Recent results from HARP-CDP and the "LSND anomaly"

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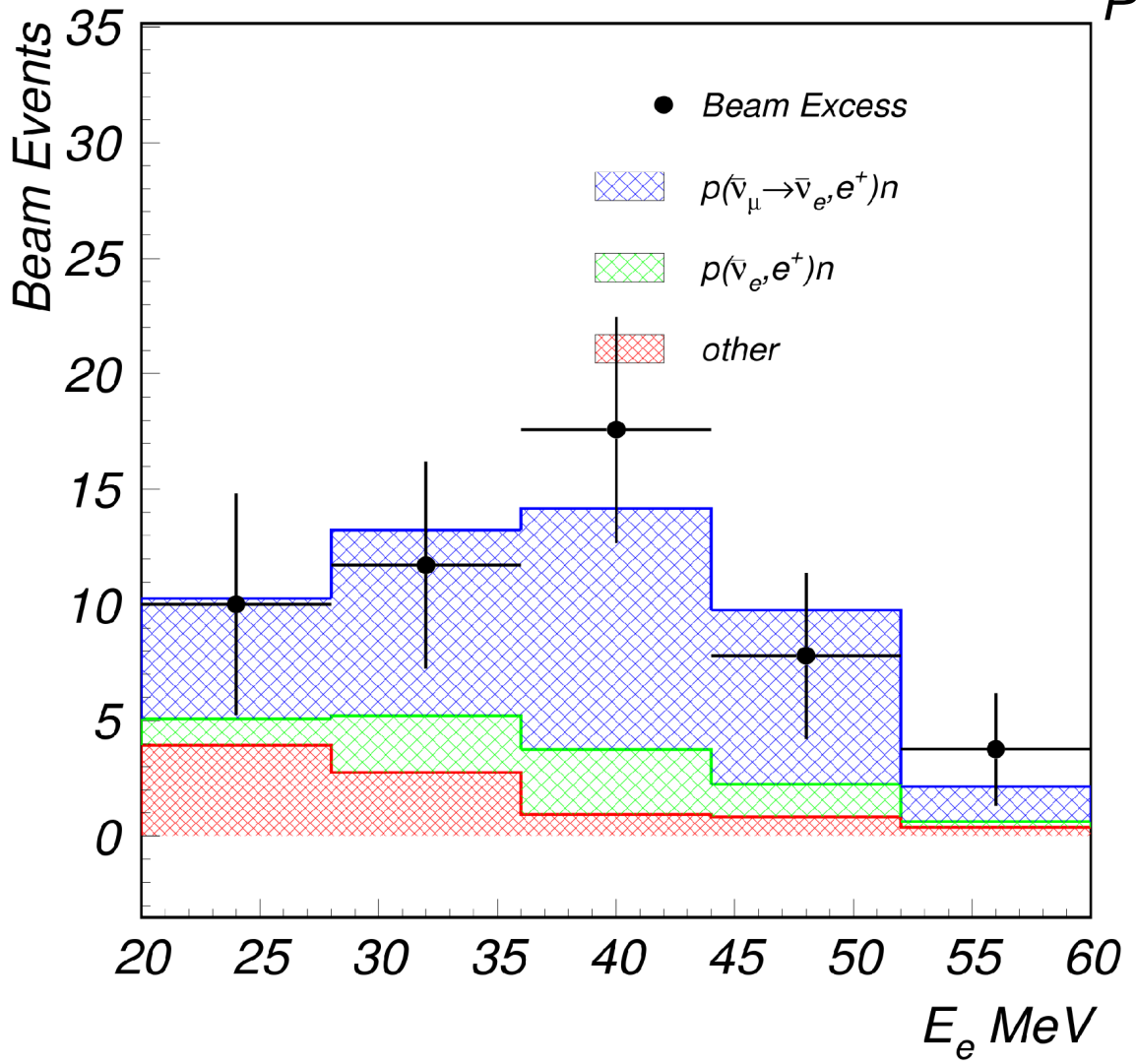
LSND

- Beam dump experiment in Los-Alamos
- Run in 1993-1998
- Claimed evidence for $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ neutrino oscillations
- This claim became known as "LSND anomaly"

The "LSND anomaly"

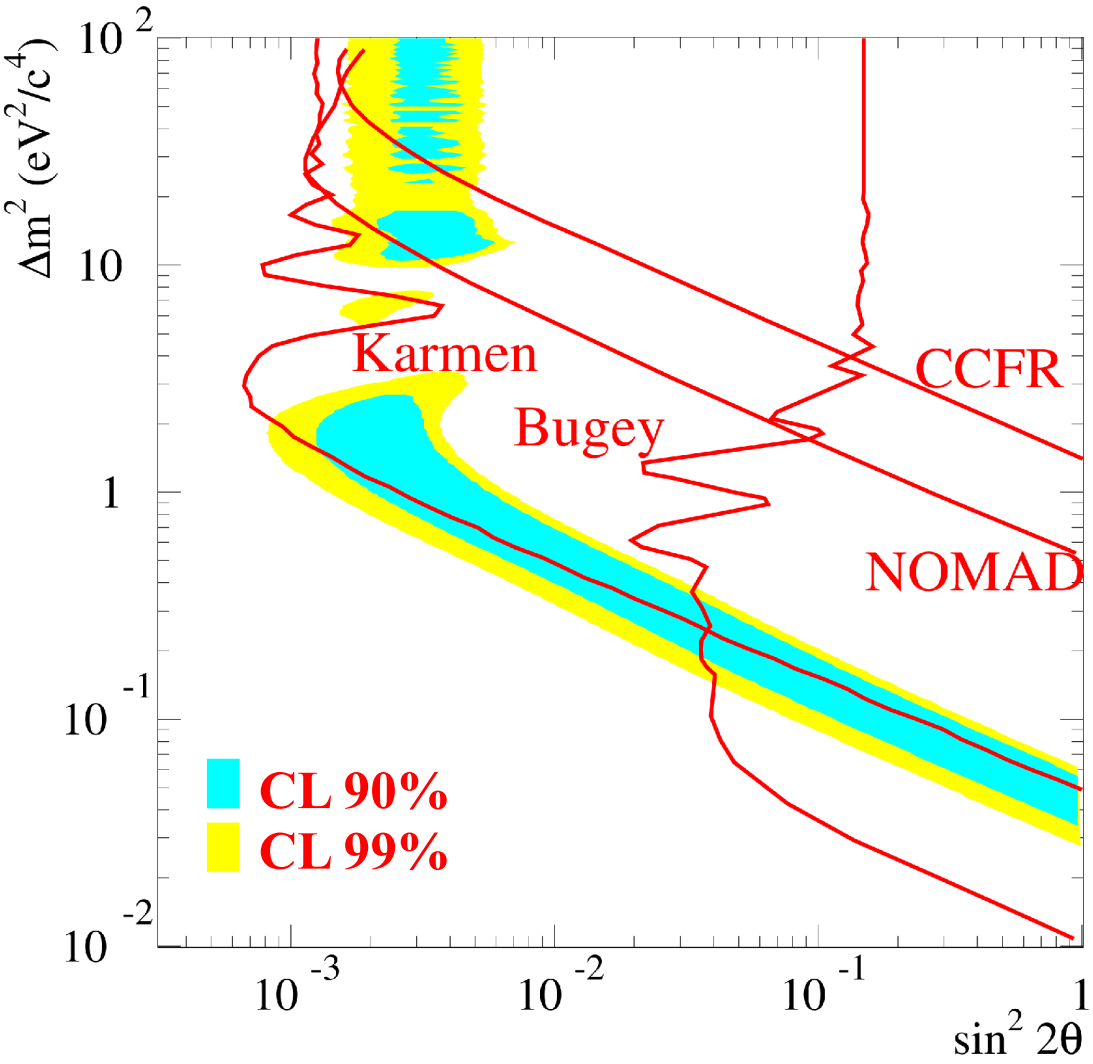
A. Aguilar et al., PRD64 (2001) 112007



A total excess of $\bar{\nu}_e$ $87.9 \pm 22.4 \pm 6.0$ events (3.8σ)

The "LSND anomaly"

A. Aguilar et al., PRD64 (2001) 112007



Δm^2 in the range of 0.2 – 10 eV^2

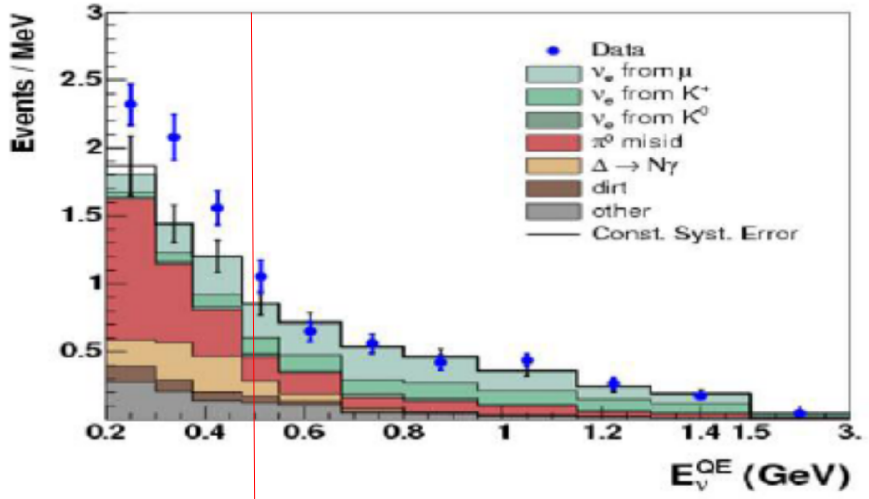
The "LSND anomaly"

- LSND result is in conflict with the measurements of solar and atmospheric neutrino oscillations
- At least one more light neutrino needed, but it contradicts LEP: $N_\nu = 2.9840 \pm 0.0082$
- Existence of at least one 'sterile' neutrino is required
- SPIRES: 800 theoretical papers on sterile neutrinos (700 after 1998)

