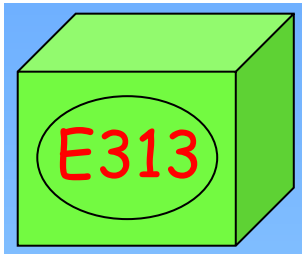
Beyond Three Neutrino Family Oscillations

LNGS Workshop 3-4 May 2011

An Experimental EXERCISE on European Sterility

Luca Stanco – INFN Padova

on behalf of a motivated group of Italian Staff Physicists



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(3) Bologna University
(4) INFN-LNF
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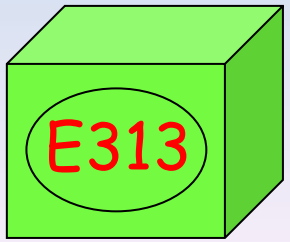
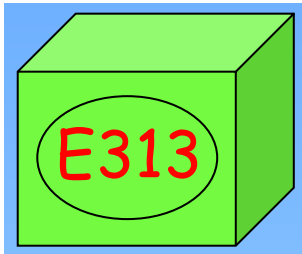
SPECTROMETER(S) Prospects for a CERN-PS Experiment

1. Physics
2. Place
3. Setup
4. Analysis
5. Achievements



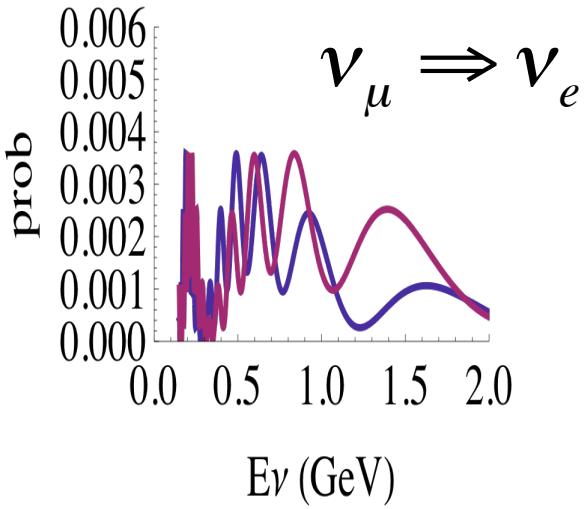


PHYSICS

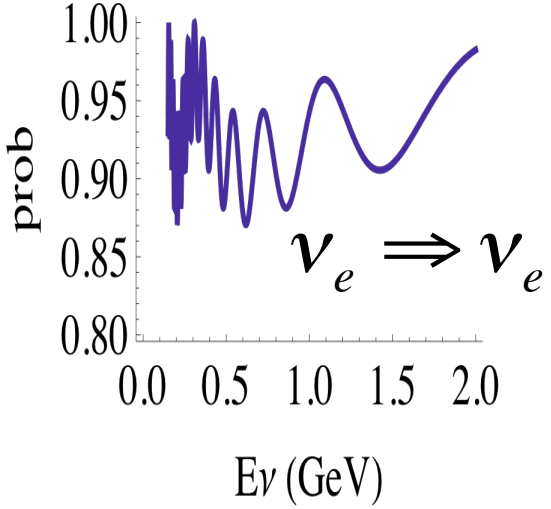
What OscillationS between Which ?

E.G. take the 3+2 model by Kopp et al. *(see also Schwetz-Mezzetto talks)*

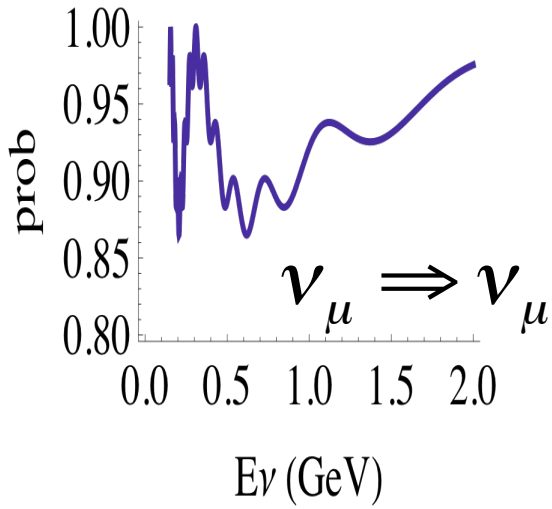
APPEARANCE



DISAPPEARANCE

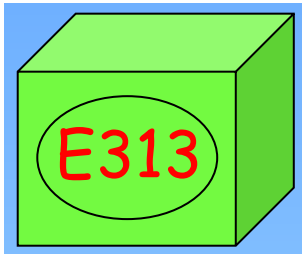


DISAPPEARANCE



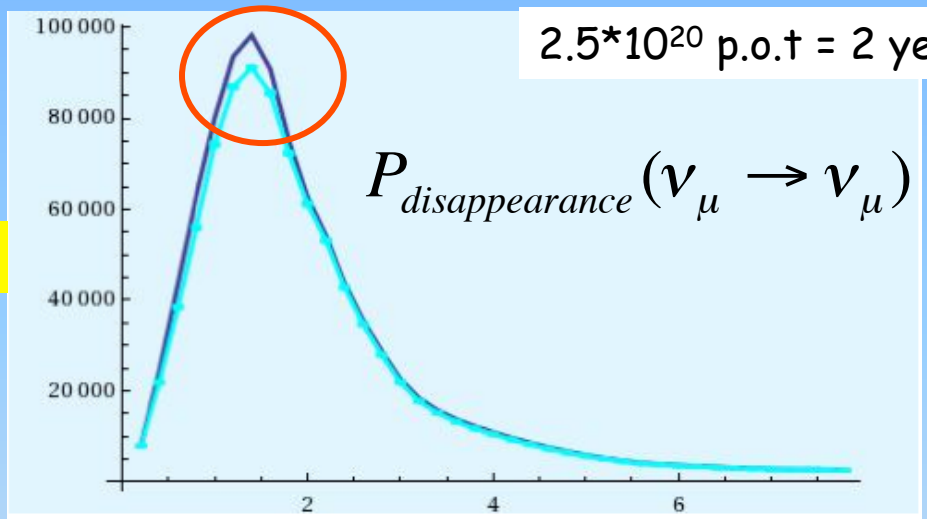
TO BE FOLDED with the ν_μ , ν_e , $\overline{\nu_\mu}$, $\overline{\nu_e}$ BEAM compositions/contaminations

and with ν and $\overline{\nu}$ cross-sections !



PHYSICS-I

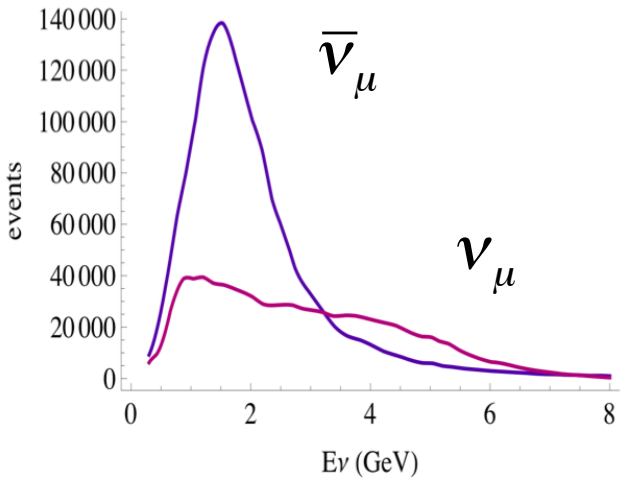
2.5*10^{20} p.o.t = 2 years of ν



from previous model

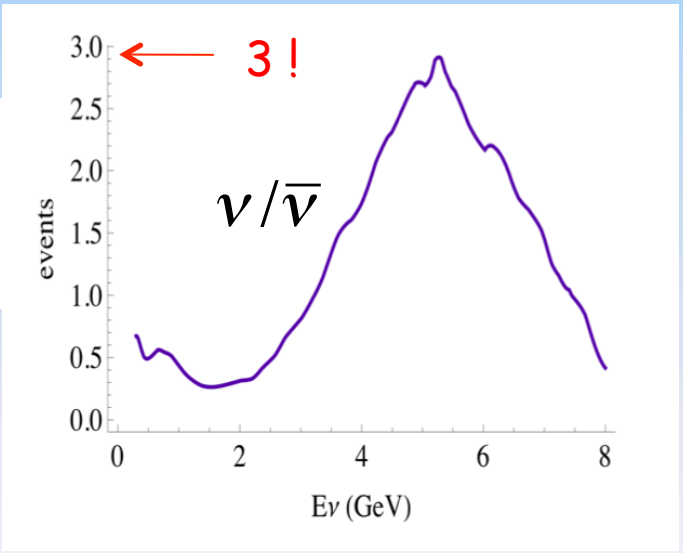
intensities

$Flux_{PS}(\bar{\nu}_\mu) \times Cross-Section$

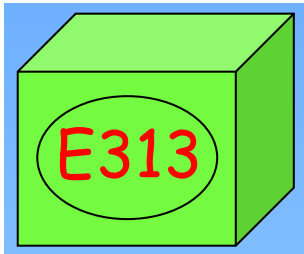


3.75*10^{20} p.o.t = 3 years of anti-ν

$$Ratio: \quad \frac{Flux(\nu_\mu) \times \sigma_{\bar{\nu}}}{Flux(\bar{\nu}_\mu) \times \sigma_\nu}$$

