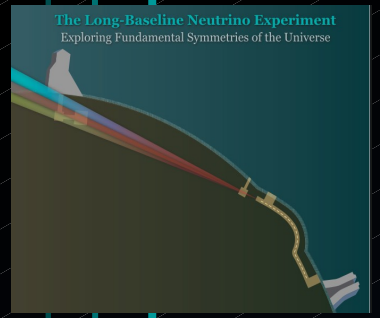


STUDY OF SPHERICAL TARGET FOR LBNE

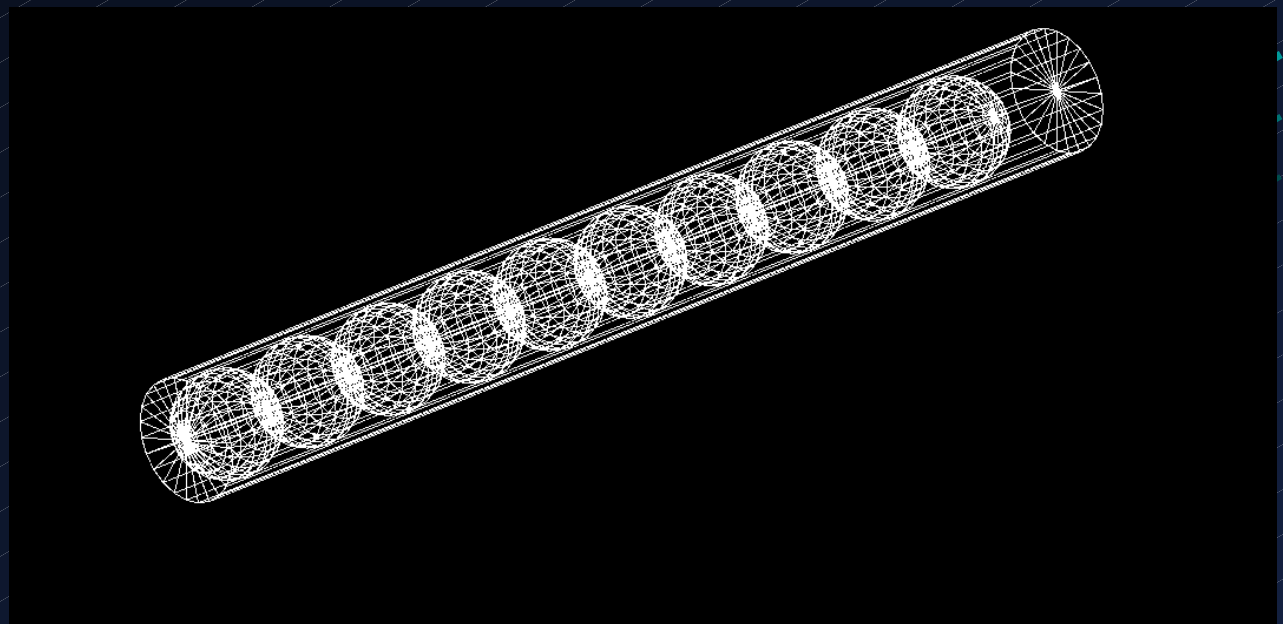
QUYNH NGUYEN
UNIVERSITY OF MINNESOTA & LEE TENG FELLOW 2014

ADVISOR: ALBERTO MARCHIONNI, PAUL LEBRUN

Goal:

- Build geometry using GEANT4 (g4lbne v3r2p4)
- To run Monte Carlo simulation of spherical array target made of Beryllium and get neutrino flux for different target and beam positions