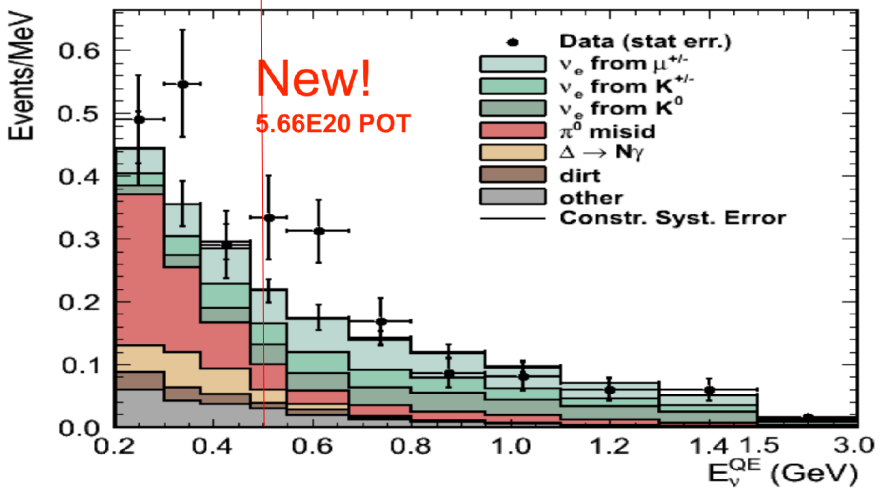
Test by MiniBooNE

MiniBooNE ν_e and $\bar{\nu}_e$ Data

ν Mode



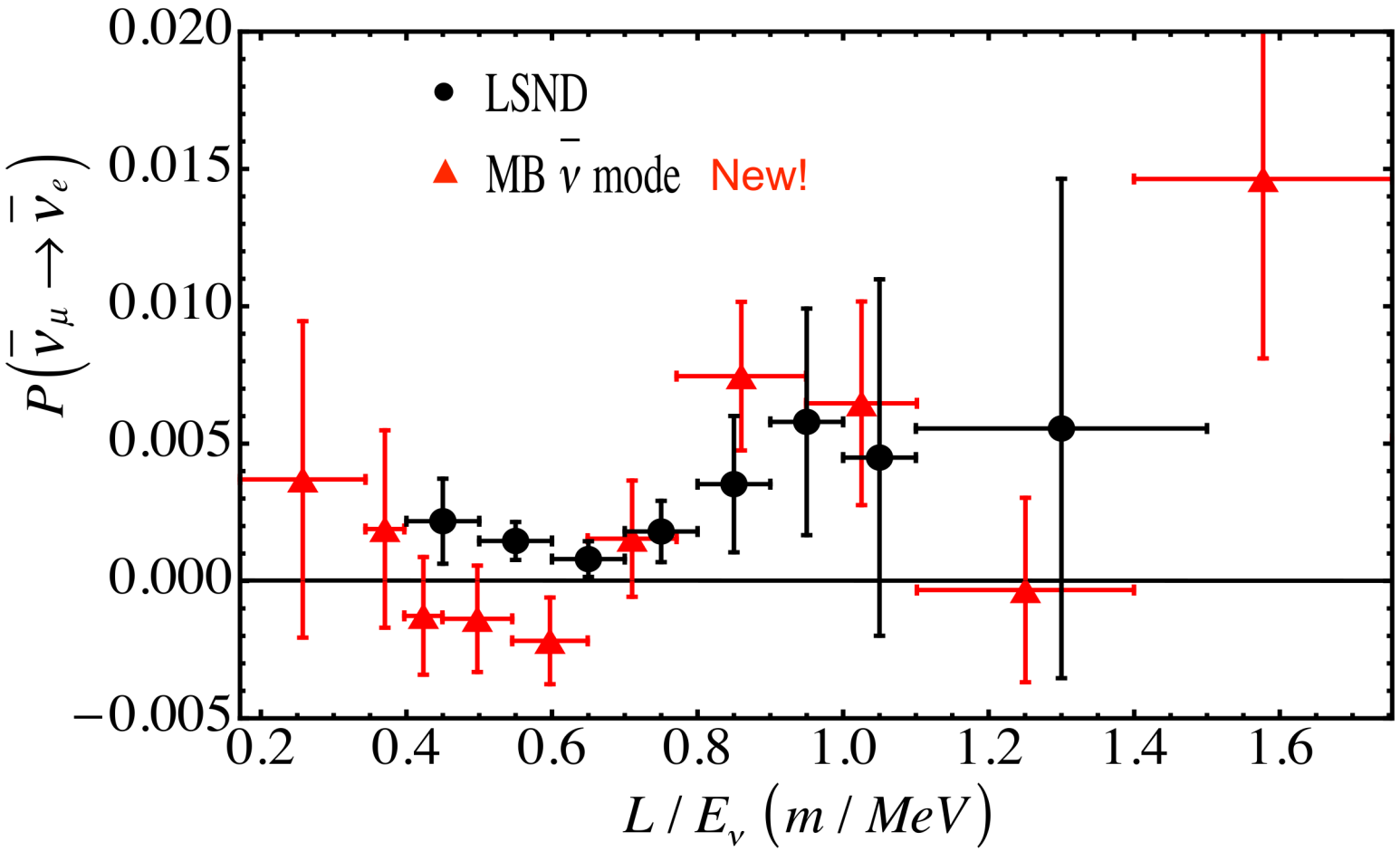
$\bar{\nu}$ Mode



G.Mills, ICHEP2010

Test by MiniBooNE

Direct MiniBooNE-LSND Comparison of $\bar{\nu}$ Data



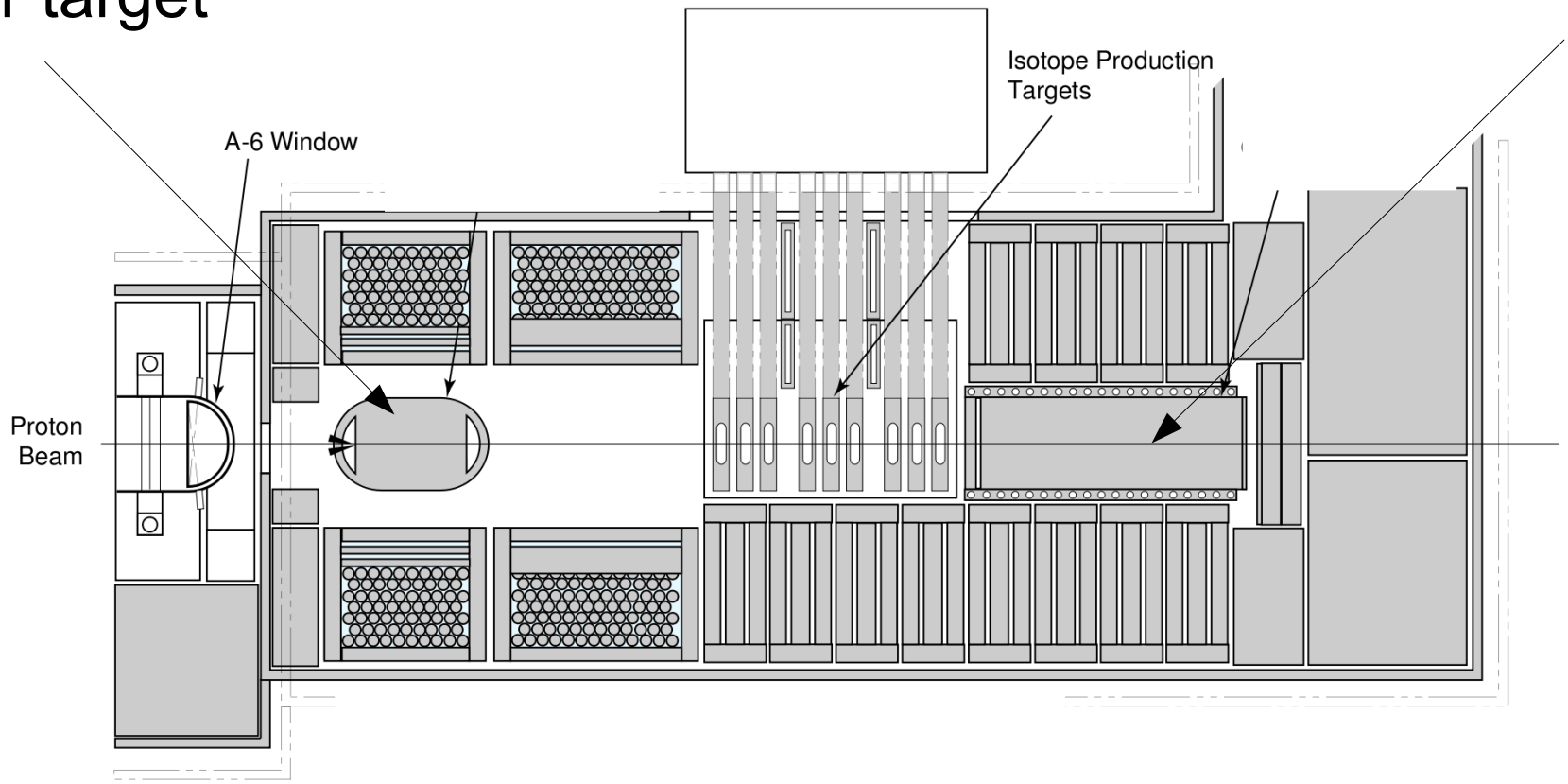
G.Mills, ICHEP2010

What did LSND actually do?

The LSND neutrino source

Water target

Copper beam stop

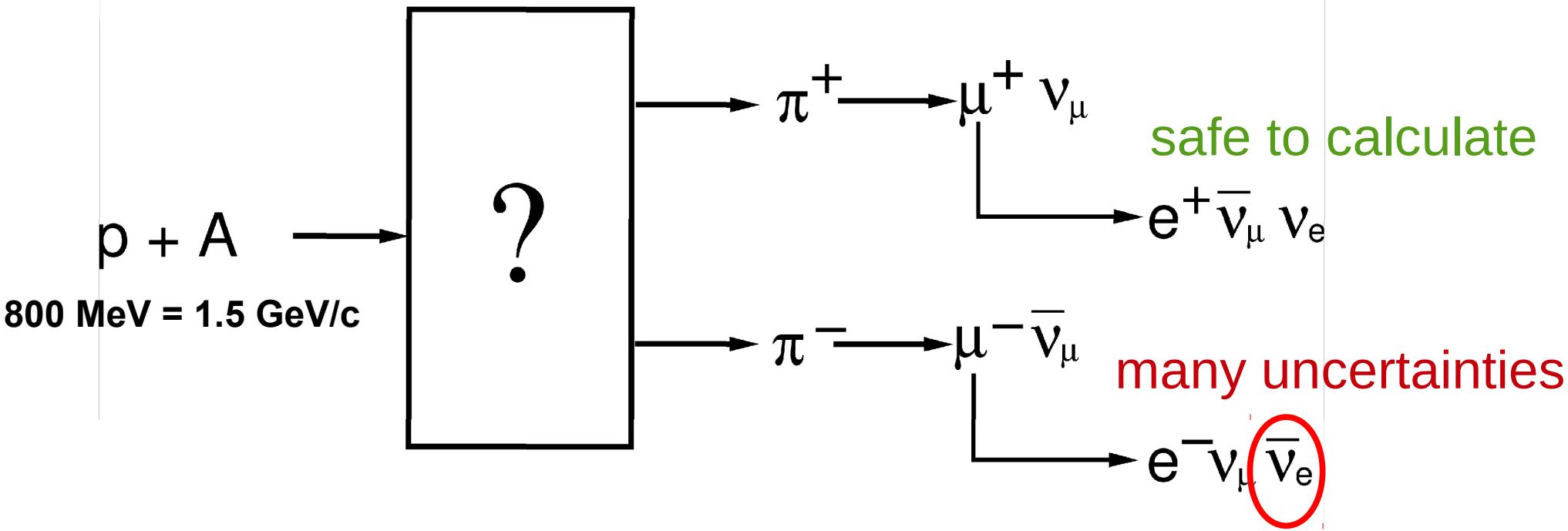


PLAN VIEW, NEUTRINO SOURCE

Geometry of 1993-1995

C.Athanassopoulos et al., NIM A388 (1997) 149-172

The LSND neutrino source



DAR = Decay at Rest

DIF = Decay in Flight

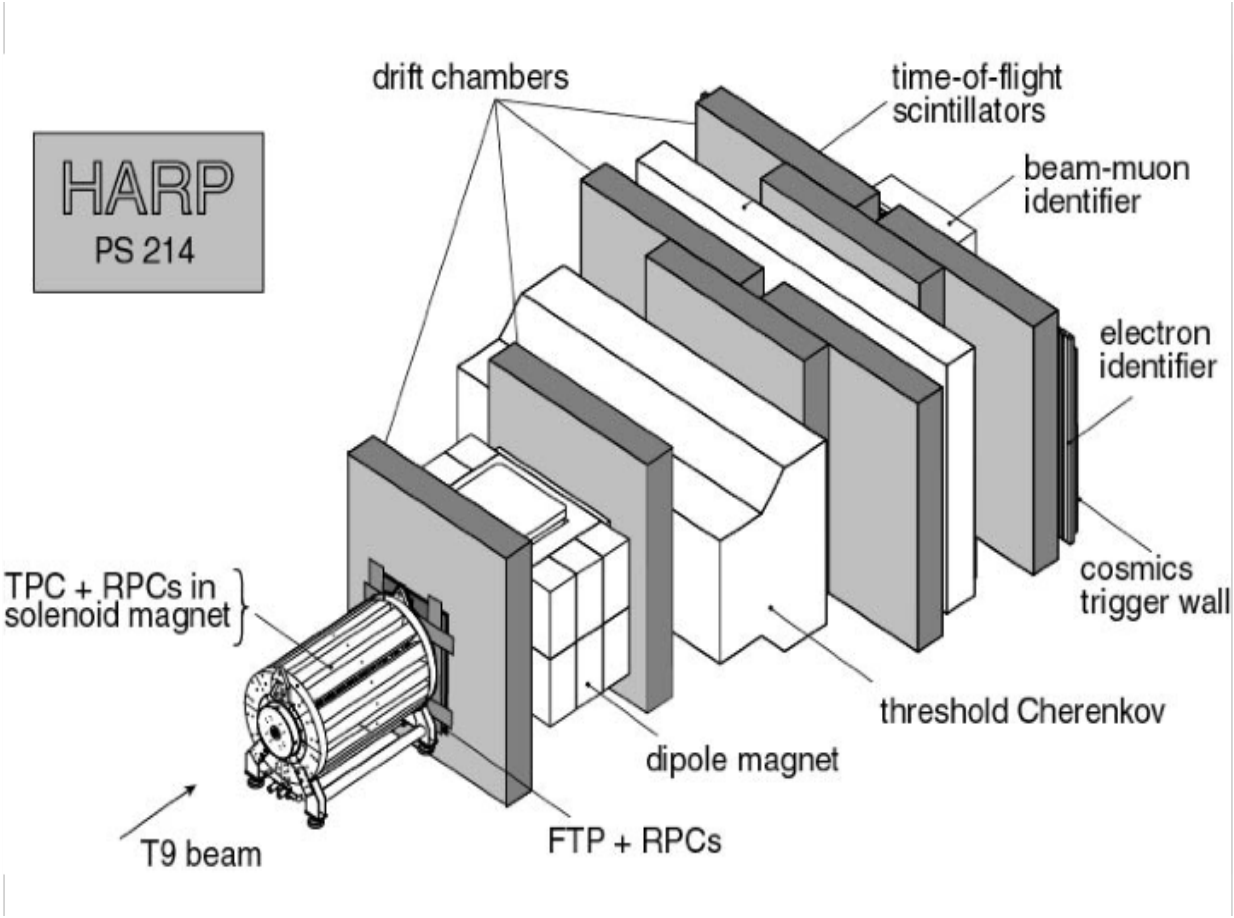
The HARP experiment (1/2)

- Proton and $\pi^{\pm}$ beams of 1.5 – 15 GeV/c
- Targets:

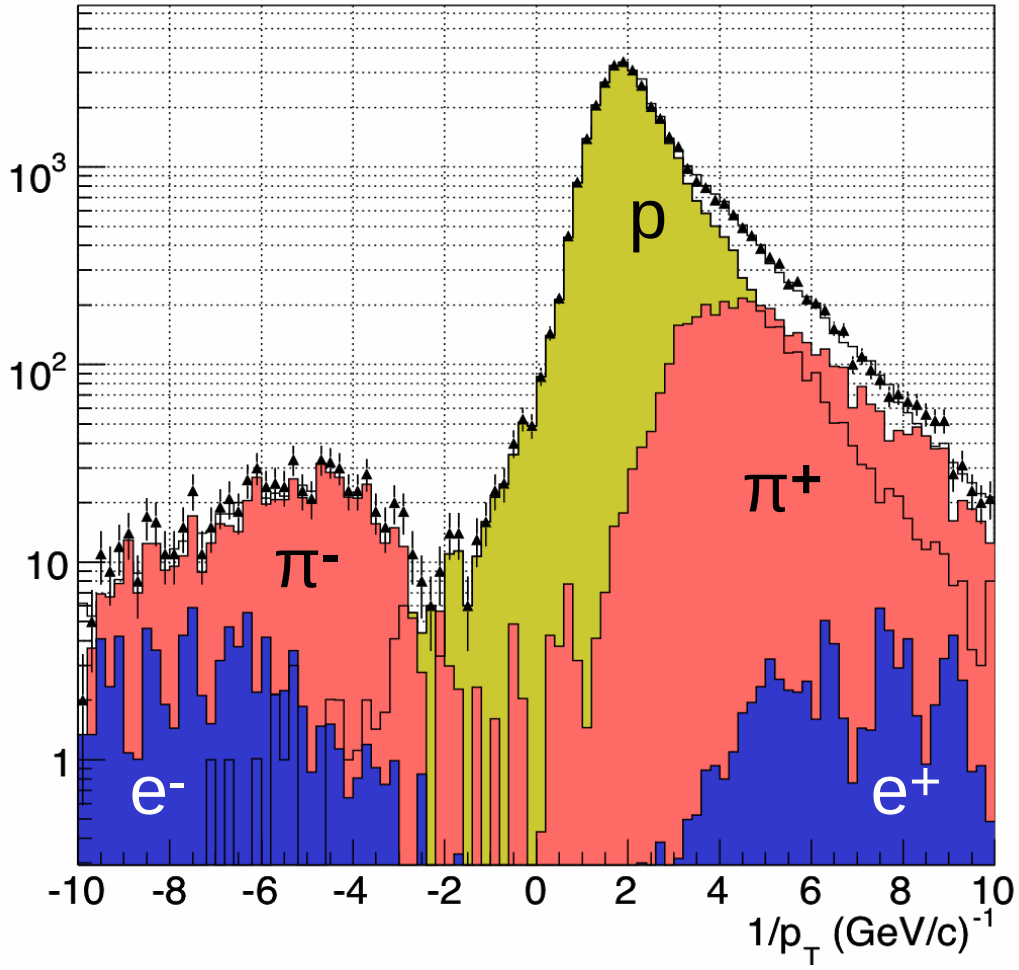
  Be C Al Cu Sn Ta Pb H_2

  D_2 N_2 O_2

  H_2O
- Large Angle Spectrometer: $20^o<\theta<140^o$



The HARP experiment (2/2)

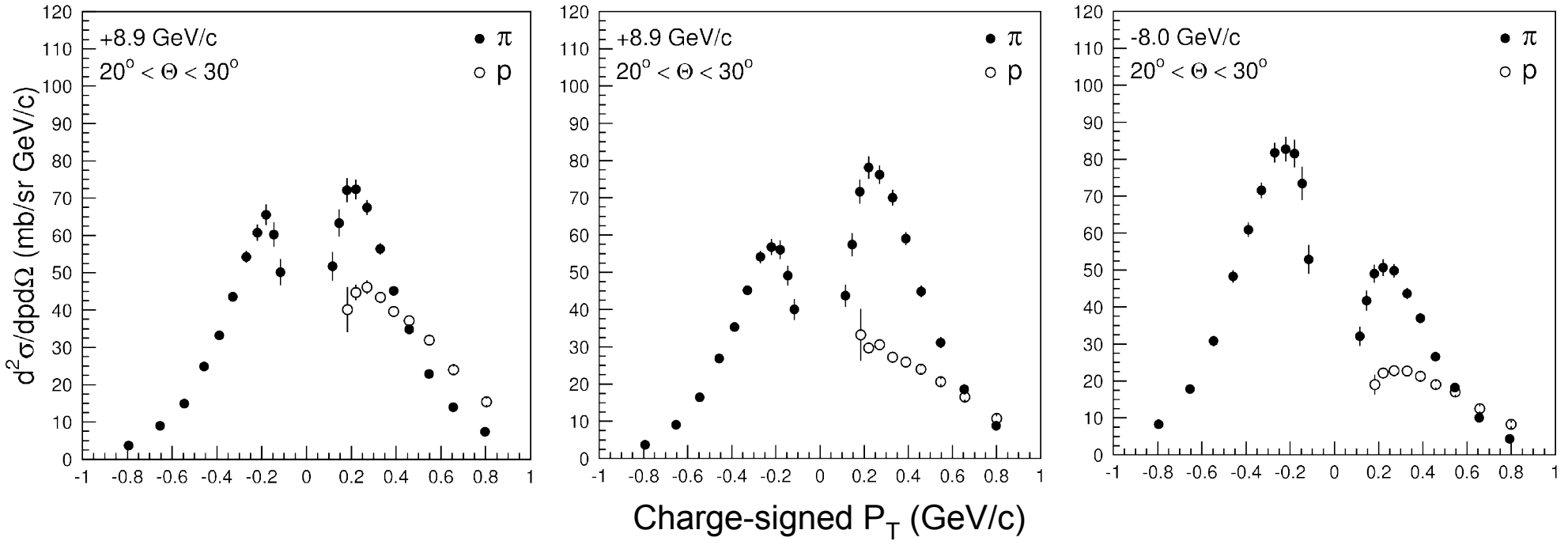


Allows to check an important ingredient of the LSND background: the production of π^- by 1.5 GeV/c protons

A 5 min digression (1/5)

Proton, π^+ and π^- production spectra (HARP-CDP)

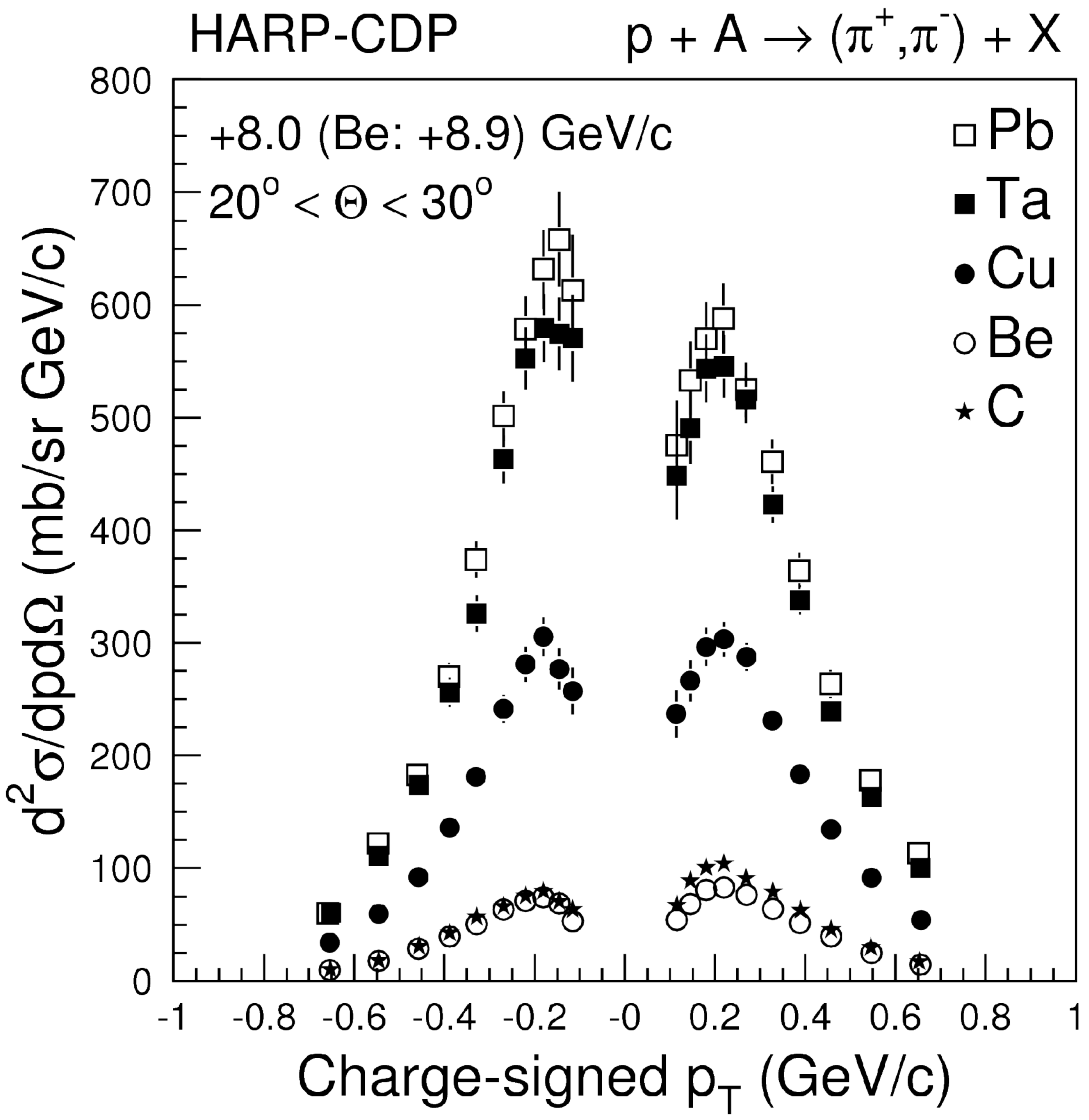
p + Be → (p, π^+,π^-) X **π^+ + Be → (p, π^+,π^-) X** **π^- + Be → (p, π^+,π^-) X**



Cross-section tables for **Be, C, Cu, Ta, Pb** (3-15 GeV/c) are published,

A 5 min digression (2/5)

Forward spectra for different nuclei

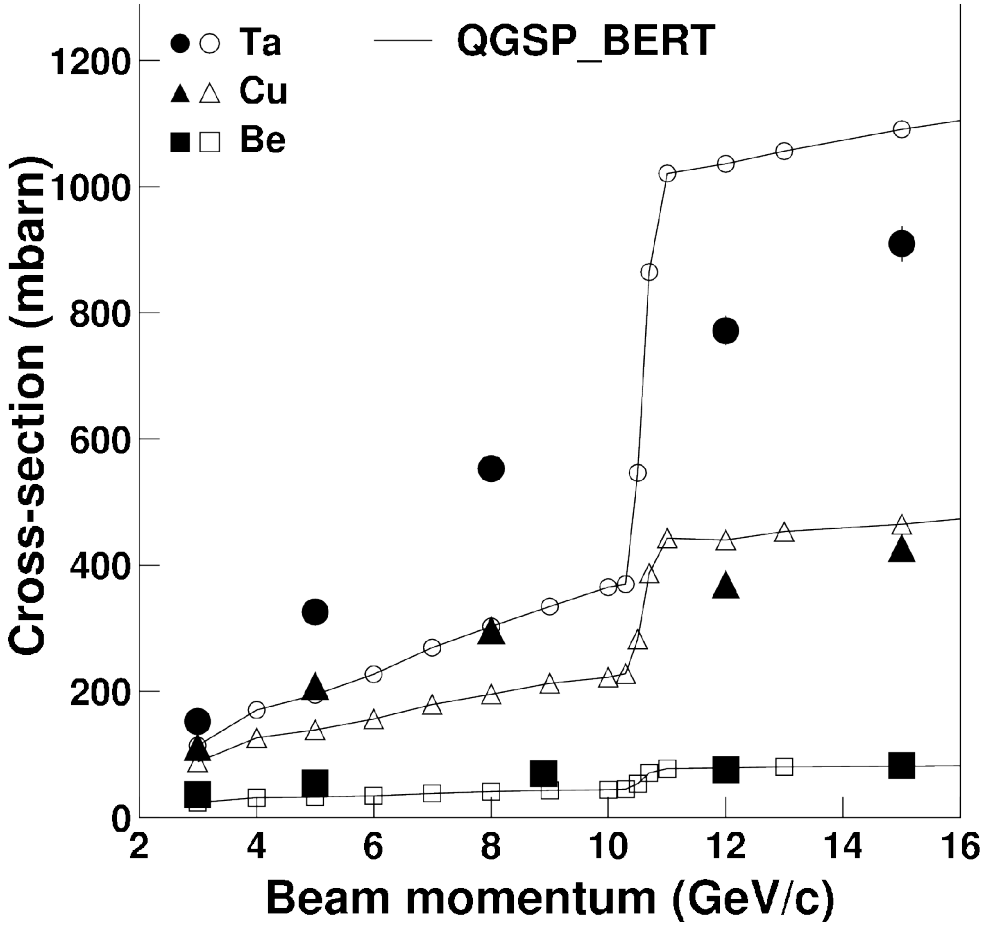


A 5 min digression (3/5)