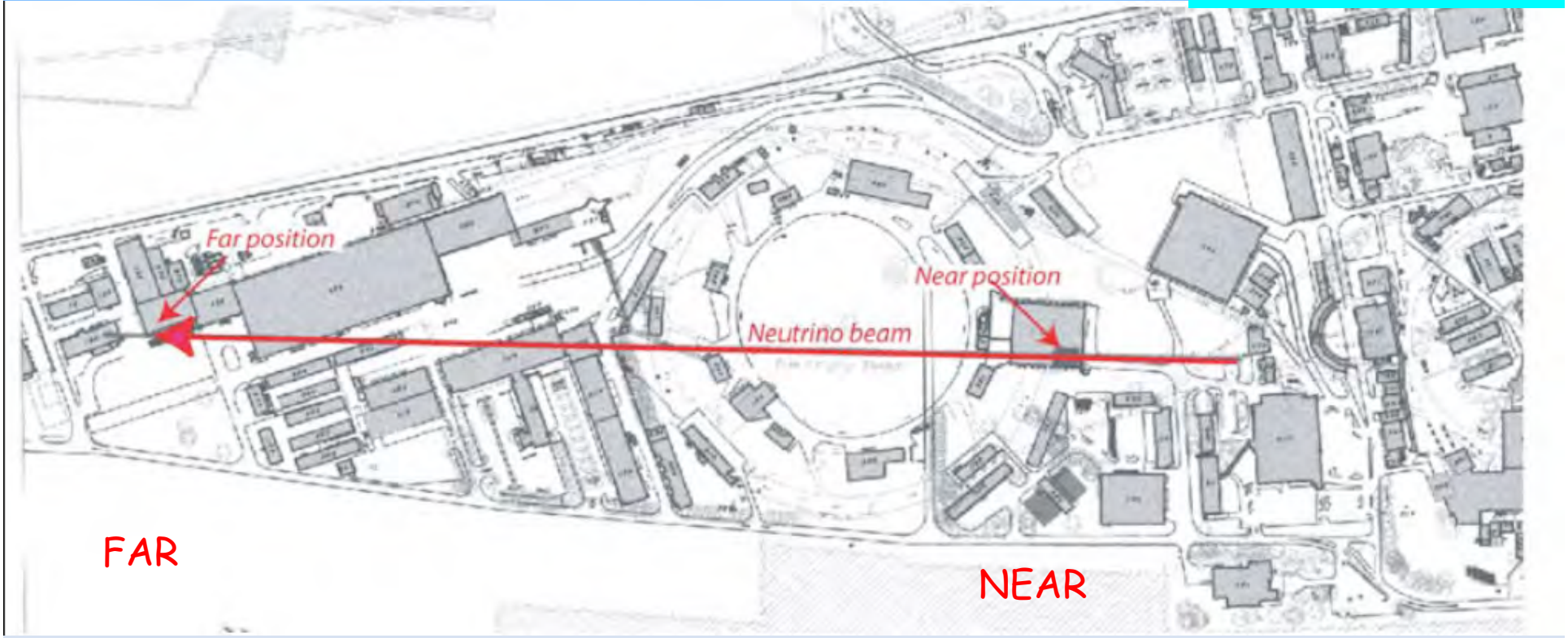


1 RUN = MANY DATA !



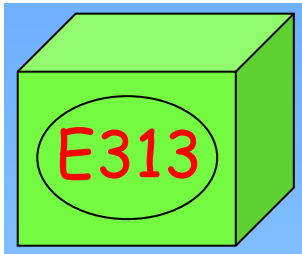
PHYSICS-II

at PS site



The large number of models (i.e. the lack of conclusive DATA) implies the ABSOLUTE need for a DOUBLE measure: FAR and NEAR **to establish what is oscillating and what is not**

→ TWO SPECTROMETERS



PHYSICS-III

Charge and **momentum** measurements in Neutrino Interactions for the Charge Current mode: **important** and **challenging**

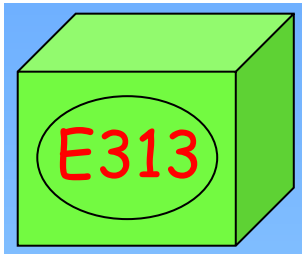
Important because:

- increase the active target mass by measuring the muon momentum
- increase the range of Δm^2 (at higher values, especially in the eV^2 range)
- calibration of the beam with a clean muon measurement at high p
- normalization point for the NC/CC rates

- clean separation of nu and anti-nu interactions
- disentangle the nu and anti-nu reverse contaminations in the beams

Challenging because:

- find best compromise between passive and active materials



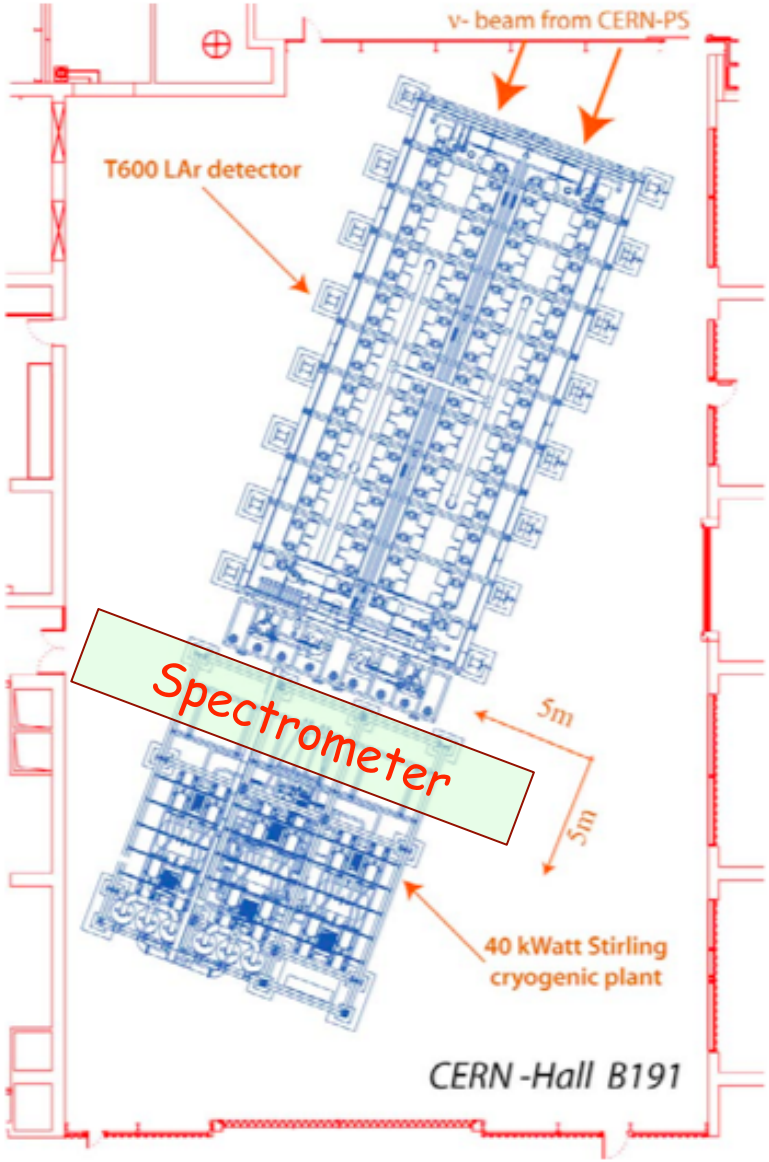
PLACE

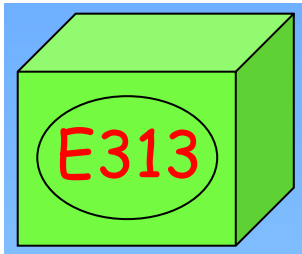
FAR site

*For semplicity take the T600 LAr proposal * (Memorandum to SPSC 09/03/2011)*

** Liquid Argon is the best option as for*
- backgrounds
- energy range
- full measure of ν interaction

The Target coverage must be as large as possible





PLACE-II

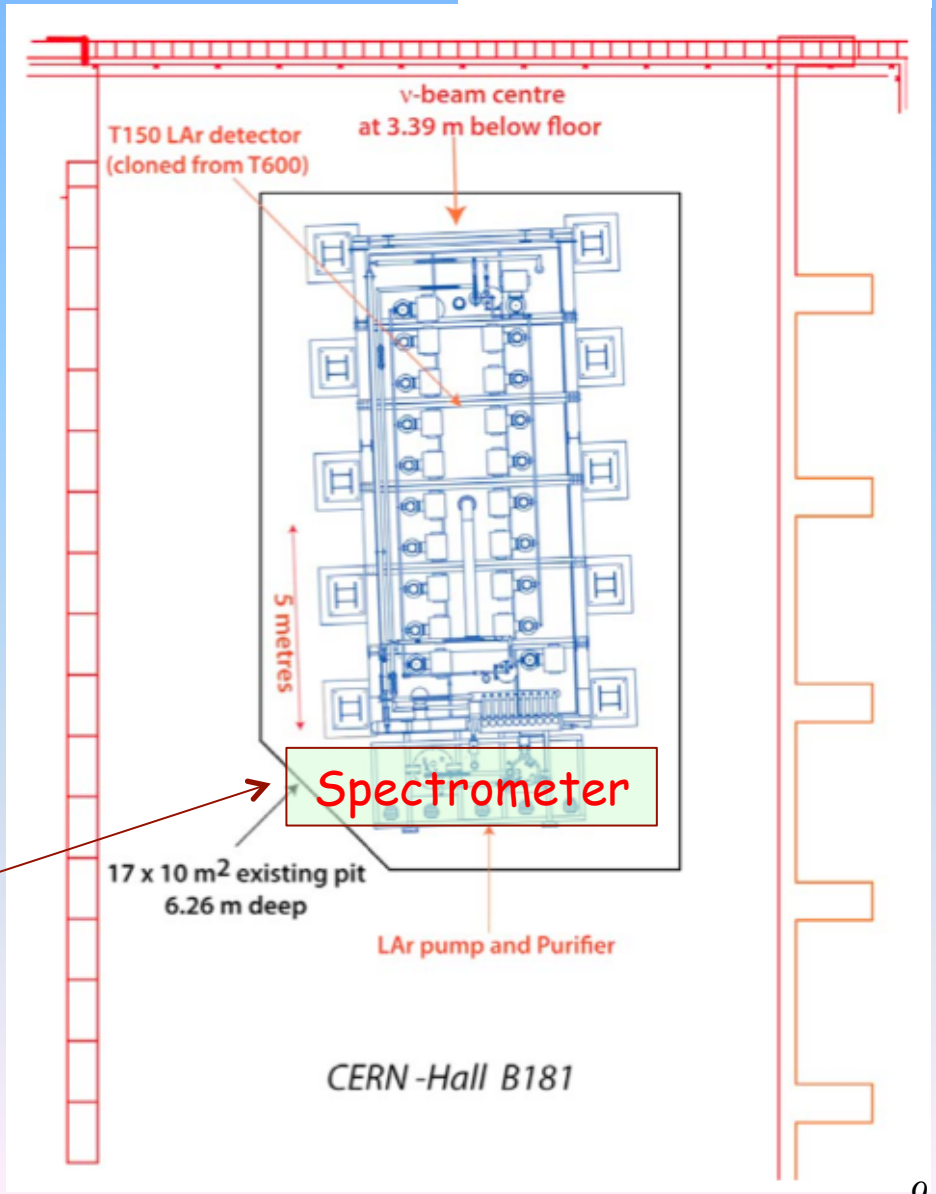
NEAR site

Same Proposal:

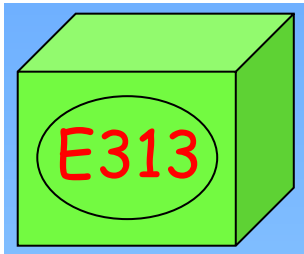
Liquid Argon is the best option as for

- *systematics control*
- *backgrounds*
- *full measure of ν interaction*

(Scintillator back-up solution ??)

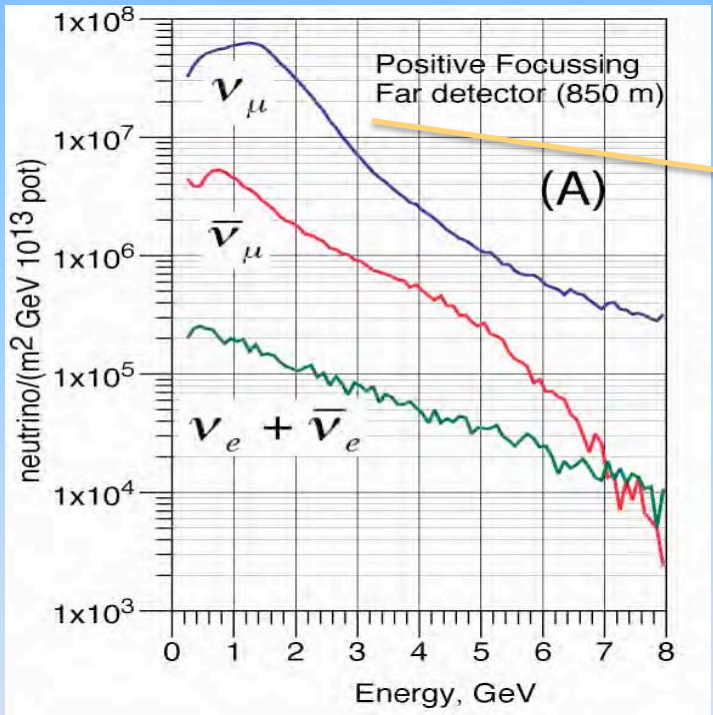


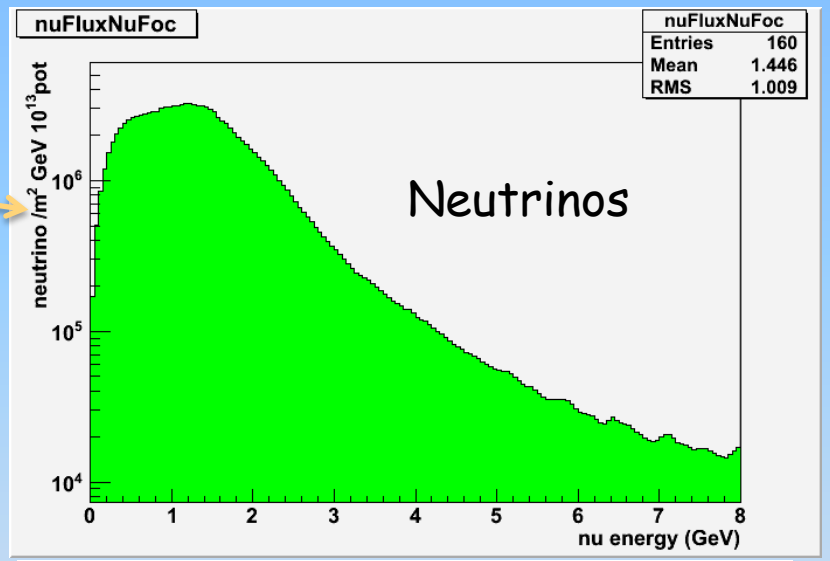
Same Spectrometer,
only half shorter
in the transverse coordinate

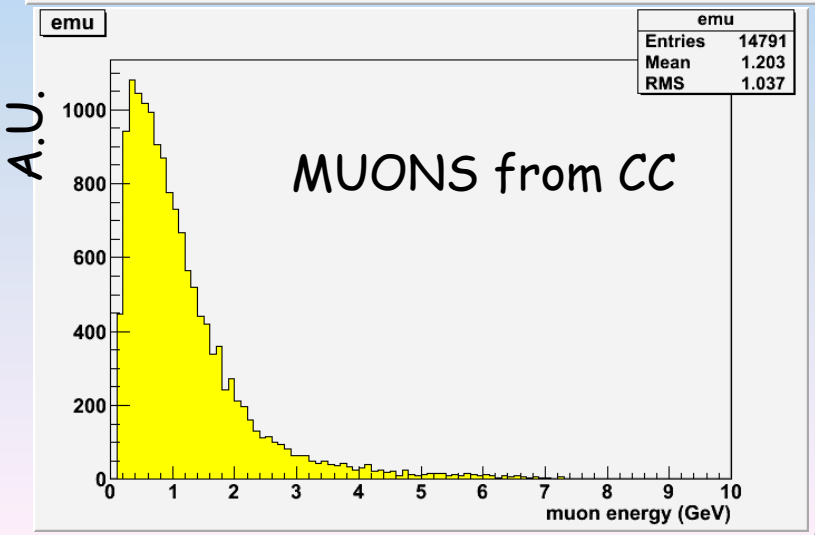


SET-UP

(which Spectrometers ?)



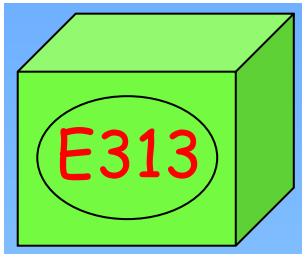




Negative Focussing rather different !

