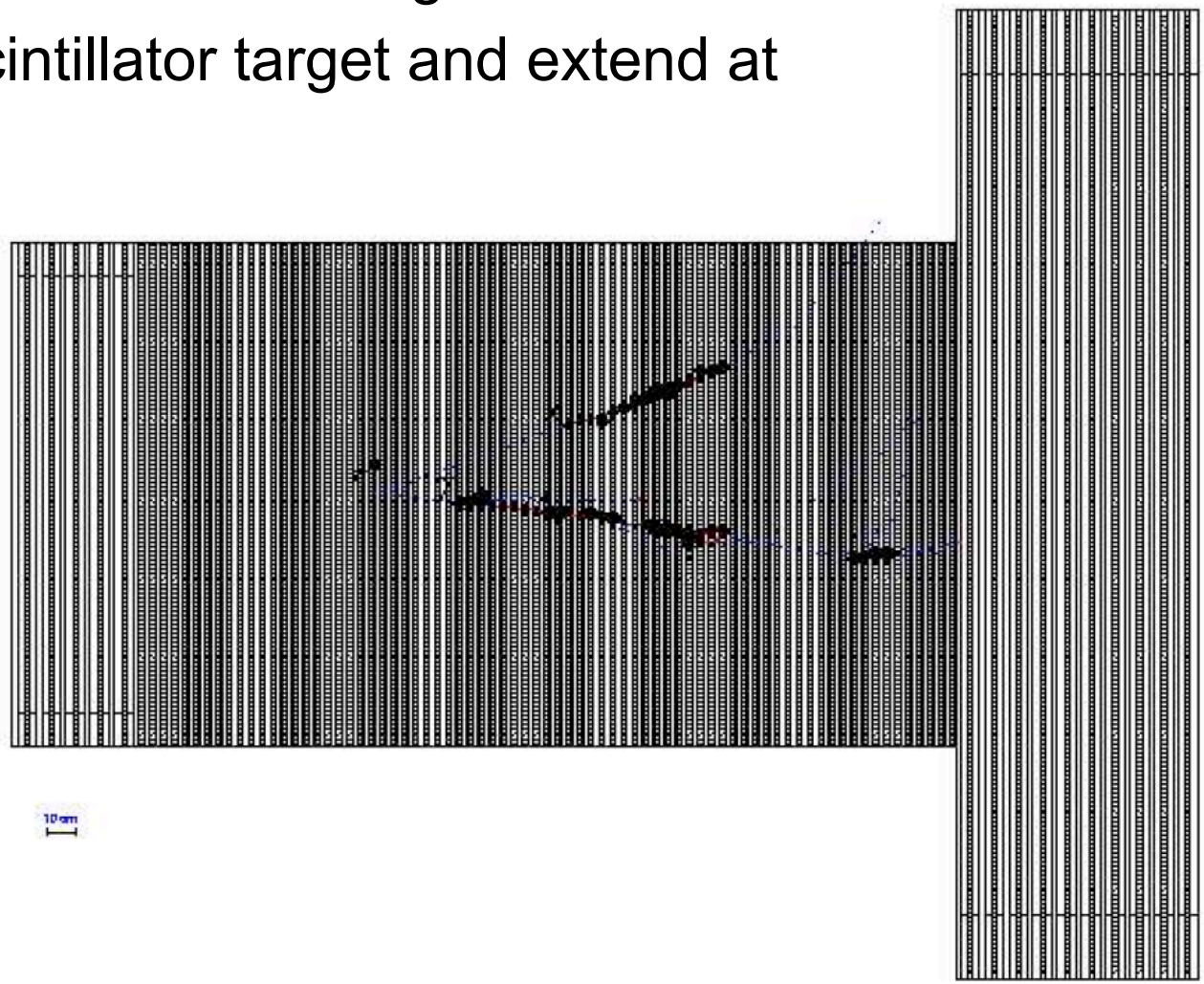
Require 2 well-separated electromagnetic clusters that shower in the scintillator target and extend at least 6 planes.