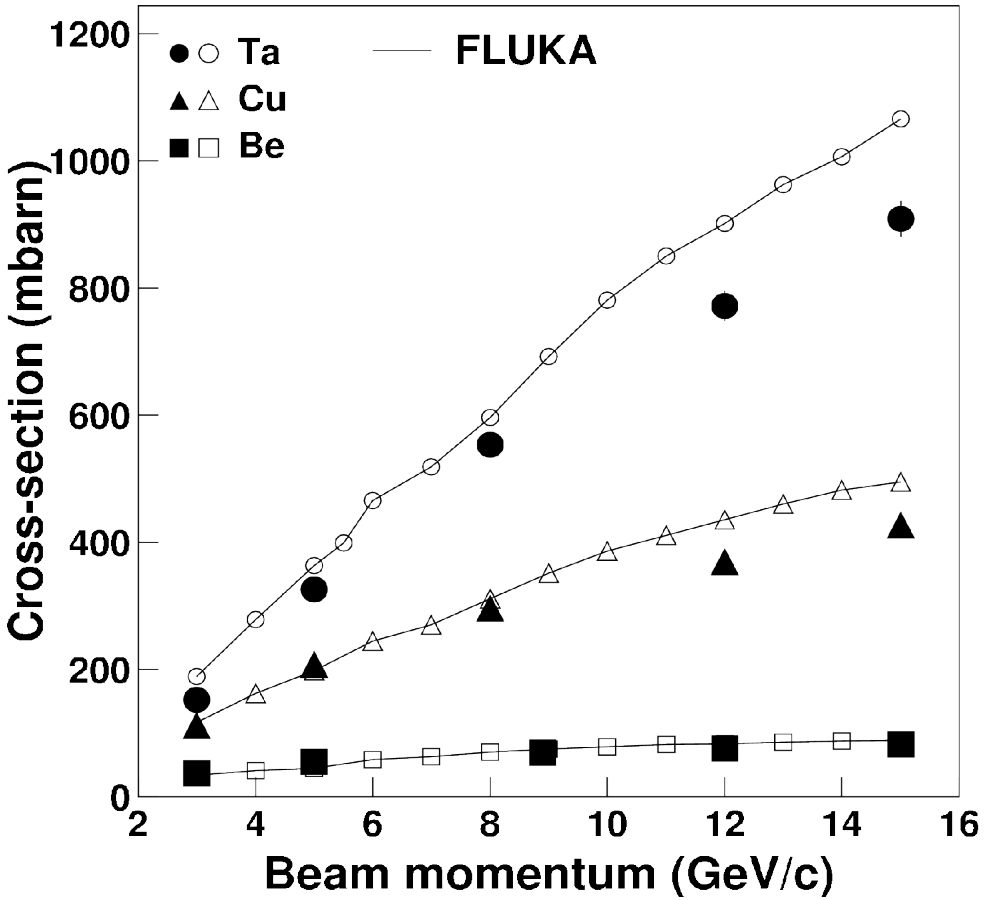
Comparison with Geant4 and FLUKA

$pA \rightarrow \pi^{+}X$ $20^{o}<\theta<50^{o}$

Geant4

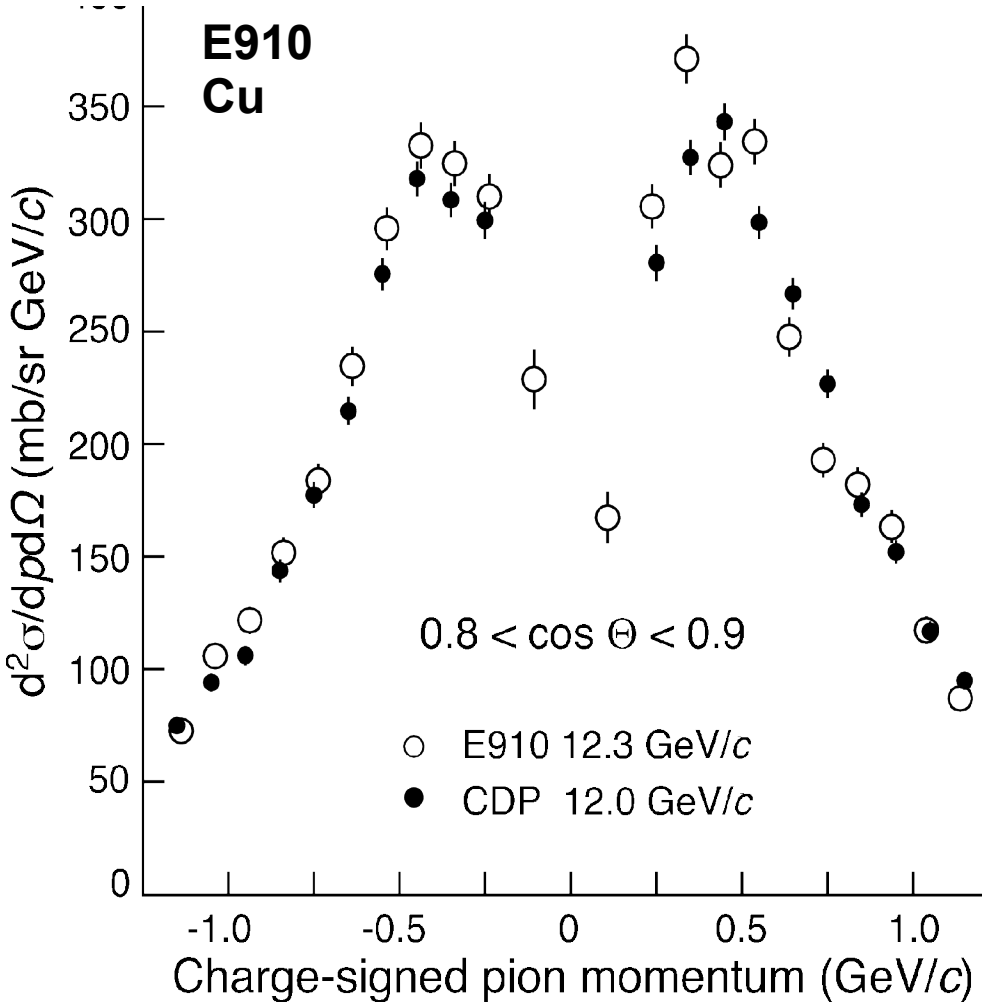


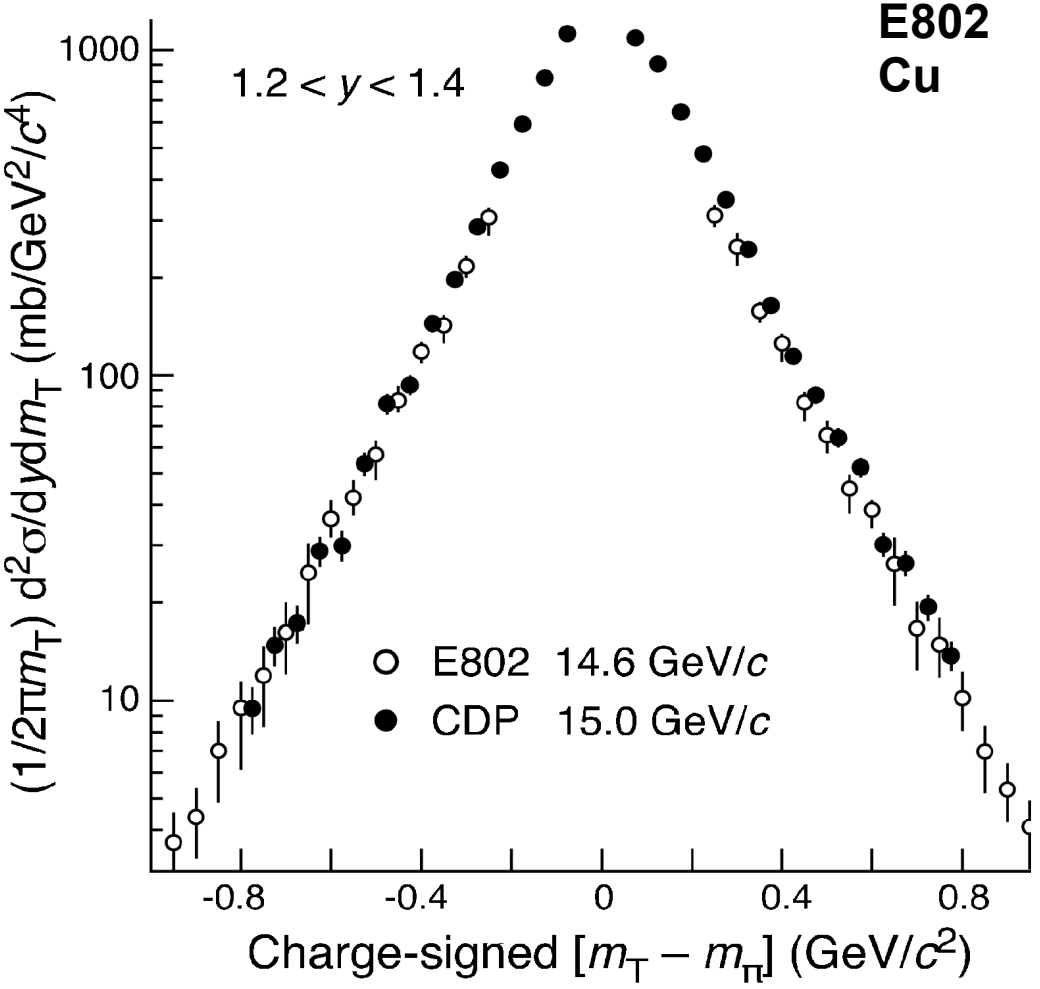
FLUKA



A 5 min digression (4/5)

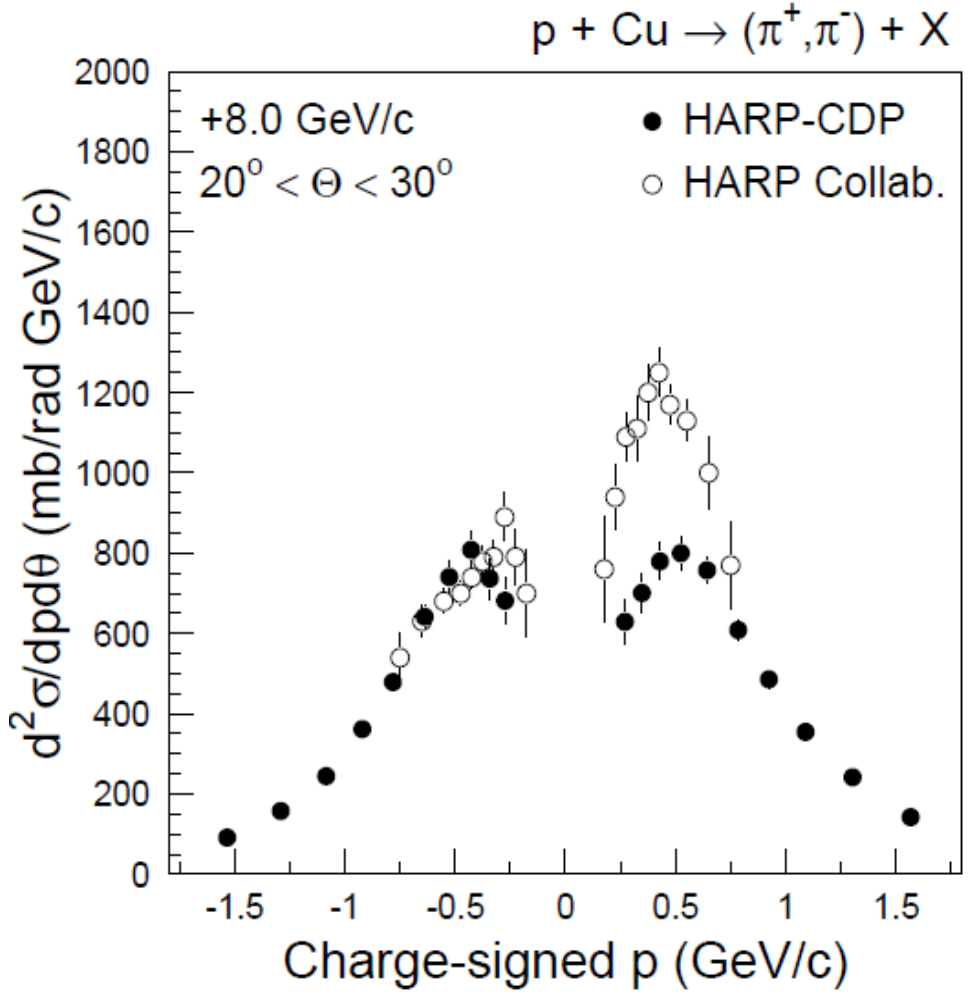
Comparison with results from other experiments