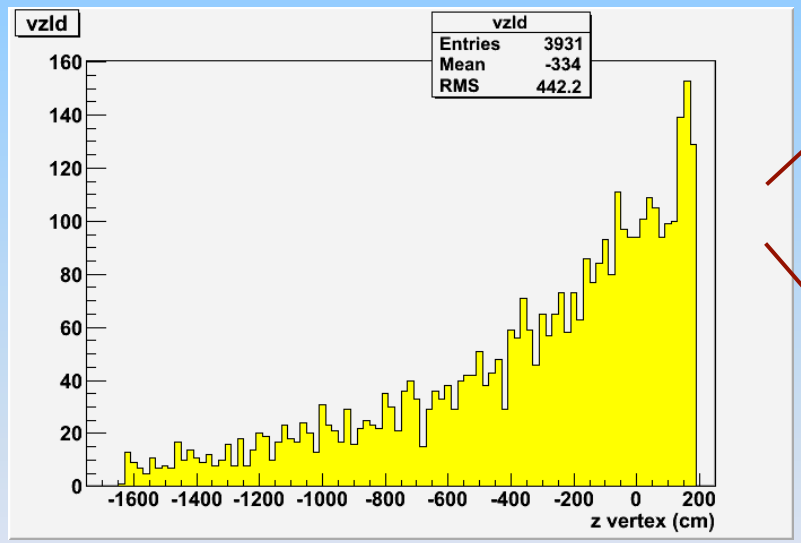
MUONS in LAr interactions

(standard GENIE simulation)

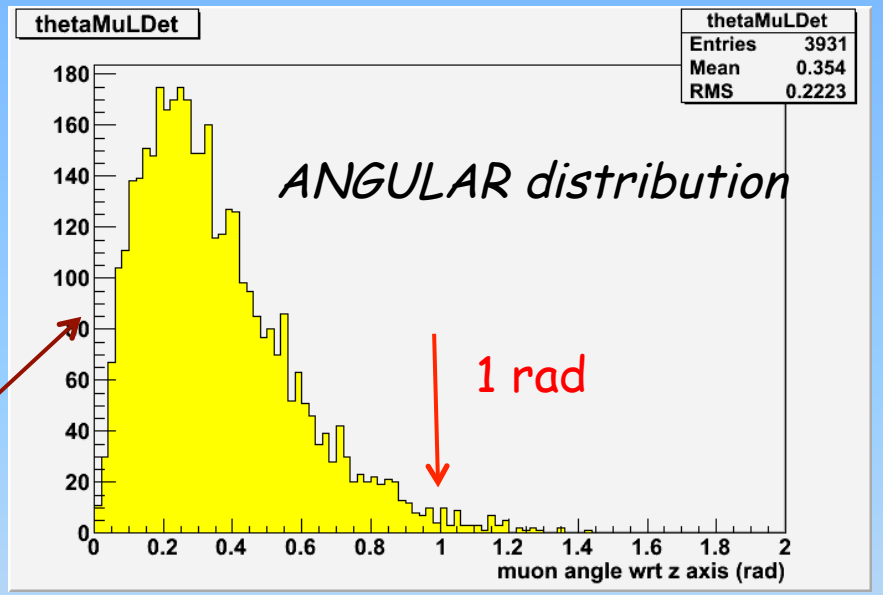


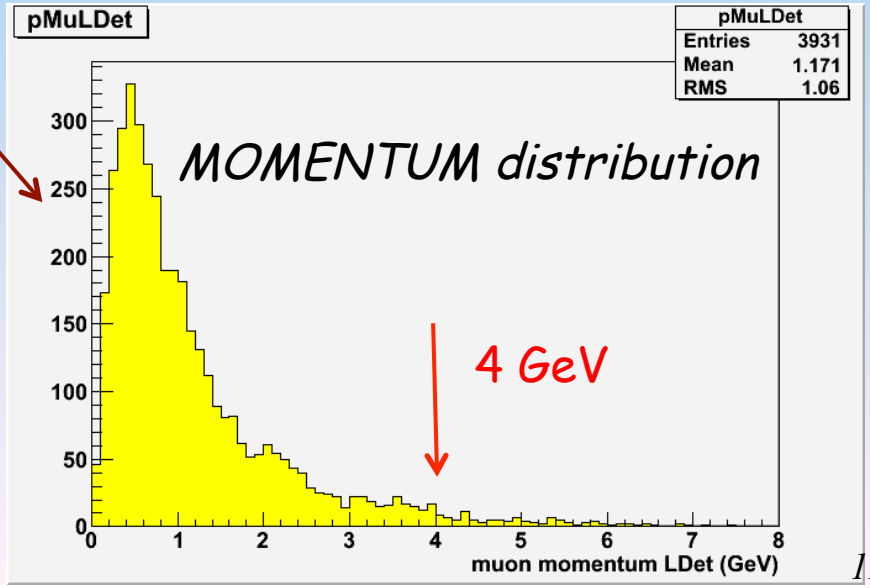
SETUP-II

MUONS coming out downstream of LAr

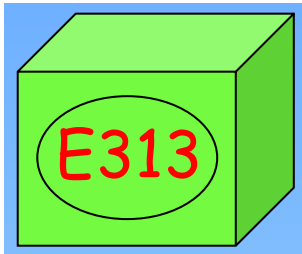


z-vertex





FAR site



SETUP-III

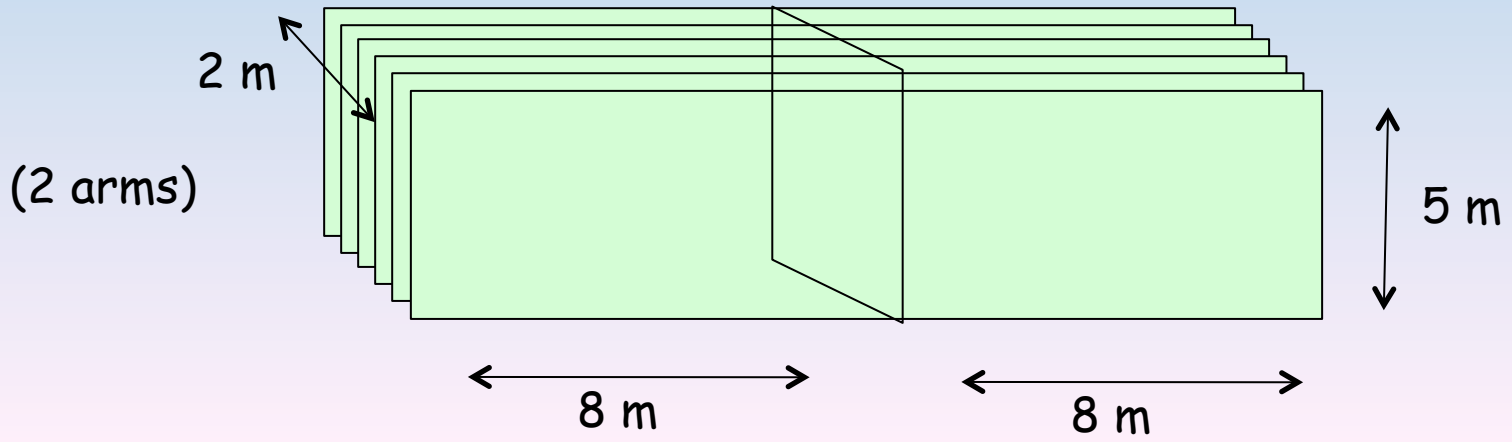
In conclusion:

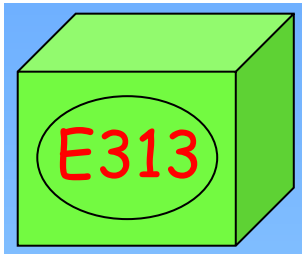
- "light" spectrometer, e.g. 2.5 cm iron slabs
- several detection layers, e.g. 8 layers per arm
- as wide as possible, e.g. 2*8 m (w) * 5 m (h)

Use RPC detectors ALAOP and Precision Trackers

Dipole with B=1.5 Tesla

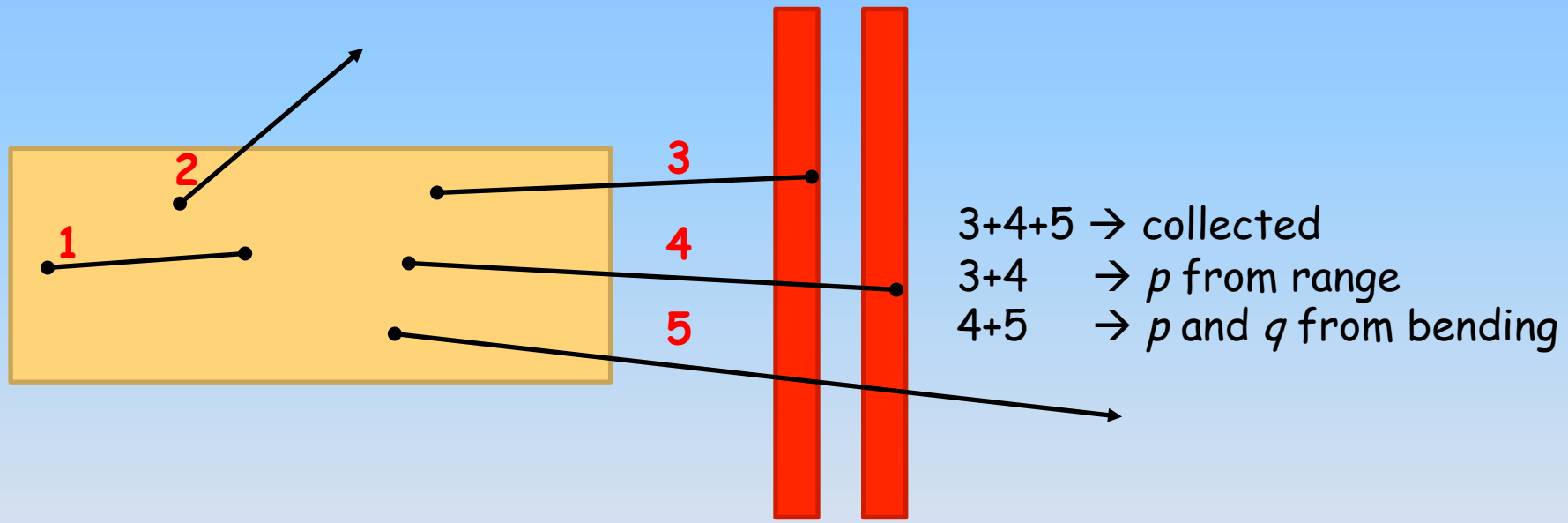
FAR = 2 * NEAR



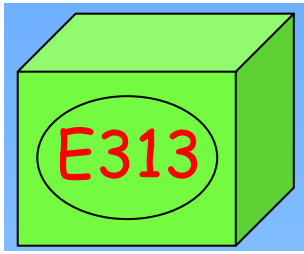


Analysis

Several topologies to be taken into account (*CC* mode):