NC Coherent Production

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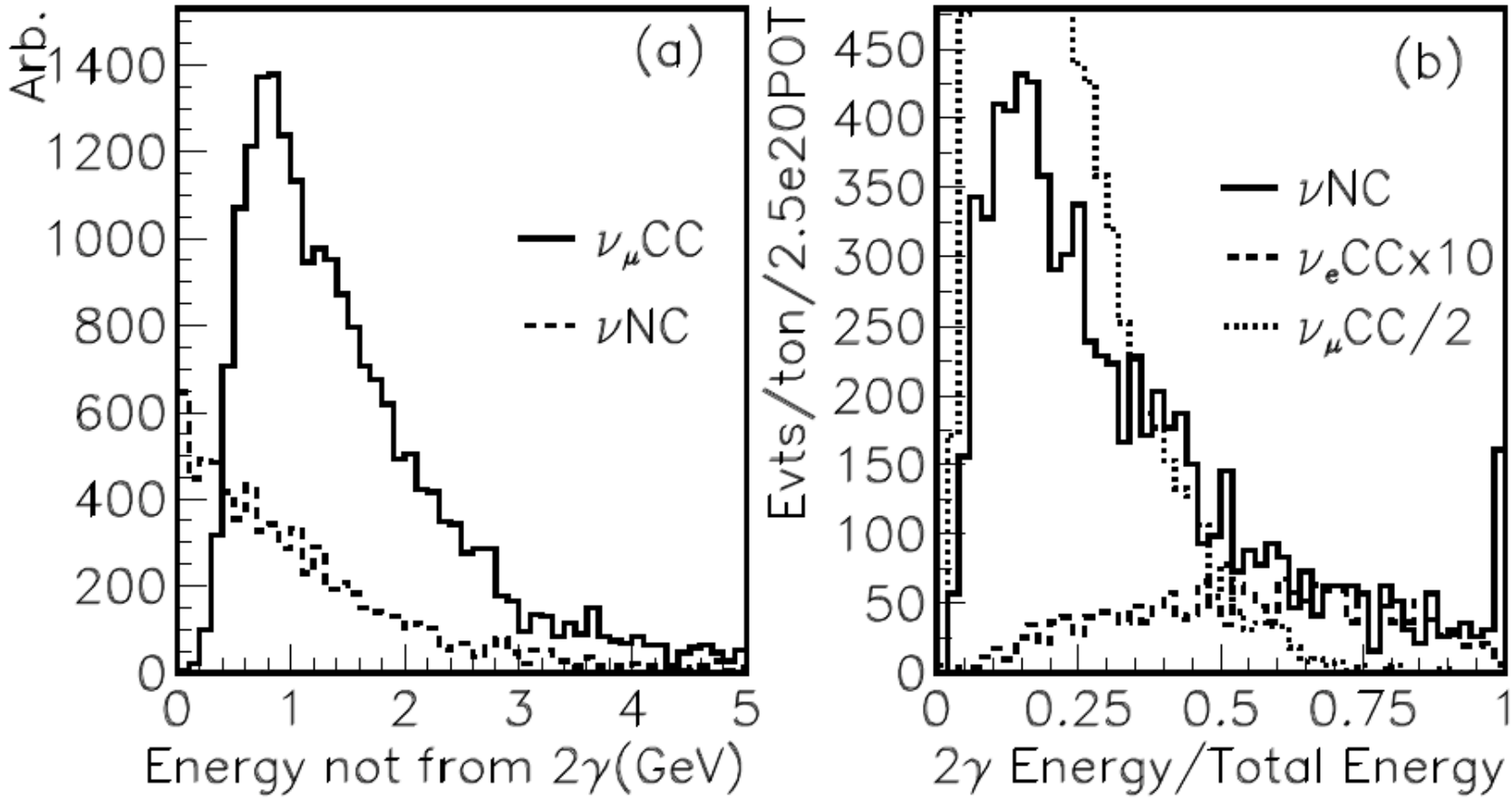
Place cuts on:

fraction of total energy in the two EM clusters

amount of energy not in the two EM clusters



Analysis Sample

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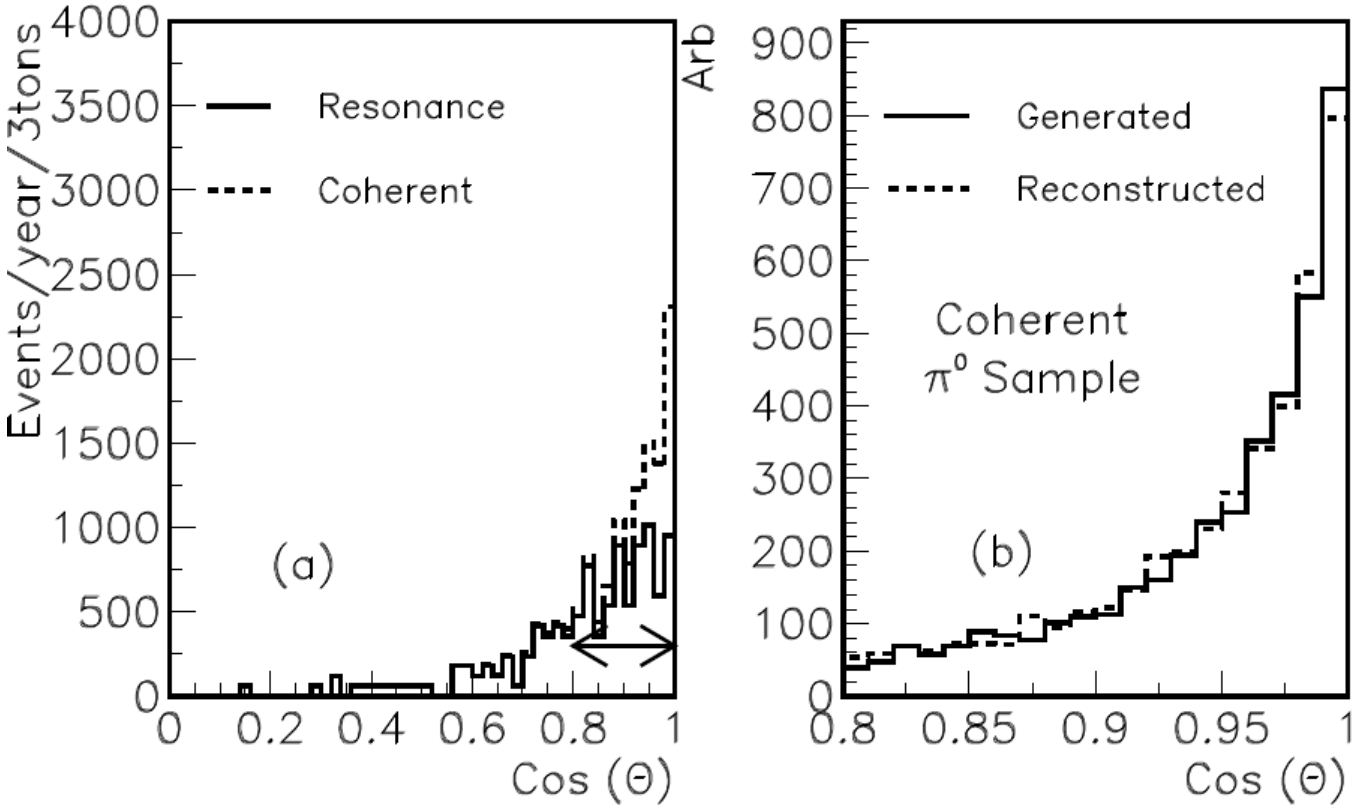
Cuts:

$E_\pi/E_{tot}>0.90$

$E_{tot}-E_\pi< 100$ MeV

Background rejection >99%
Efficiency approximately 40%
17k NC coherent events in analysis sample



Conclusions

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The Minerva experiment will be able to study neutrino-induced coherent scattering with unprecedented precision.