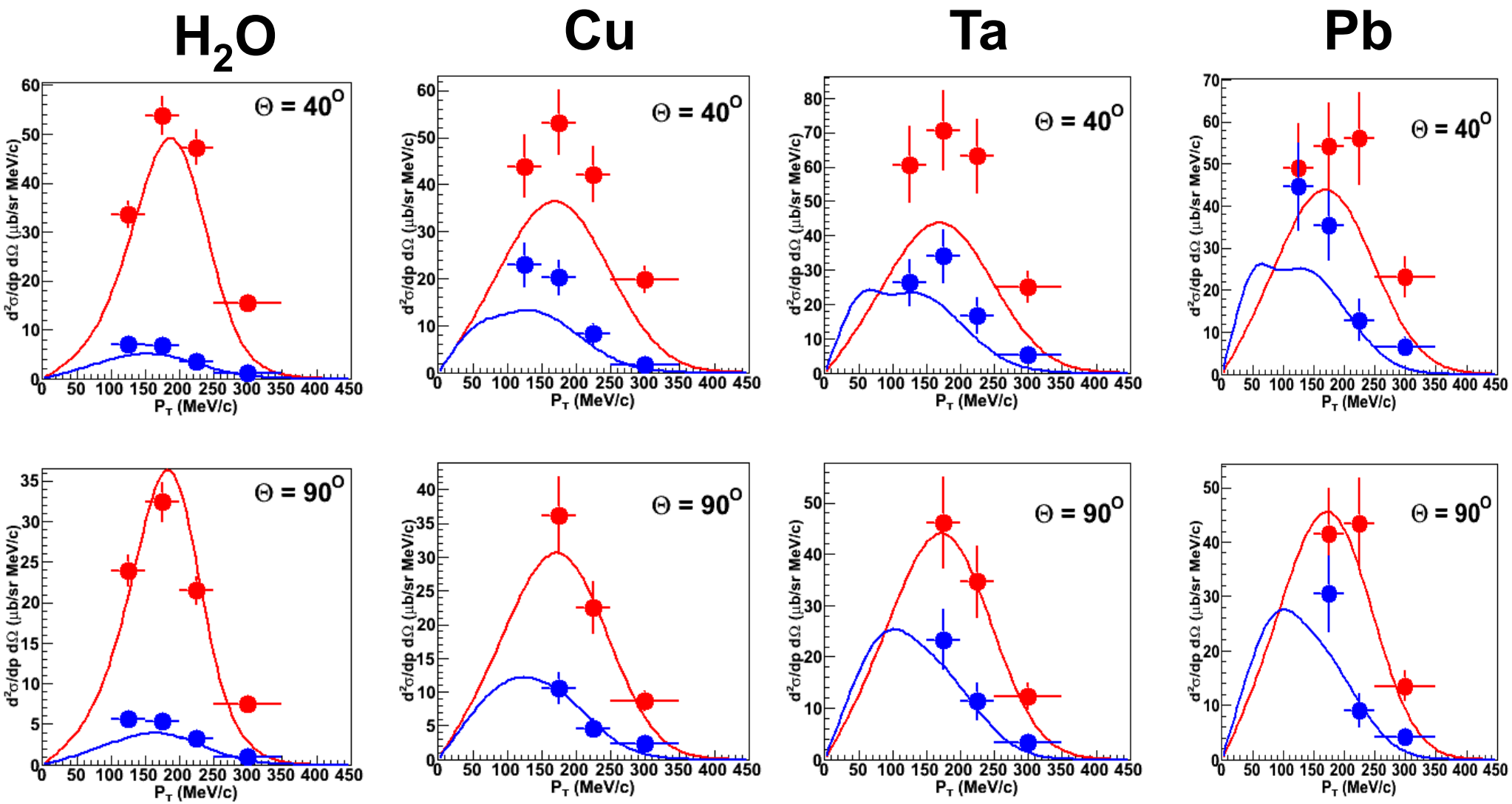
A 5 min digression (5/5)

Comparison with results from the HARP Collaboration



HARP-CDP data vs LSND parametrization

$$p(1.5\ \text{GeV/c}) + A \rightarrow (\pi^+, \pi^-)\, X$$



Our simulation

Two independent simulations

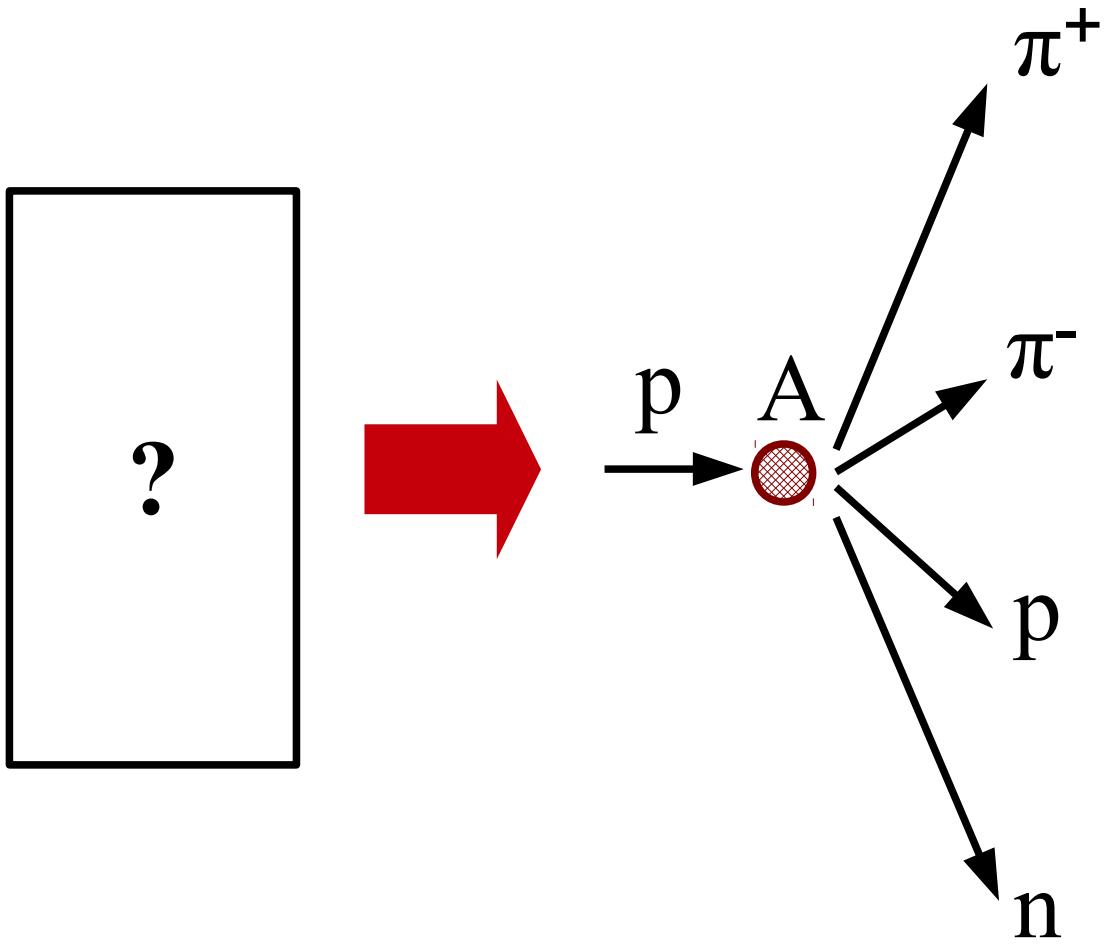
Geant4-based

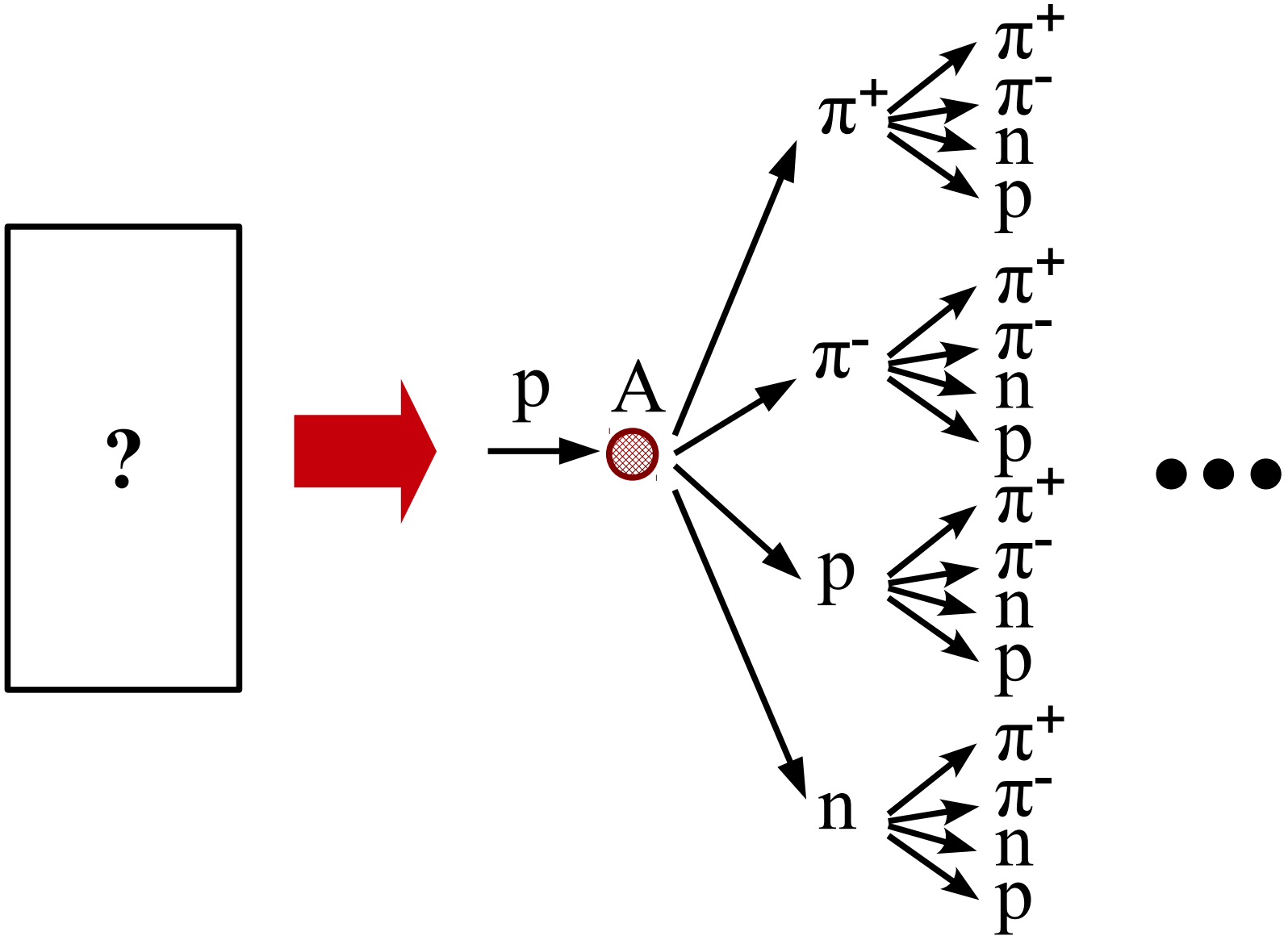
- Detailed description of geometry
- Geant4 or LSND cross-sections

Standalone

- Less detailed geometry
- LSND, FLUKA or Geant4 cross-sections
- Experimental cross-sections

Give consistent results


?
p
A
π+
π-
p
n


?
p
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π+
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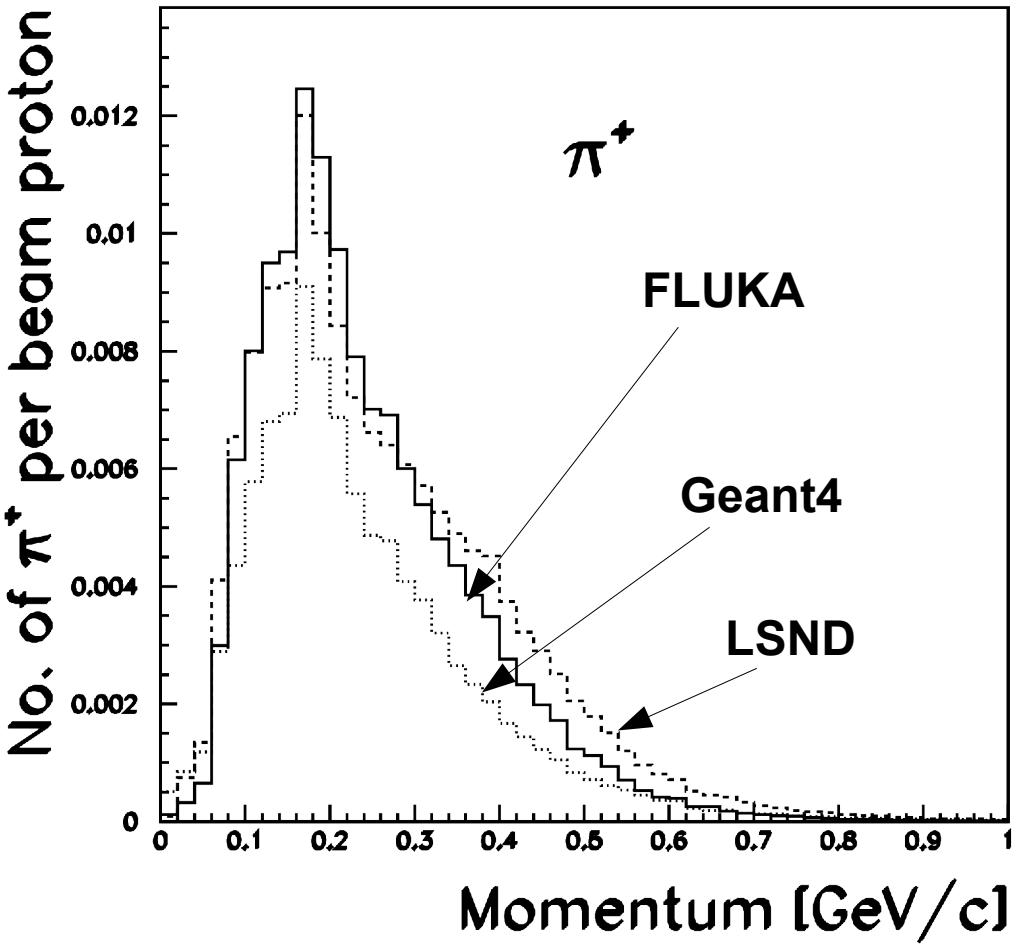
Our simulation