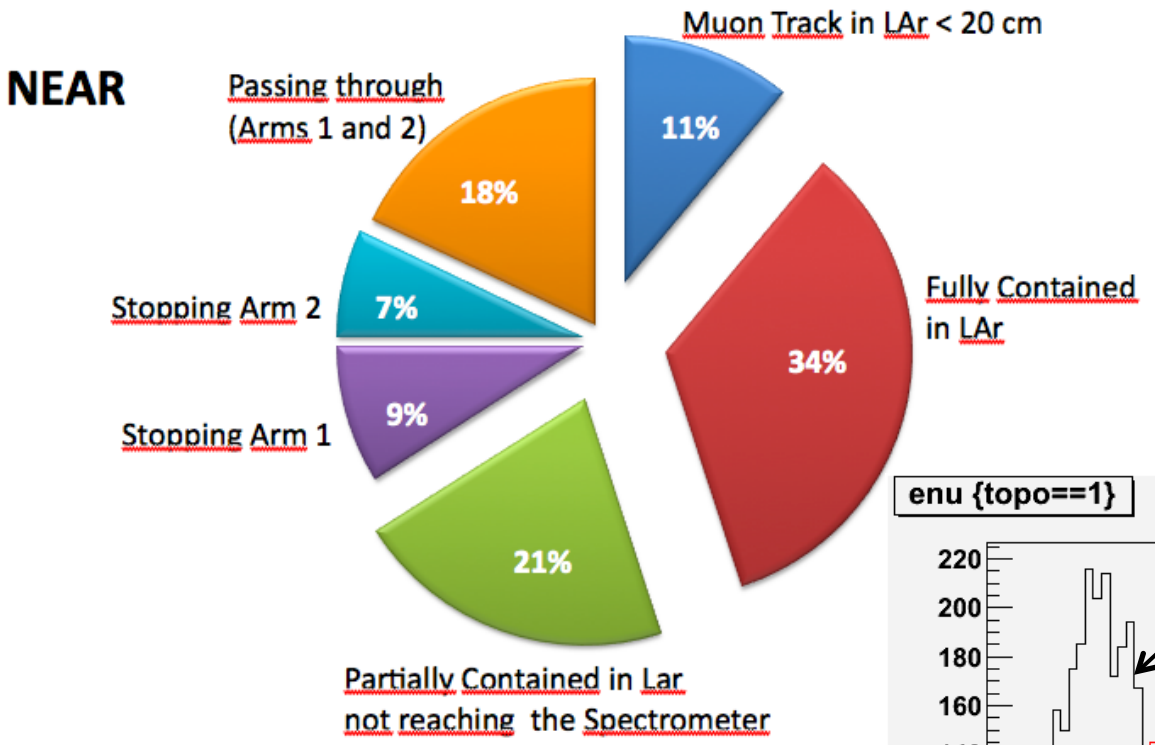


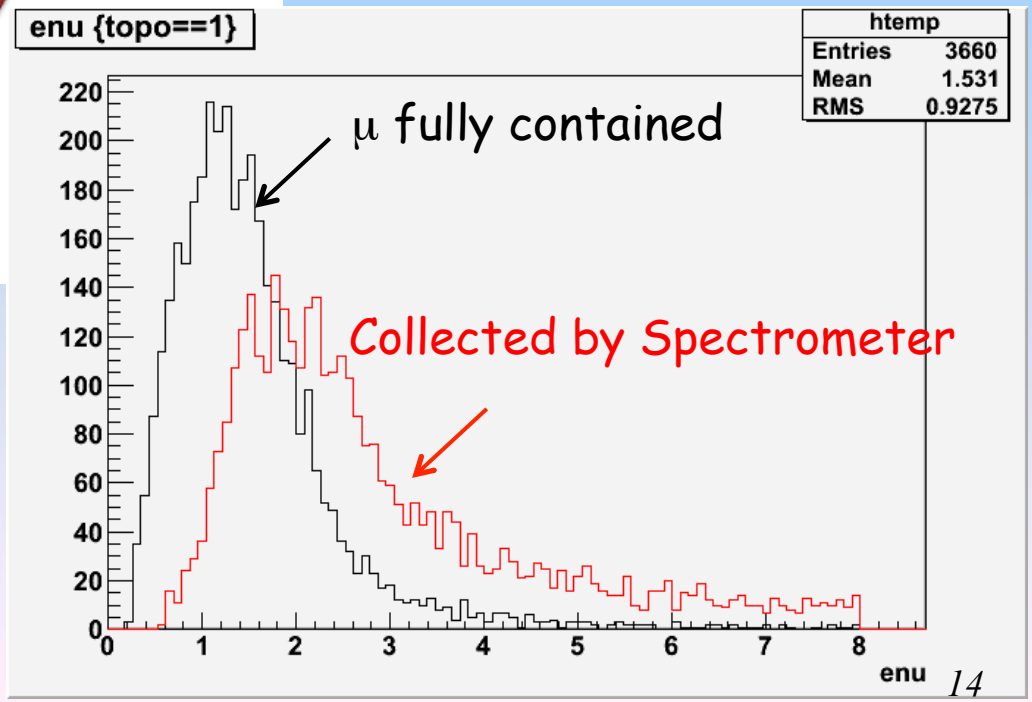
Parametrized simulation and reconstruction of LAr target.
Full simulation of Spectrometers' responses