Designed by Rutherford Appleton Lab



BEAM LINE

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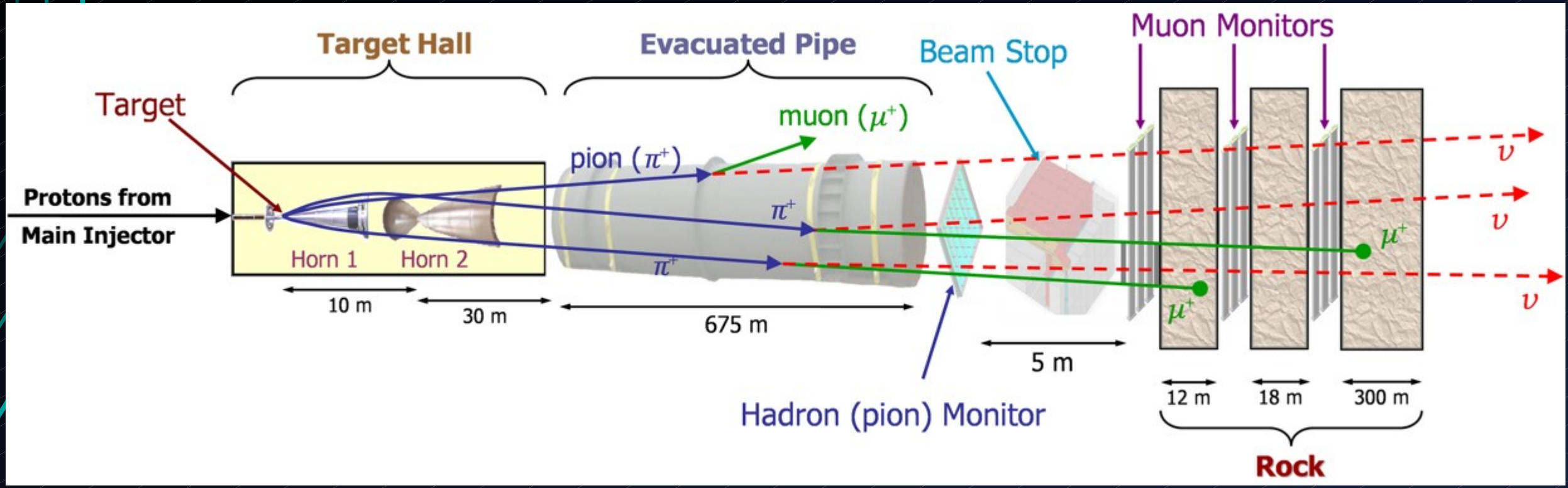

MINOS beam line. arXiv:1307.0721 [hep-ex] FERMILAB-PUB-13-279-PPD

NuMi Target (slide from J. Hylen)

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NuMI Target

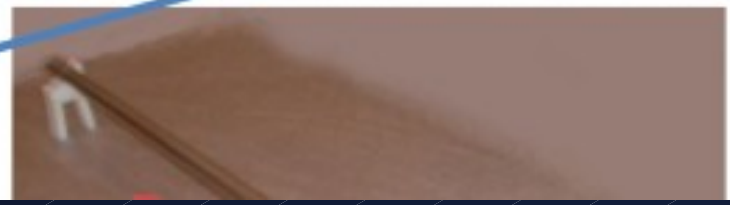
At center of Graphite, temperature jumps by
272 deg C in 10 microseconds, every 2 seconds

Graphite Fin Core, 2 int. len.
(6.4 mm x 15 mm x 20 mm) x 47 segments

Water cooling tube also provides mech. support
(steel soldered to graphite)

Anodized Al spacer (electrical insulation)

Water turn-around at end of target



STUDY MOTIVATION

Graphite target: breaks often, water leak

Spherical Array target:
- Made of Beryllium
- Stronger material, better heat conduction
- Cooled by He, larger surface for cooling
- Lower stresses than a cylinder target

* However: Harder to work with, toxic, less elastic than graphite

Peak stress for a 2 sigma off center beam (worst case design point)