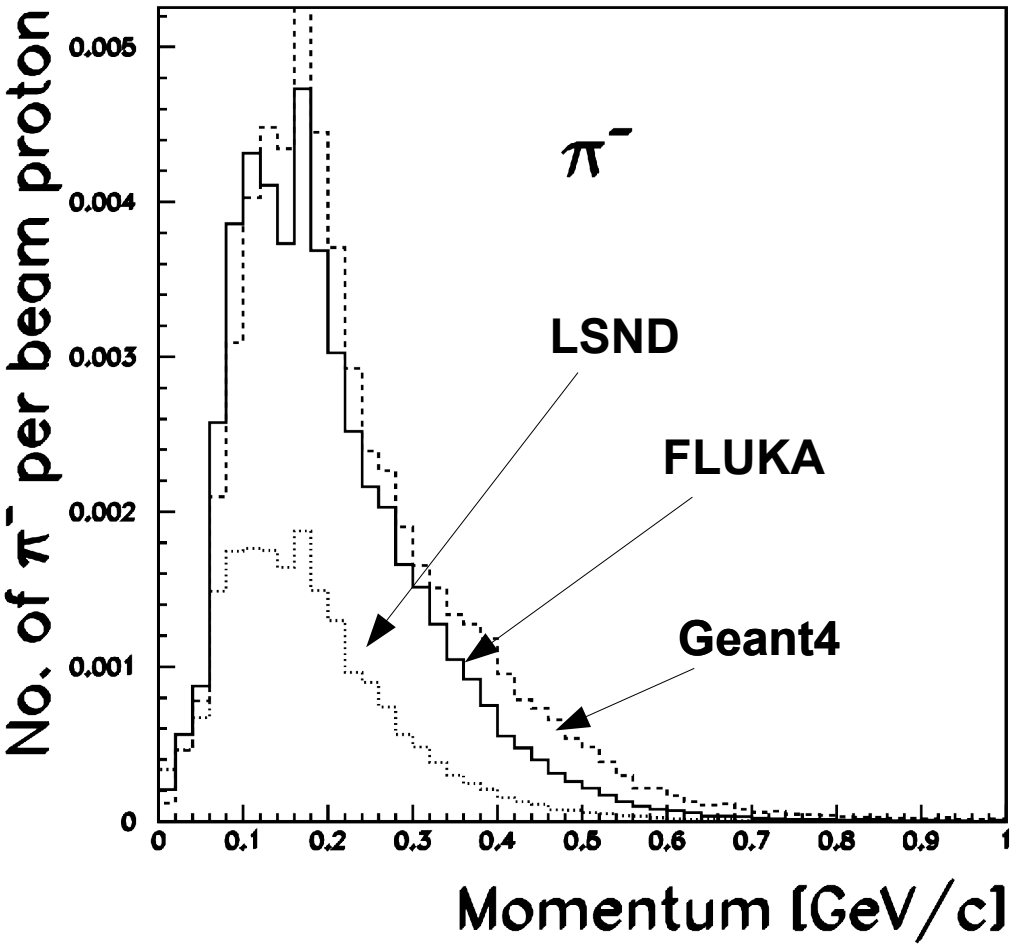
PRETTY COMPLICATED TASK

We need differential pion production cross-sections:

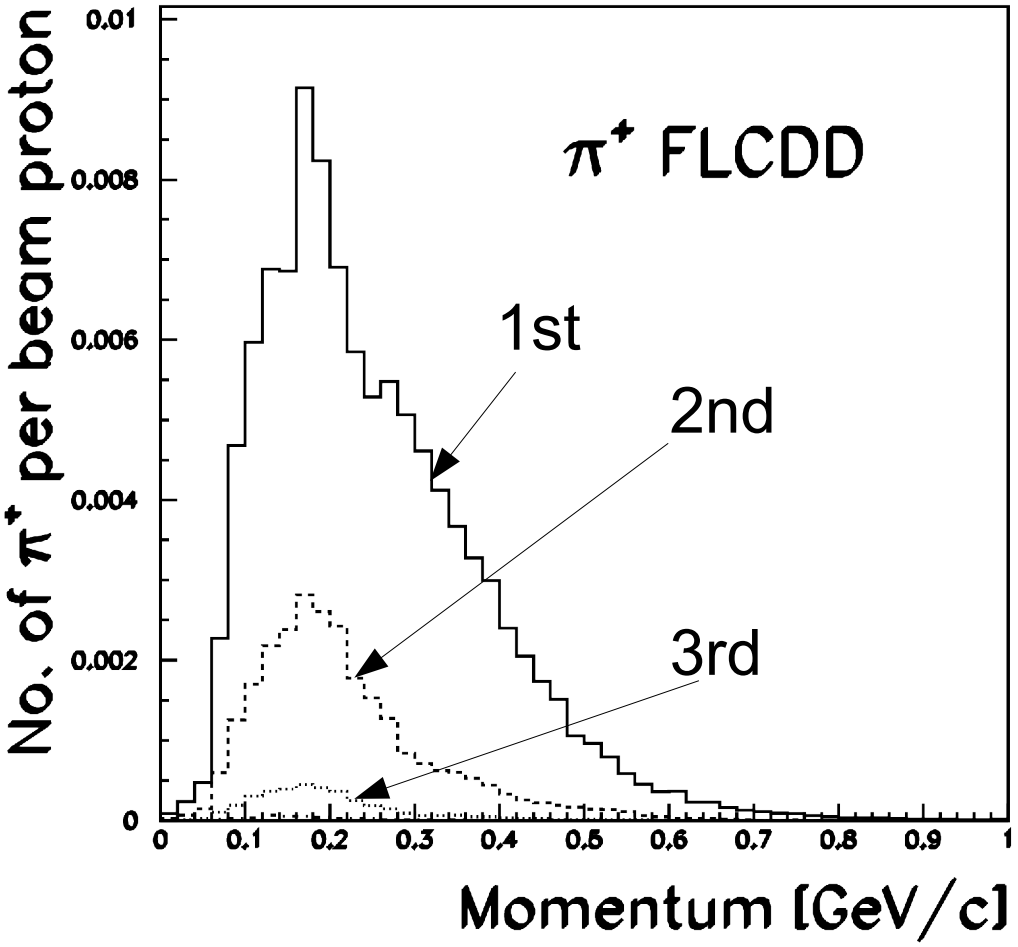
- of p, n, π^+,π^-
- on H_2O, Fe, Cu, Al, Mo, Air
- as a function of projectile momentum