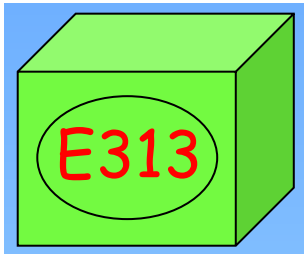


Analysis-II

NEAR site

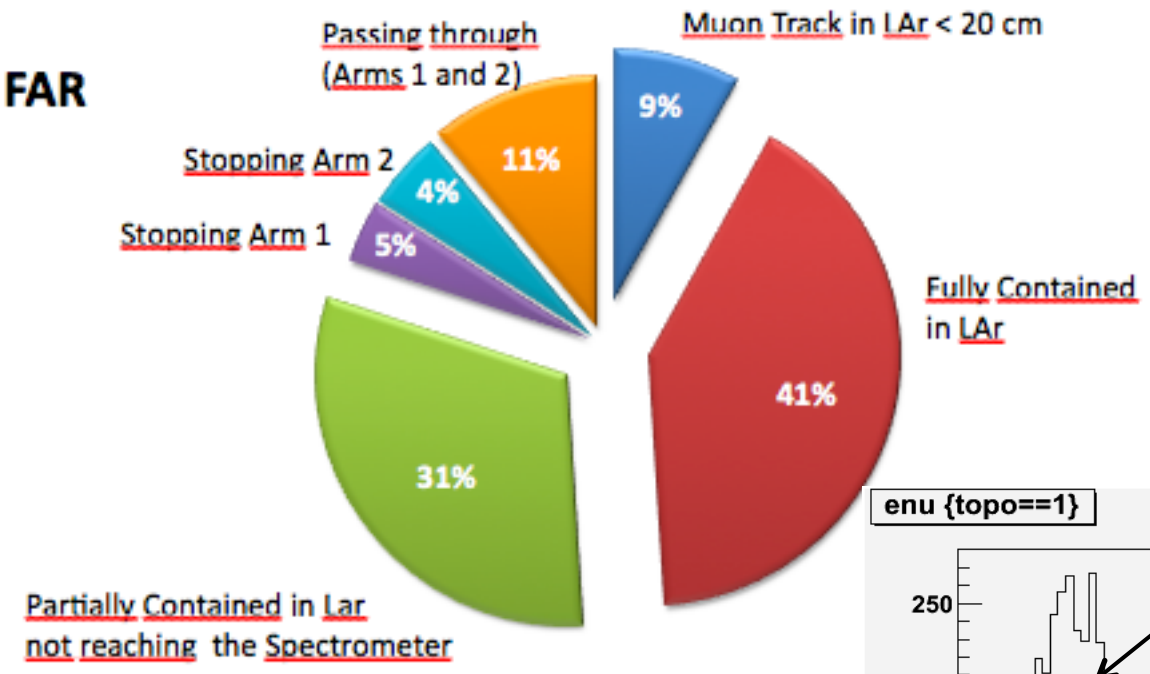


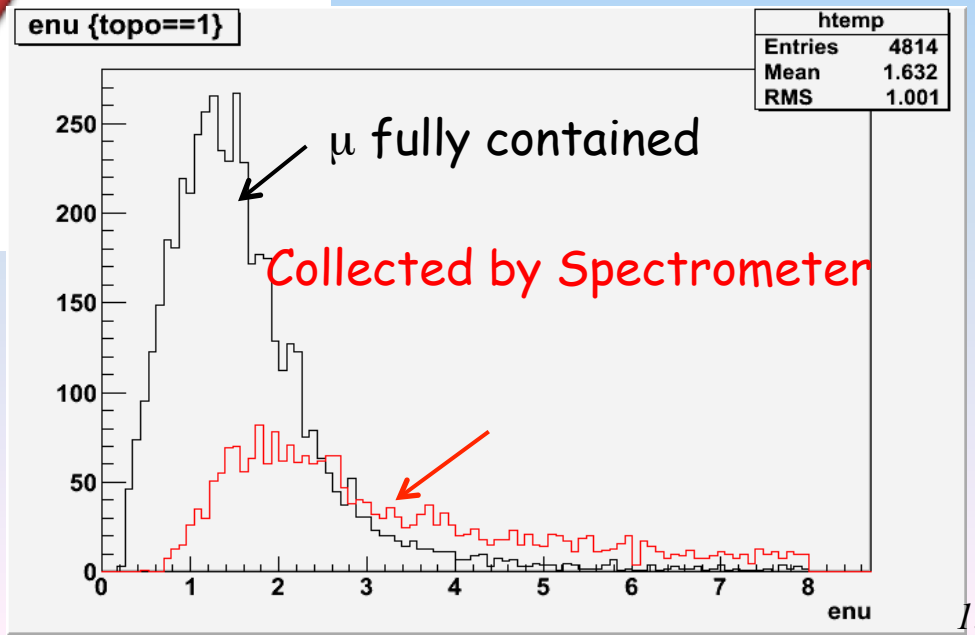


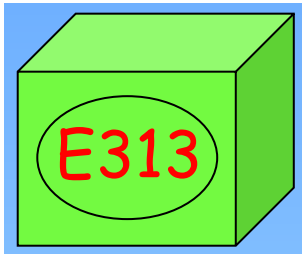


Analysis-III

FAR site



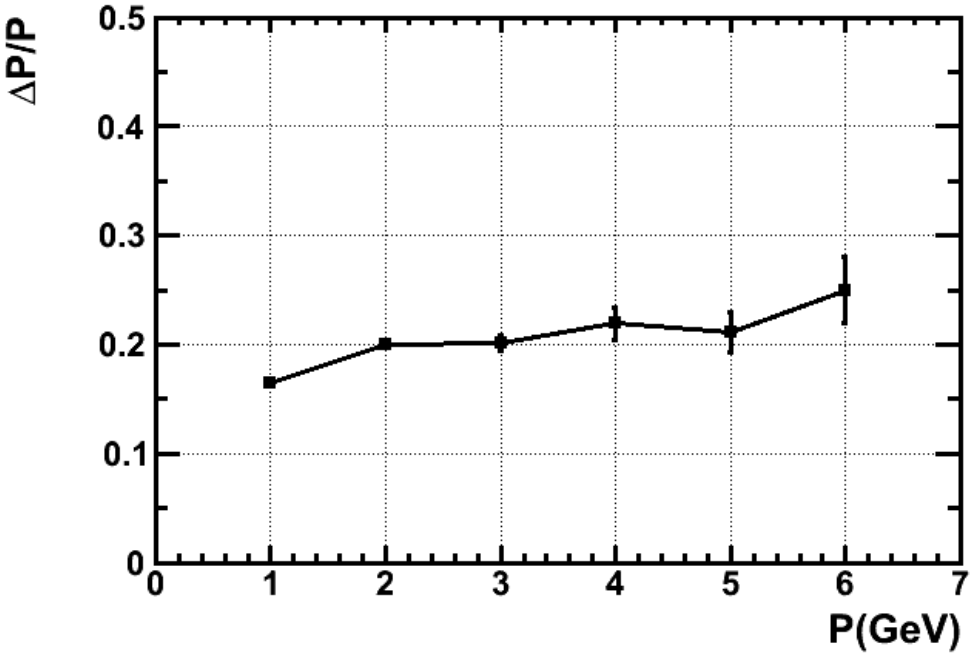


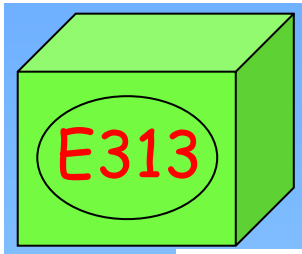


Achievements-I

- The Charge Identification is better than 98.5% up to ~ 5 GeV momentum
- $\Delta p/p$ has to be optimized depending on B*dl, no. of planes of measurements and the Iron slab thickness
- The containment is dominated by transverse dimensions (!)

E.G. Momentum Resolution of largest sample (full crossing)