- 25.5k CC events, 17k NC coherent interactions
- systematics-limited measurements of $\sigma(E)$
- Measurement of A-dependence of CC production
- Detailed studies of kinematic distributions possible

Backup

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Kinematics and Smearing

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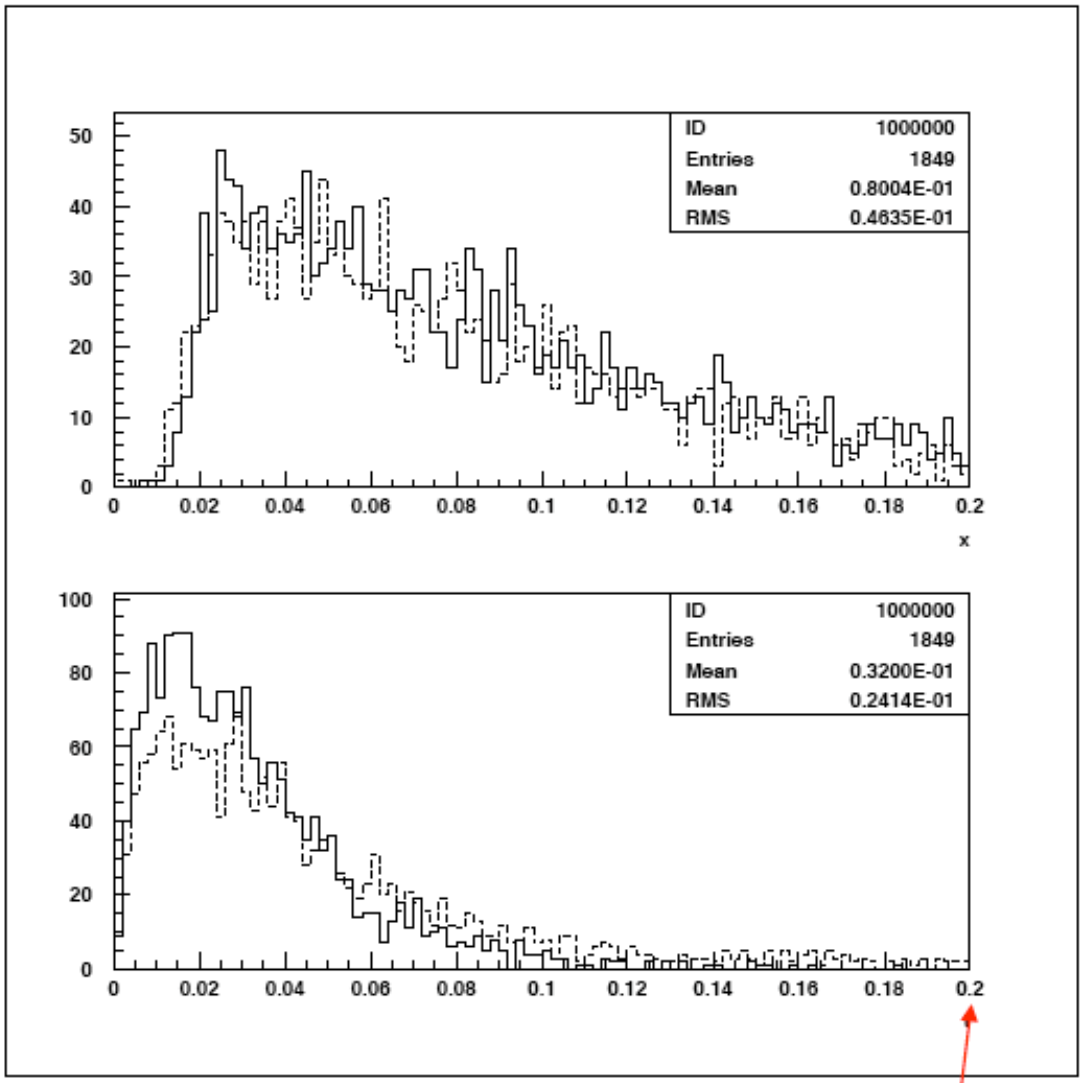