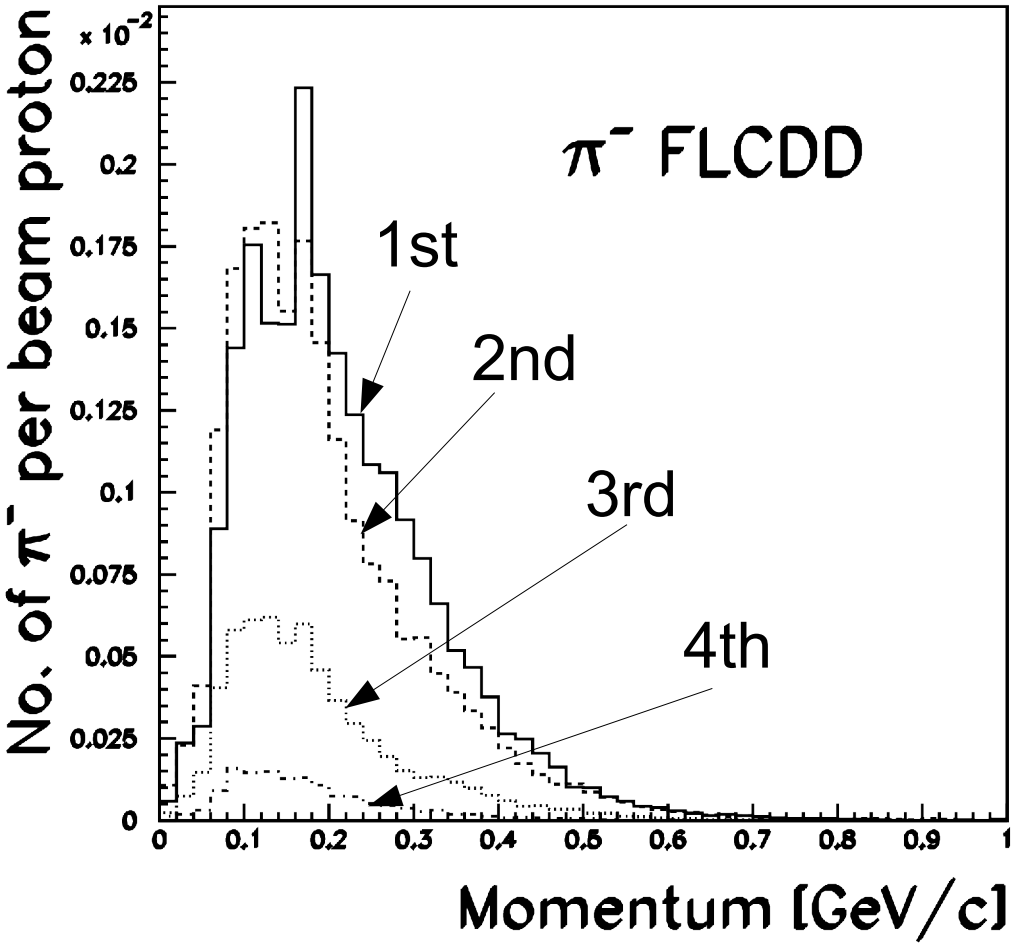
Pions from different models



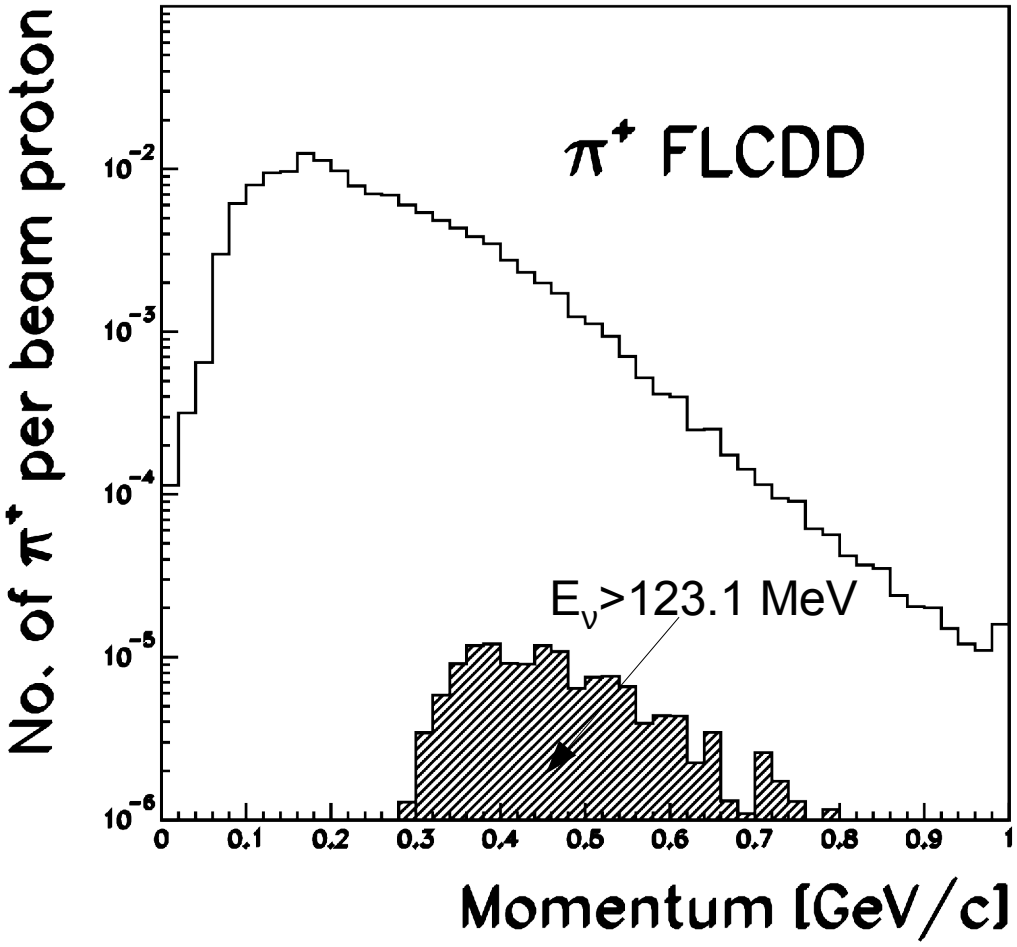


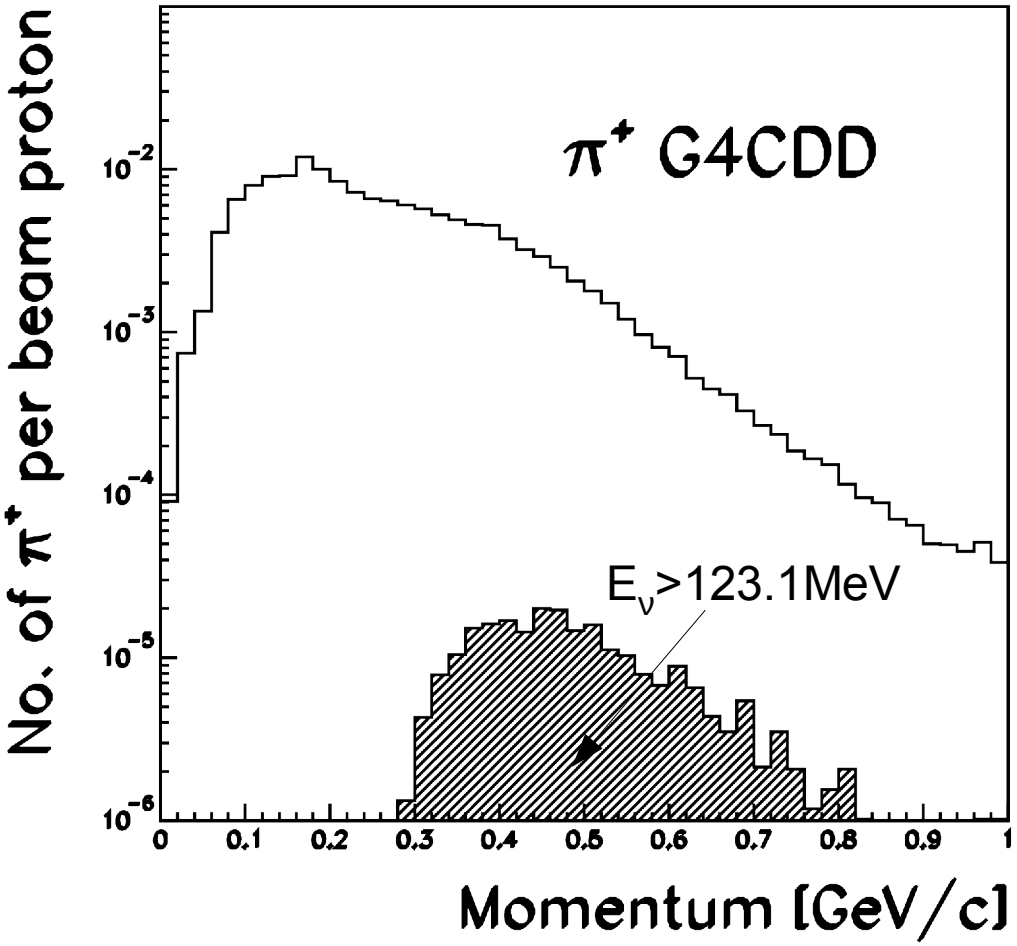
Pion generations





Pion momentum spectra



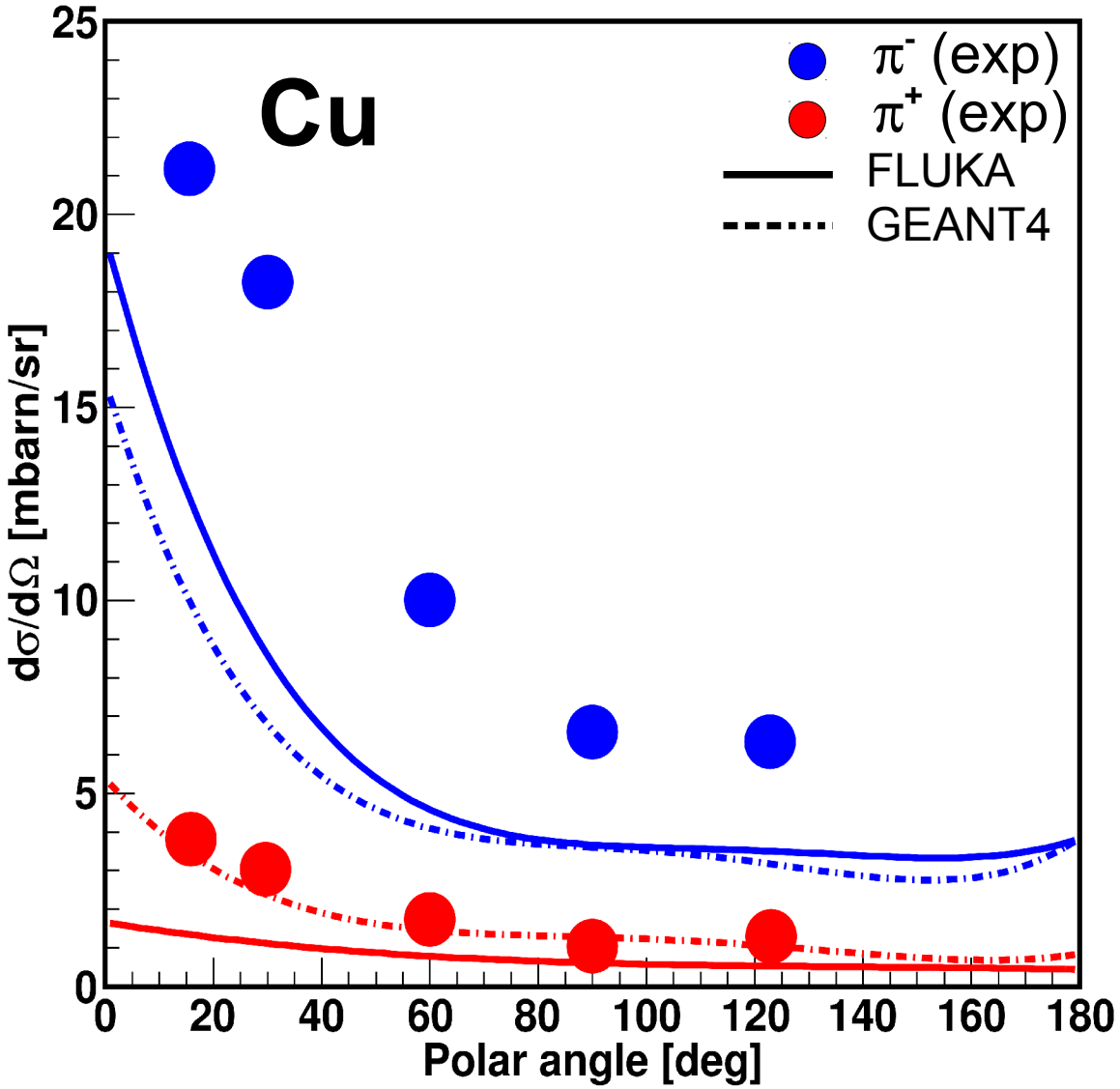


We realized that

- LSND used pions from the first generation only
- LSND ignored pion production by neutrons

Pion production by 600 MeV neutrons

K.O. Oganesian, JETP 54 (1968) 1273



HARP-CDP simulation results

	LSND published (1993-1995)
π^-/π^+	(0.12)
DAR $\bar{\nu}_\mu$ [ν/PoT/cm^2]	0.8×10^{-9}
DAR $\bar{\nu}_e$ [ν/PoT/cm^2]	0.65×10^{-12}

HARP-CDP simulation results

	LSND published (1993-1995)	LSND "emulation"
π^-/π^+	(0.12)	0.203
DAR $\bar{\nu}_\mu$ [ν/PoT/cm^2]	0.8×10^{-9}	0.72×10^{-9}
DAR $\bar{\nu}_e$ [ν/PoT/cm^2]	0.65×10^{-12}	0.56×10^{-12}

HARP-CDP simulation results

	LSND published (1993-1995)	LSND "emulation"	Geant4 ⊕ Exp. data
π^-/π^+	(0.12)	0.203	0.382
DAR $\bar{\nu}_\mu$ [ν/PoT/cm^2]	0.8×10^{-9}	0.72×10^{-9}	0.76×10^{-9}
DAR $\bar{\nu}_e$ [ν/PoT/cm^2]	0.65×10^{-12}	0.56×10^{-12}	0.96×10^{-12}

HARP-CDP simulation results

	LSND published (1993-1995)	LSND "emulation"	Geant4 ⊕ Exp. data	FLUKA ⊕ Exp. data
π^-/π^+	(0.12)	0.203	0.382	0.356
DAR $\bar{\nu}_\mu$ [ν/PoT/cm^2]	0.8×10^{-9}	0.72×10^{-9}	0.76×10^{-9}	0.75×10^{-9}
DAR $\bar{\nu}_e$ [ν/PoT/cm^2]	0.65×10^{-12}	0.56×10^{-12}	0.96×10^{-12}	0.89×10^{-12}

HARP-CDP simulation results

- HARP-CDP "emulation" of LSND is satisfactory

- HARP-CDP best estimate of $\bar{\nu}_e$ rate is higher by factor of **1.7** w.r.t. LSND emulation

Estimate of signal significance

	LSND	HARP-CDP
Total number of $\bar{\nu}_e$ events	117.9 ± 22.4	
Background I ($\bar{\nu}_e$ produced at beam stop)	19.5 ± 3.9	32.5 ± 9.3
Background II (misidentification of ν_μ and $\bar{\nu}_\mu$)	10.5 ± 4.6	10.5 ± 4.6
Excess	87.9 ± 22.4 ± 6.0 (3.8 σ)	74.9 ± 22.4 ± 10.3 (3.0 σ)

But, LSND say:

We have verified neutrino fluxes by the cross-section measurements of known processes.

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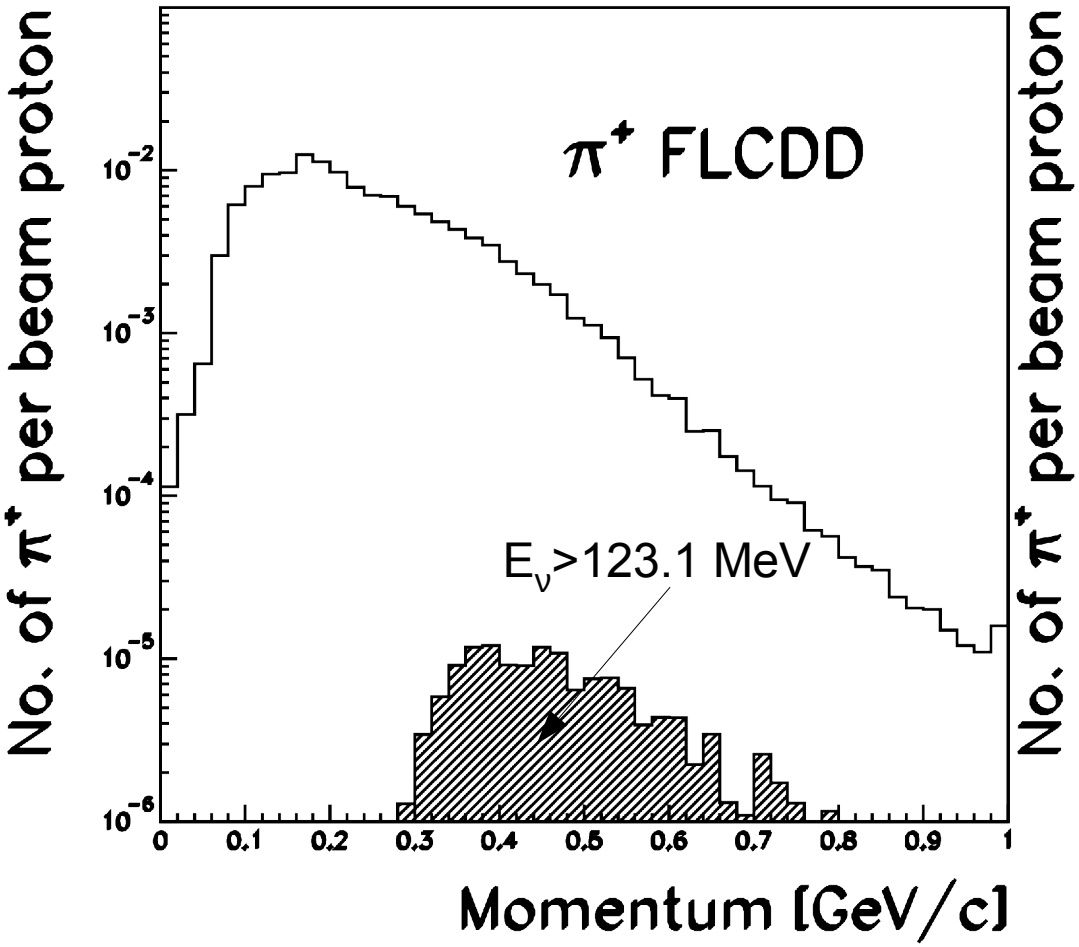
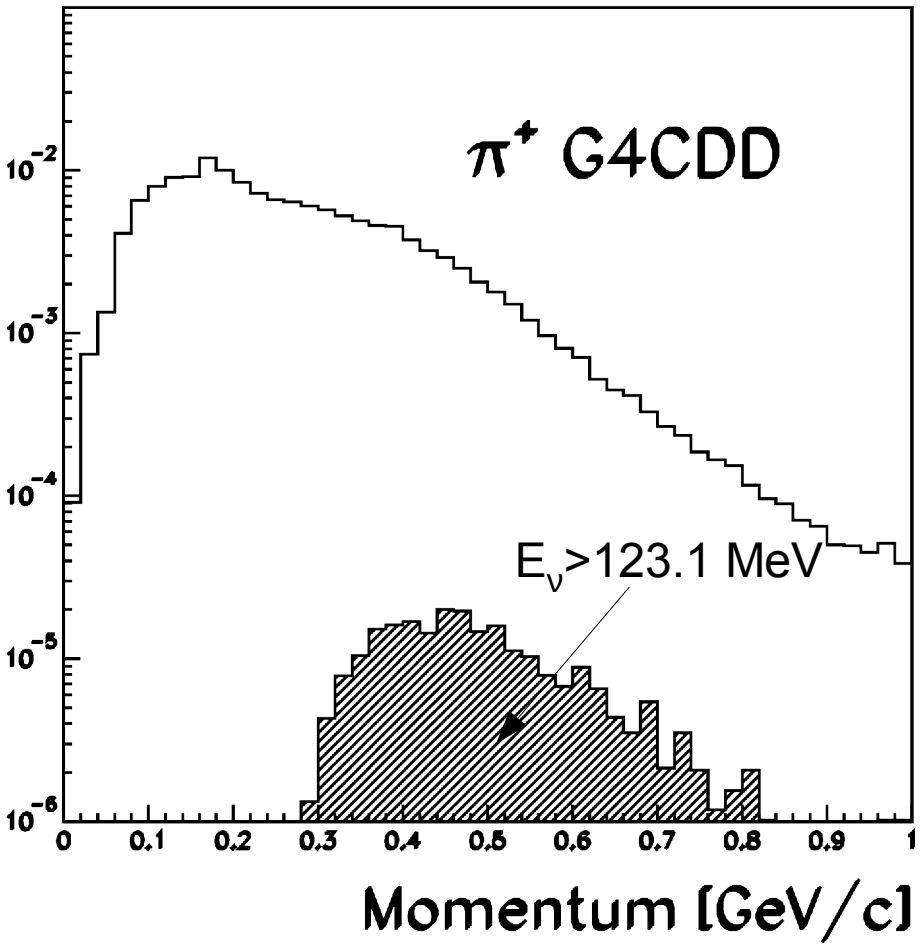
We have verified neutrino fluxes by the cross-section measurements of known processes.