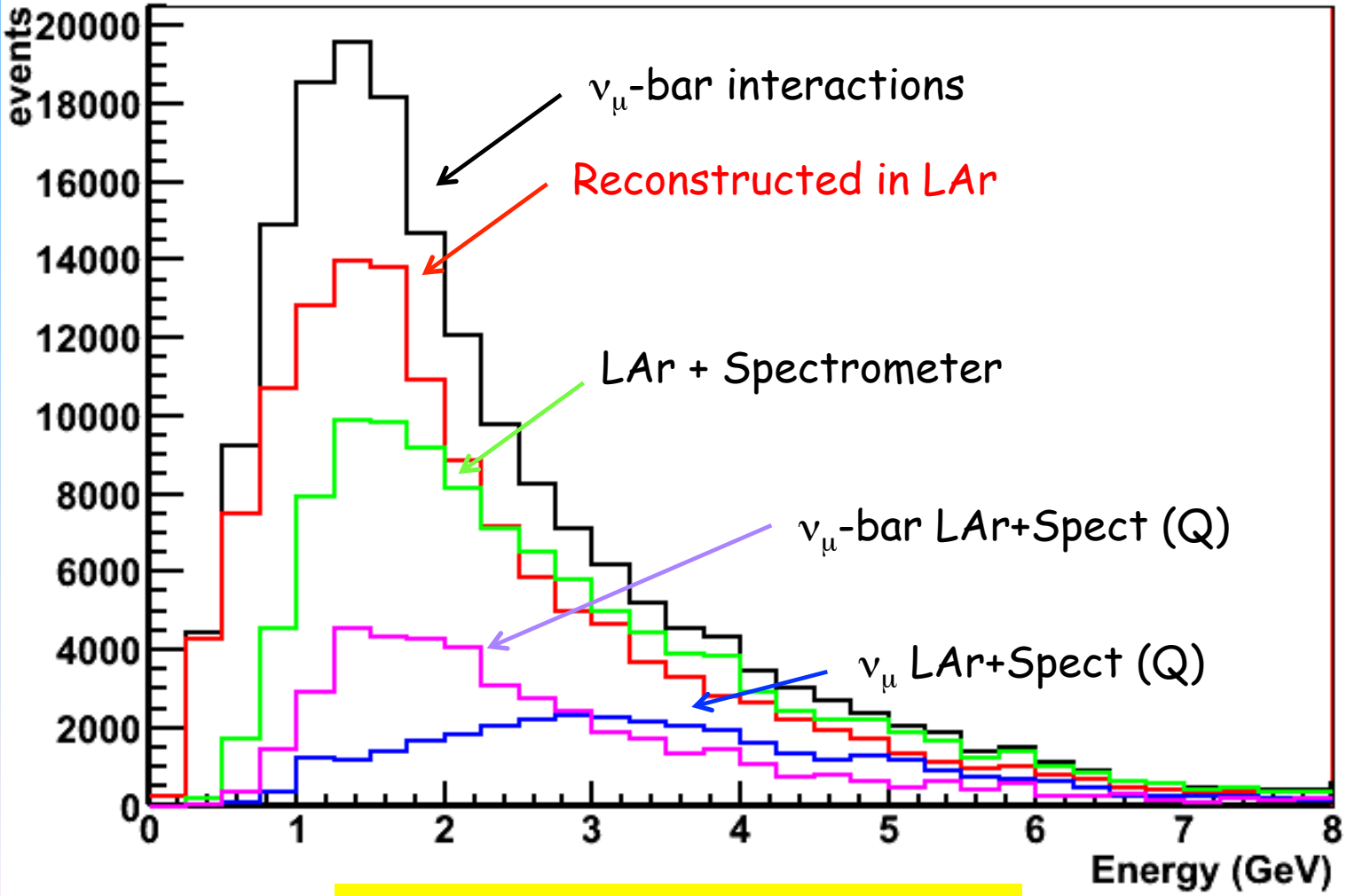




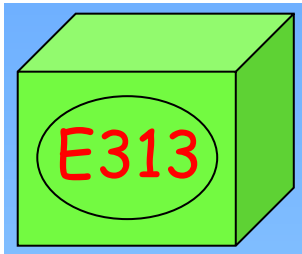
Achievements-II

3.75x10^{20} pot

NEAR site

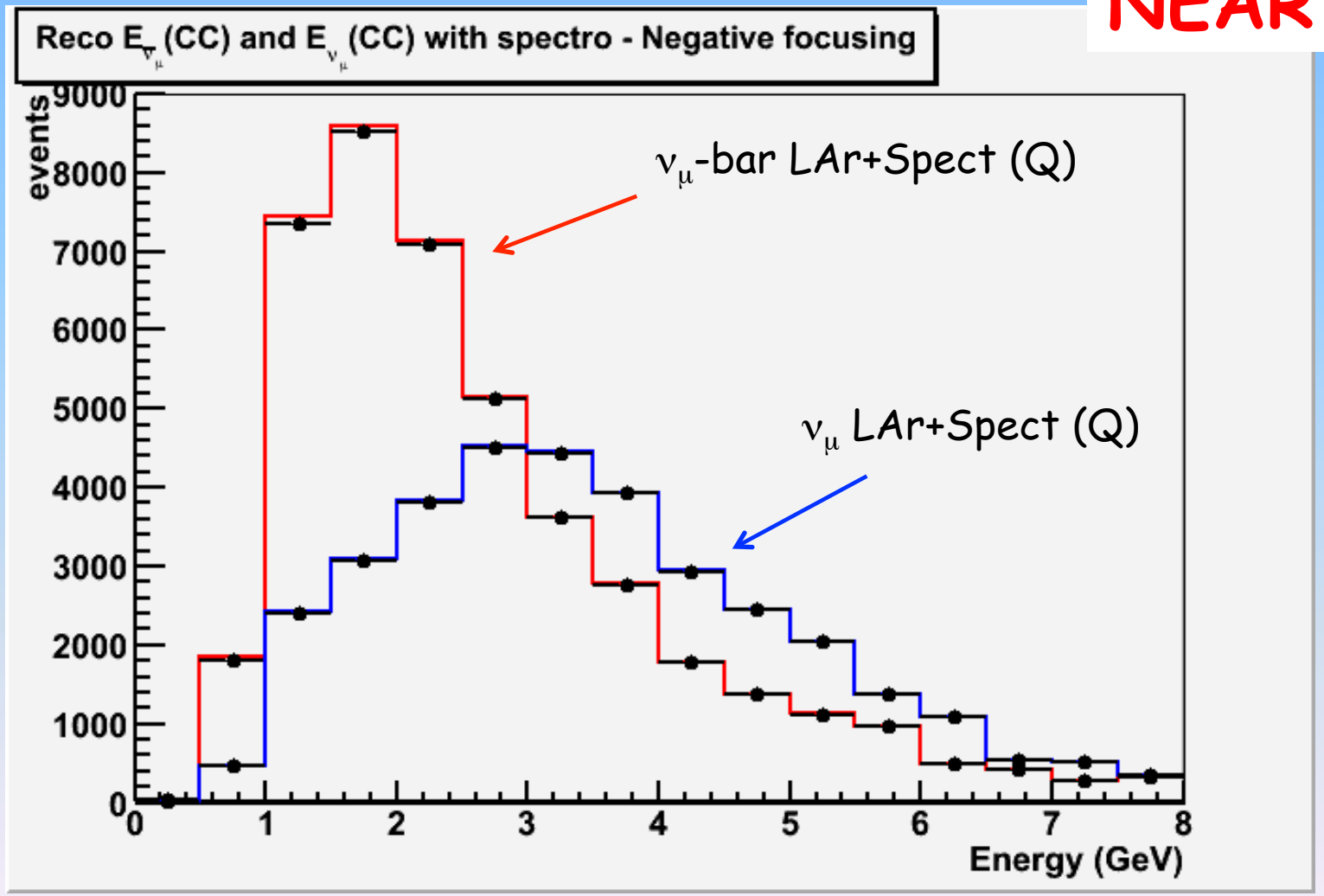


Reconstructed Neutrino Energy

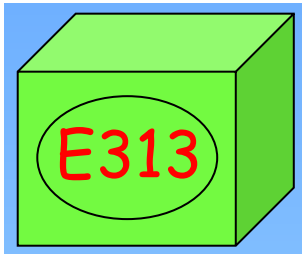


Achievements-IIbis

NEAR site

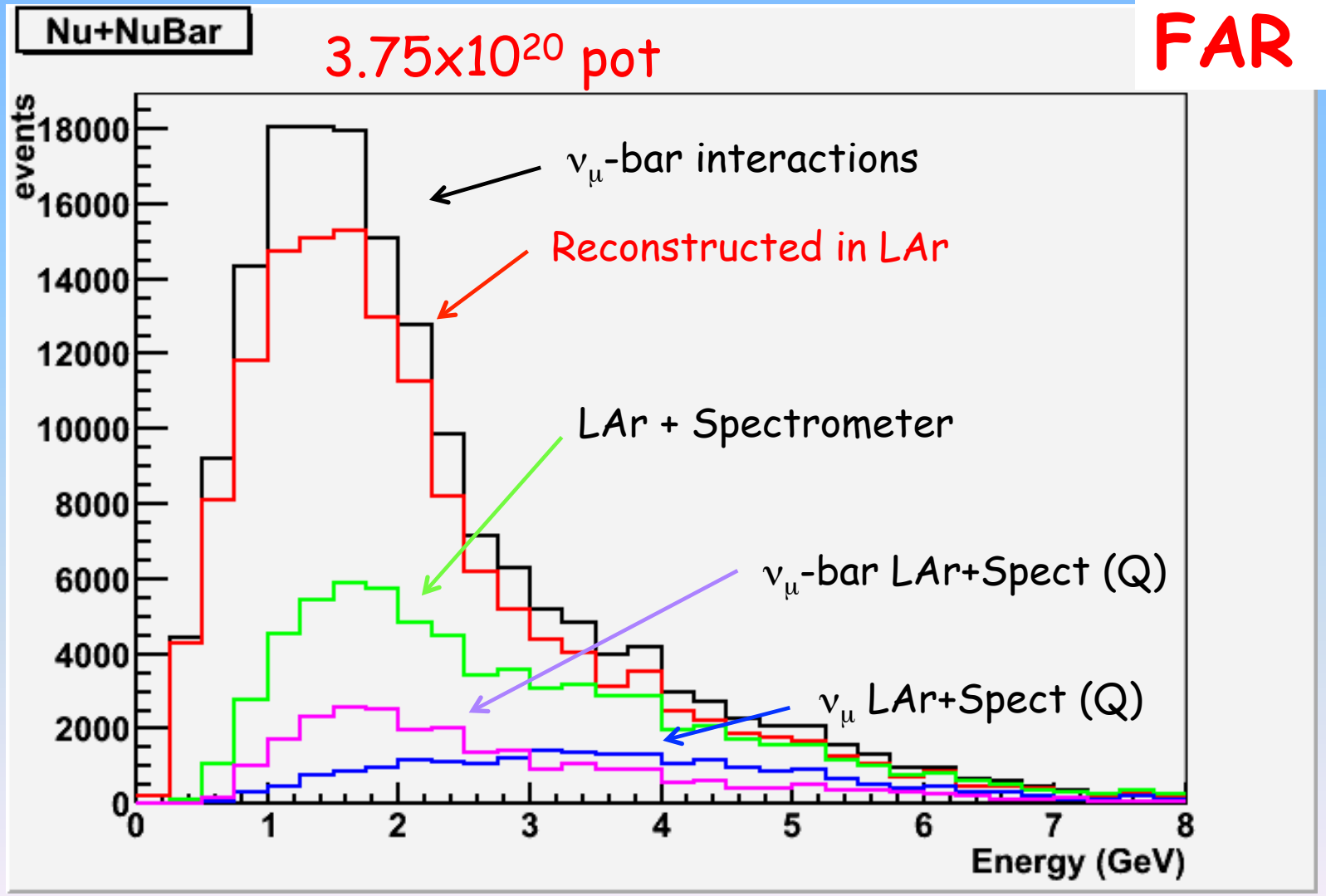


Reconstructed Neutrino Energy

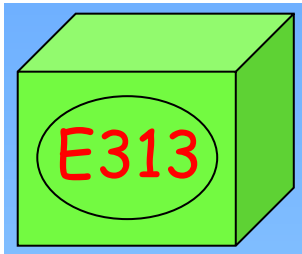


Achievements-III

FAR site

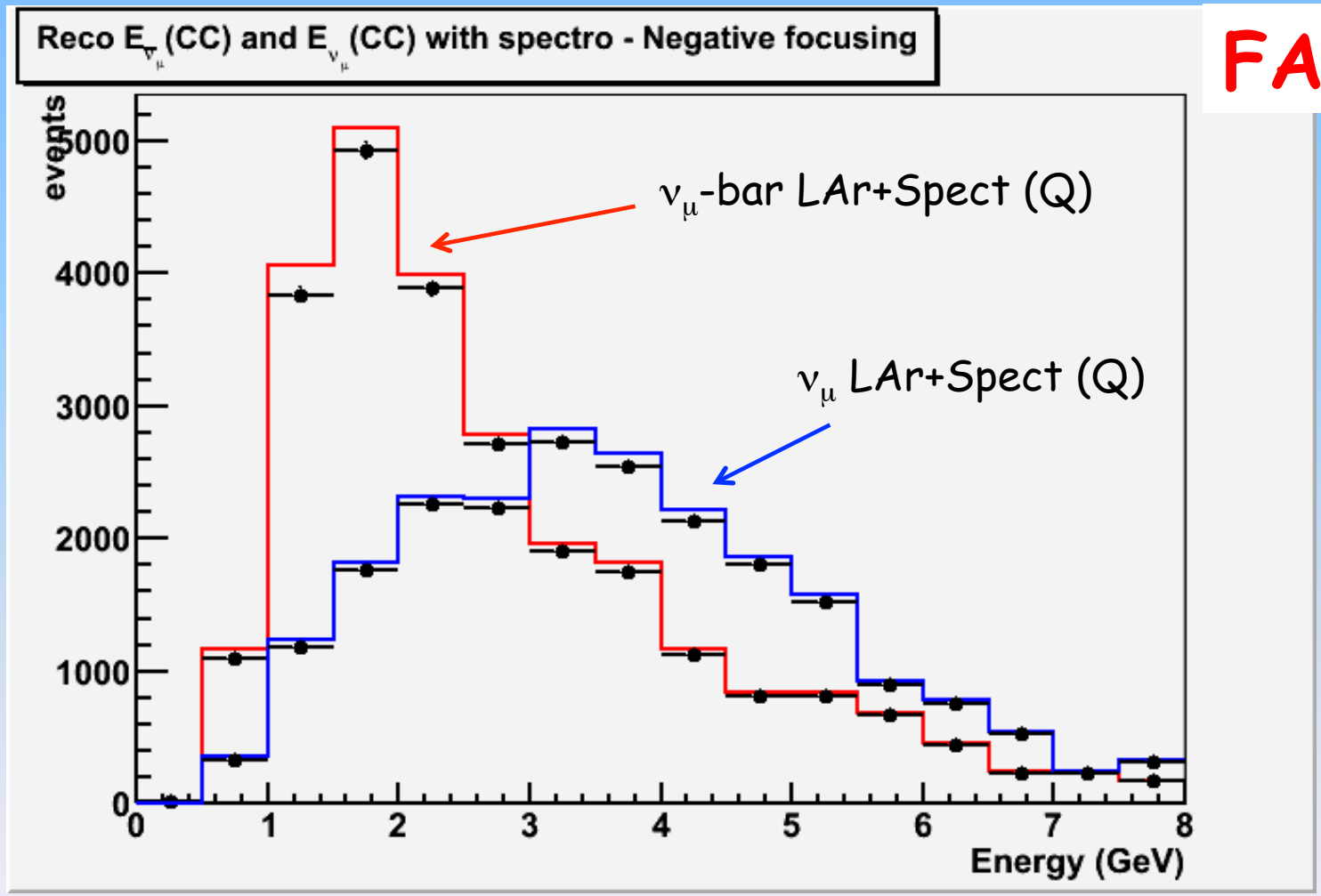


Reconstructed Neutrino Energy

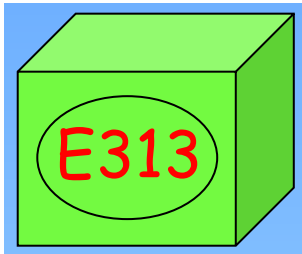


Achievements-IIIbis

FAR site



Reconstructed Neutrino Energy



Conclusions

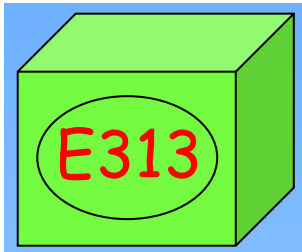
There is great INTEREST in the PHYSICS of the Sterile Neutrinos

Well prompted PHYSICISTS made an Exercise

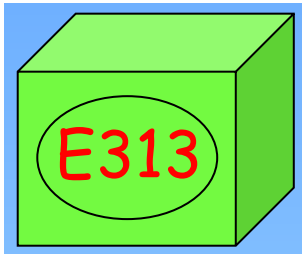
The PS-CERN option seems to match many QUESTIONS on the subject of Sterile Neutrinos

The use of Spectrometers (FAR and NEAR) can be a very important handle (if not mandatory)

("There is a great confusion under the sky,
Then the situation could indeed be excellent")



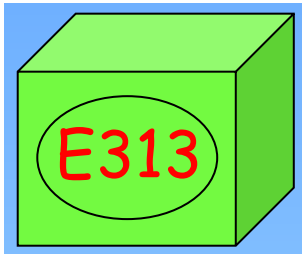
Backup Slides



Neutrino energy reconstruction

- Muon momentum reconstruction:
  - If contained in LAr → range
  - If not contained in LAr and not crossing the spectro and distance(LAr)>2m → MCS