Resolutions

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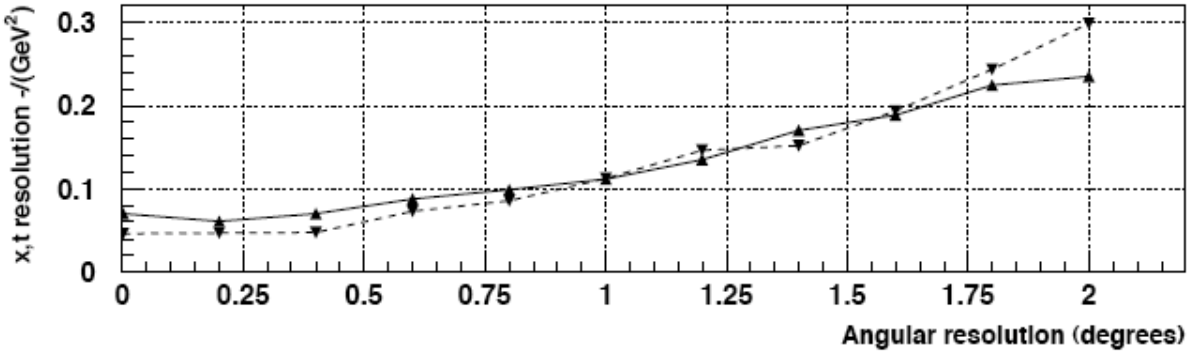

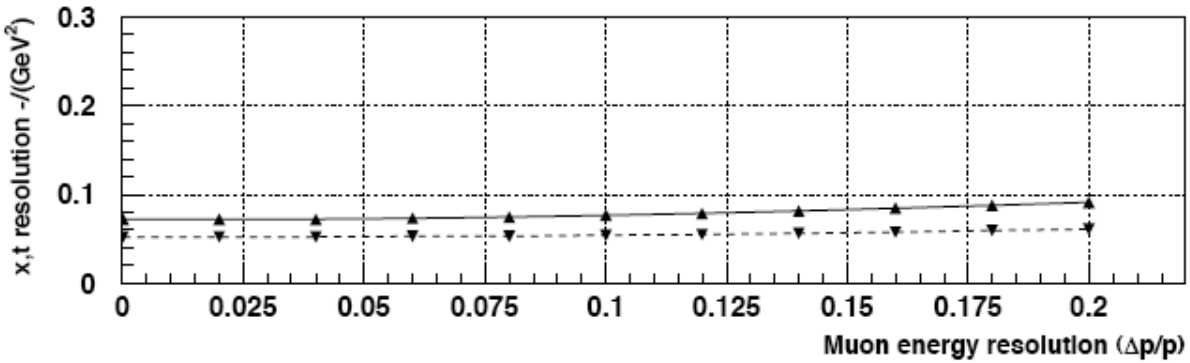

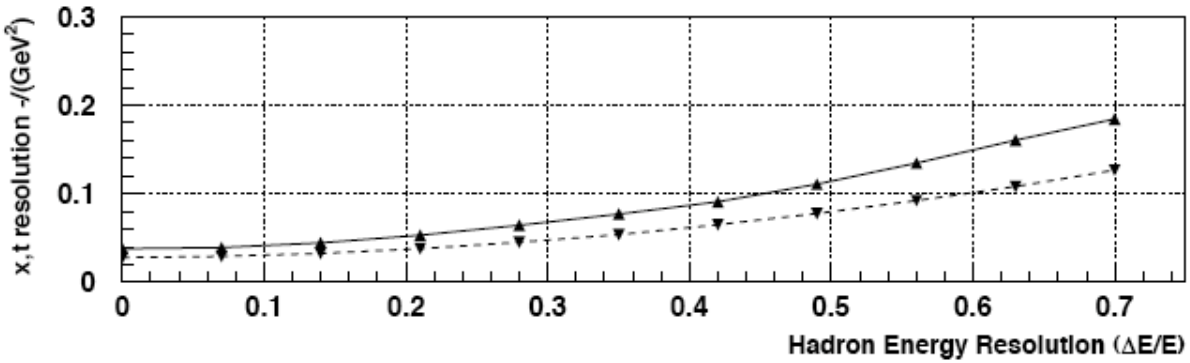

NC Coherent

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