$\nu_\mu + A \rightarrow \mu^- + X + n$ – constrains the π^+-induced chain

Pion momentum spectra





But, LSND say:

Our DIF analysis of $\nu_\mu \rightarrow \nu_e$ is consistent with our DAR results

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Our DIF analysis of $\nu_\mu \rightarrow \nu_e$ is consistent with our DAR results

- The signal is not significant (0.6σ)
- Not confirmed by MiniBooNE

Summary

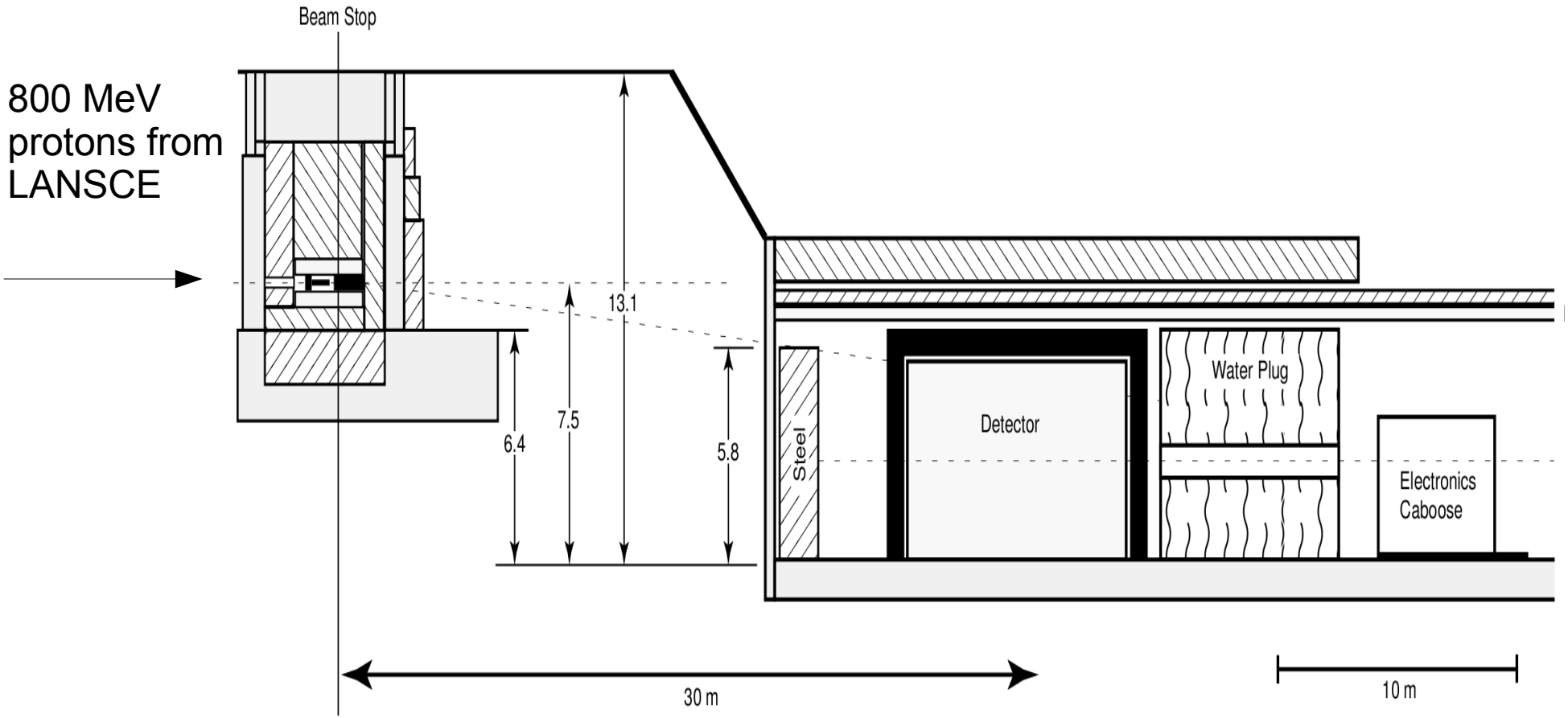
- Independent simulation of the background to the LSND $\bar{\nu}_e$ signal carried out
- FLUKA and Geant4 cross-sections used as starting point, adjusted by HARP-CDP data and experimental pion production by neutrons
- The larger part of the background of the LSND signal increases by a factor of 1.7.
- The claim of a 3.8 σ significance of the LSND anomaly cannot be upheld

The HARP-CDP group

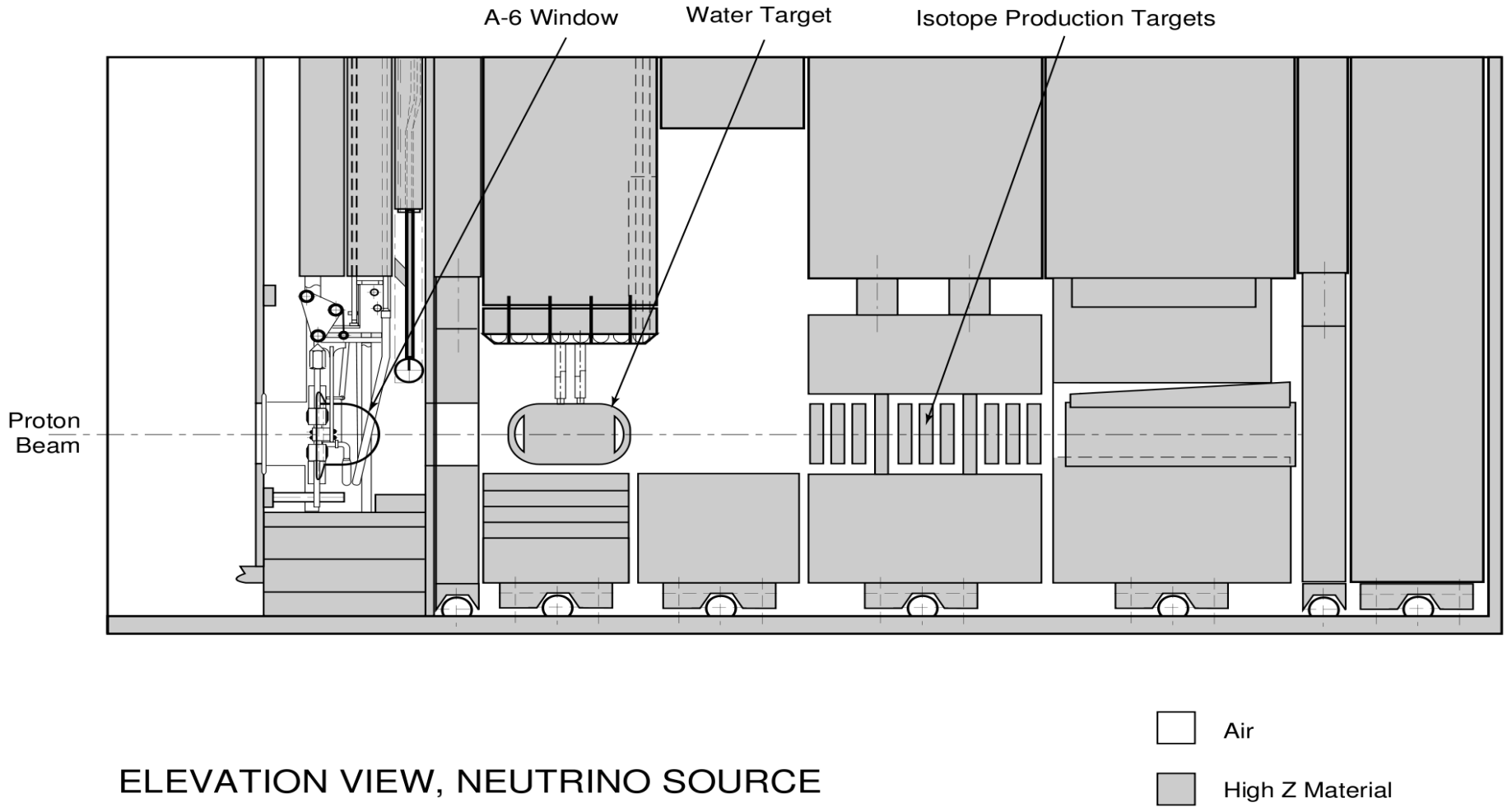
A. Bolshakova, I. Boyko, G. Chelkov, D. Dedovich,
A. Elagin, D. Emelyanov, M. Gostkin, A. Guskov,
Z. Kroumchtein, Yu. Nefedov, K. Nikolaev,
A. Zhemchugov, F. Dydak, J. Wotschack,
A. De Min, V. Ammosov, V. Gapienko, V. Koreshev,
A. Semak, Yu. Sviridov, E. Usenko, V. Zaets

Backup

The LSND experiment



The LSND neutrino source (side view)

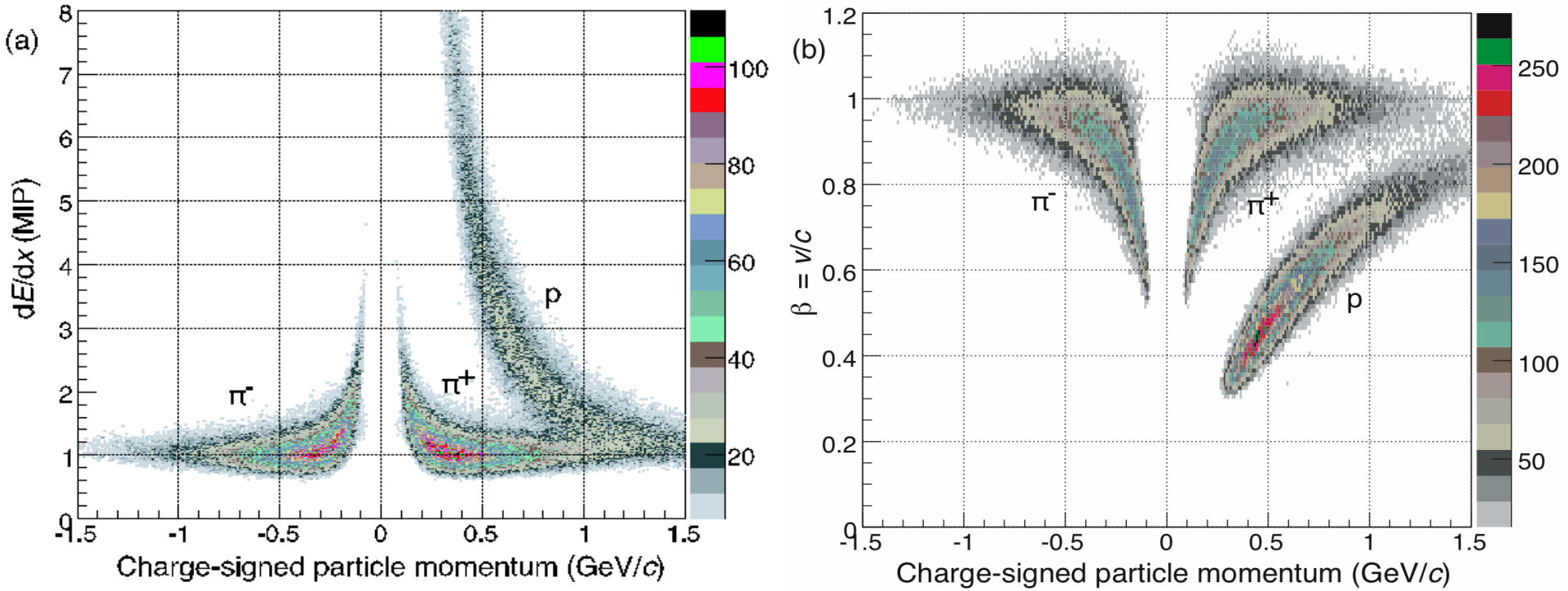


ELEVATION VIEW, NEUTRINO SOURCE

C.Athanassopoulos et al., NIM A388 (1997) 149-172

Geometry of 1993-1995

The HARP experiment (2/3)



Good particle identification by combining d*E*/d*x* from TPC and TOF from RPCs

Systematic error

π^+ chain		π^- chain	
HARP-CDP statistics	5%	HARP-CDP statistics	9%
HARP-CDP syst.	8%	LSNDsim statistics	3%
Rescaling outside HARP-CDP	3%	n->pi	3%
Generator	5%	p->n	3%
Geometry	3%	muon capture	4%
Coarse binning	5%	decay space geometry	5%
Interpolation of cross-section	5%	DIF prob. from momentum spectrum	15%
Multiplicity	5%		
Extrapolation to different nuclei	4%		
5^{th} generation	1%		
TOTAL	15.0% - 'best estimate' 8.7% - LSND 'emulation'		24.5% - 'best estimate' 11.2% - LSND 'emulation'