  - If stop in Arm1 → range
  - If stop in Arm2 → range (and charge from bending in Arm1)
  - If cross Arm1 & Arm2 → Bending (charge and momentum) + MCS in LAr
- Neutrino energy reconstruction:
  - If QE: two-body kinematics →
  - If not-QE: gaussian smearing on the hadronic component $\sigma_E/E = 0.3/\sqrt{E}$

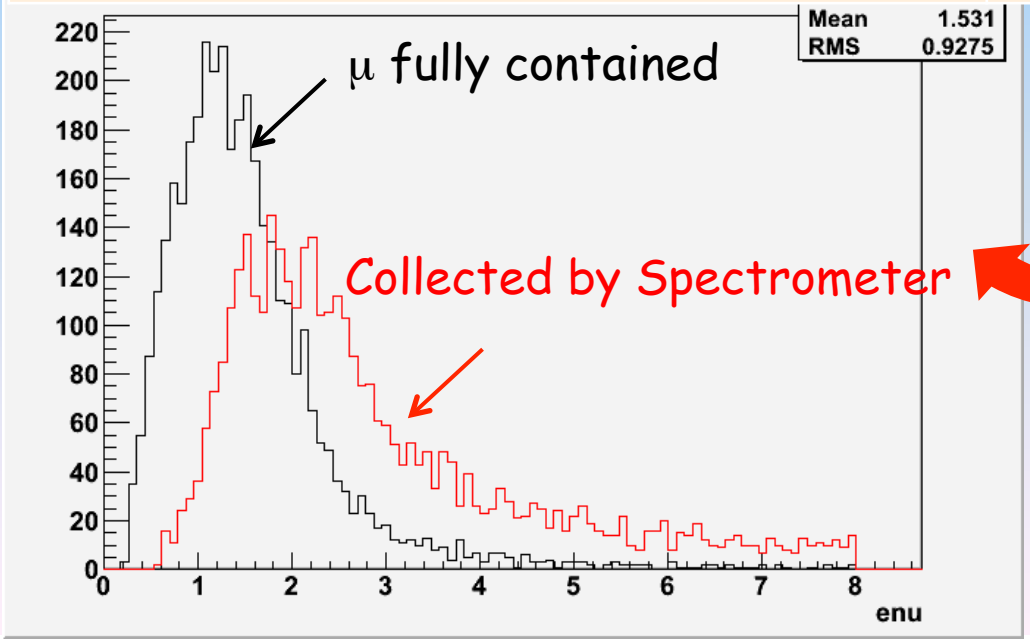
$$E_\nu^{\mathrm{rec}} = \frac{1}{2}\frac{(M_p^2 - m_\mu^2) + 2E_\mu(M_n - V) - (M_n - V)^2}{-E_\mu + (M_n - V) + p_\mu \cos\theta_\mu}$$

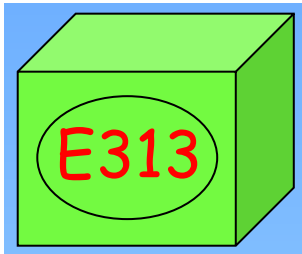


Analysis-II

NEAR site

Vertex Interaction in Fiducial Volume	100%	
" & μ-track in LAr > 20 cm	89%	
" & " & escape from LAr	55%	μ Partiall ycontained
" & " & Spectrometer (with distance in LAr < 2 m)	**34%** (17%)	collected by Spectr.
" & " & stop in arm1	9%	stopping in 1rst arm
" & " & stop in arm2	7%	stopping in 2nd arm
" & " & passing through	18%	passing through





Analysis-III

FAR site

Vertex Interaction in Fiducial Volume	100%	
" & μ-track in LAr > 20 cm	92%	
" & " & escape from LAr	51%	μ partially contained
" & " & Spectrometer (with distance in LAr < 2 m)	**20%** (9%)	collected by Spectr.
" & " & stop in arm1	4%	stopping in 1rst arm
" & " & stop in arm2	5%	stopping in 2nd arm
" & " & passing through	11%	Passing through