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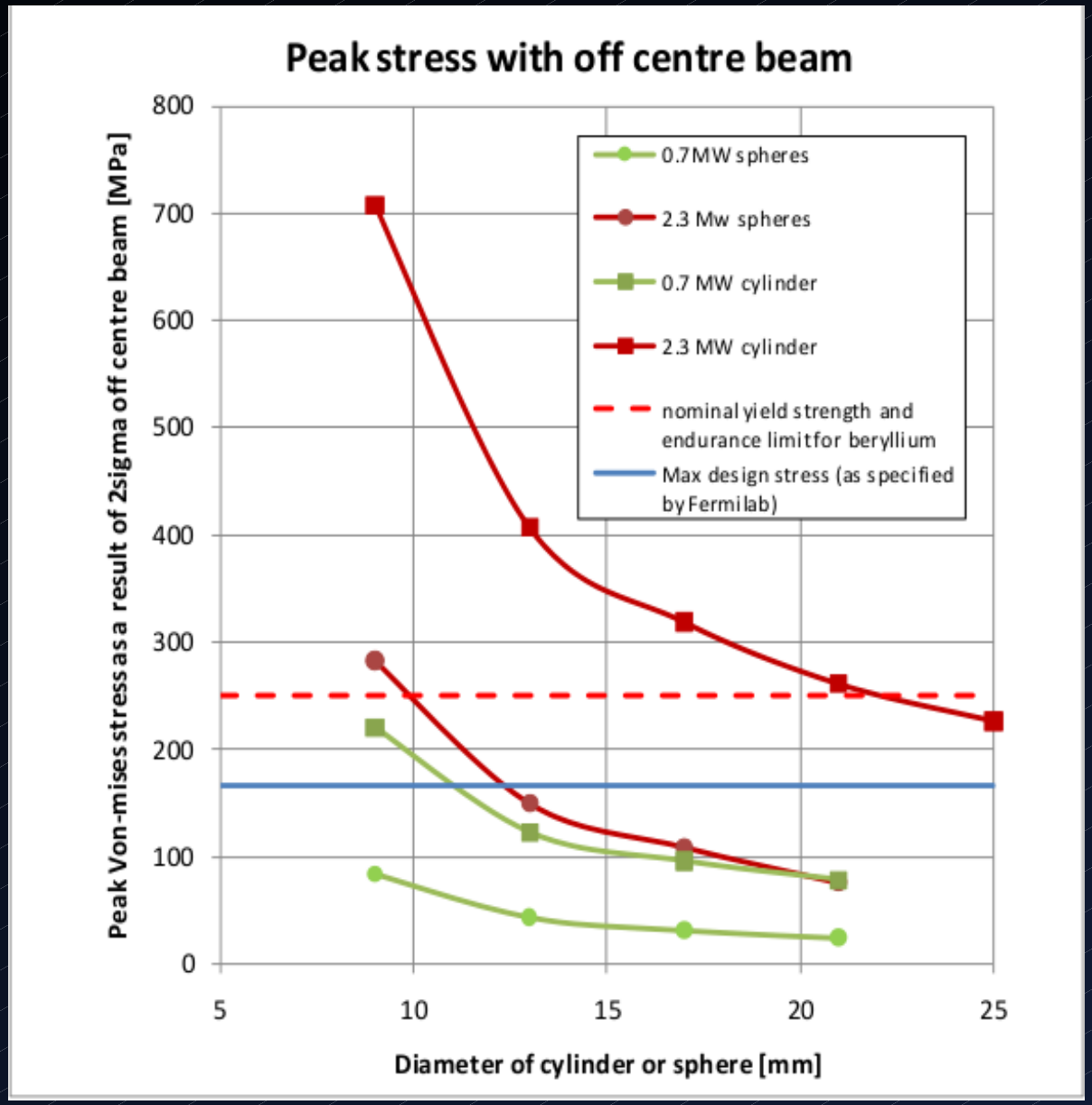

(Study by Rutherford Appleton Lab)

CALCULATING TARGET DIMENSION

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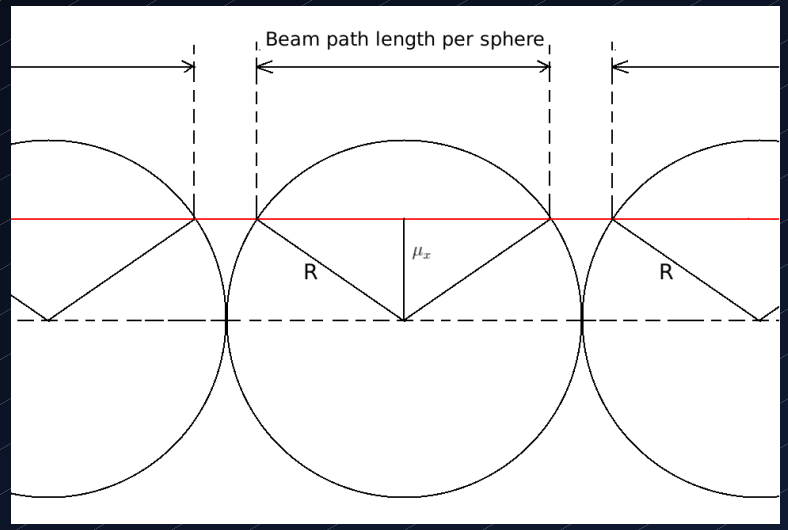
- Calculate effective interaction length as a function of beam position, weighted by Gaussian distribution of the beam (with σ = R/3)

-Two interaction lengths equivalence for Beryllium:

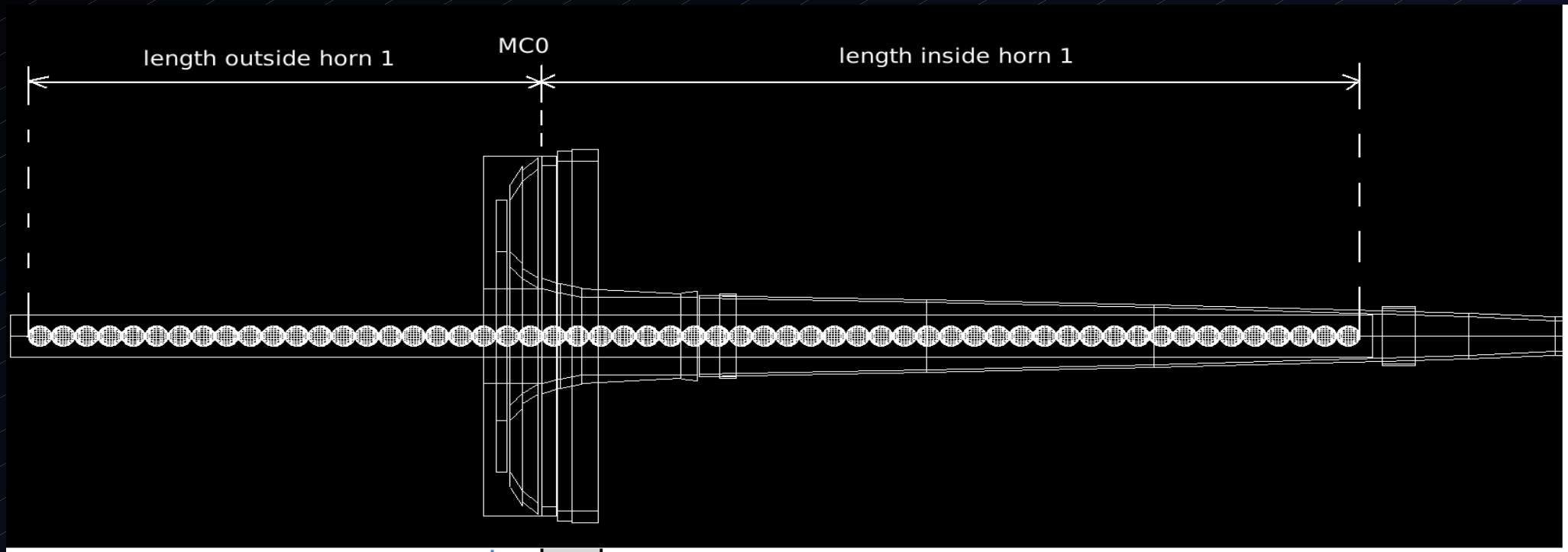
$$\int_{-\sqrt{R^2-x^2}}^{\sqrt{R^2-x^2}} \int_{-R}^{R} \left(\frac{1}{2\pi\sigma_x\sigma_y} e^{-\frac{x^2}{2\sigma_x^2}-\frac{y^2}{2\sigma_y^2}} \right) \times 2N\sqrt{R^2-x^2-y^2}\,\mathrm{d}x\mathrm{d}y = 2 \times \text{interaction length}$$

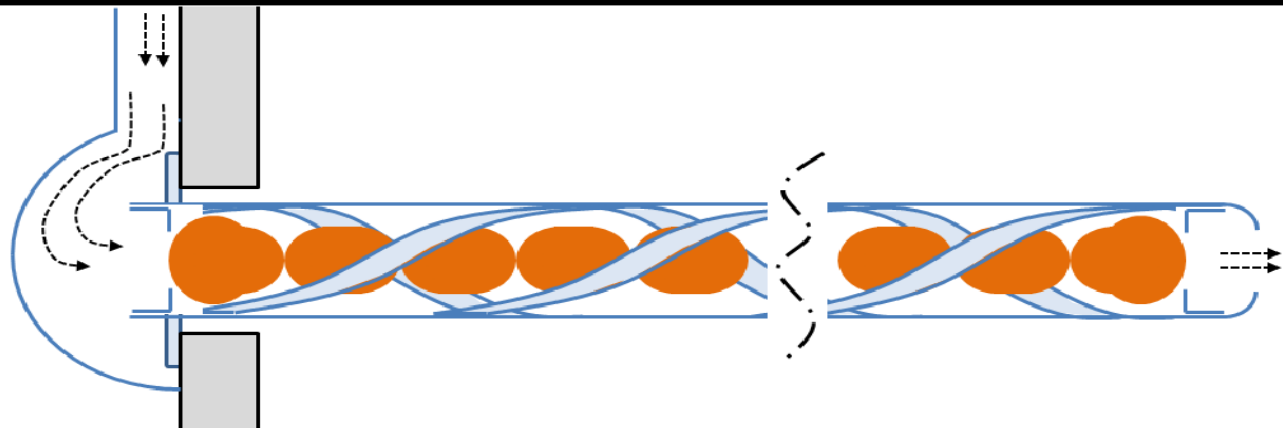
Number of spheres: N = 53 of Φ17mm, 75 of Φ13mm



NEW TARGET POSITION

- Using Φ17mm/13mm sphere in Φ36mm can, and 3 mm radial clearance from the horn





PROBABILITY OF INTERACTION FOR OFF-CENTRE PROTONS

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- Estimate probability of interaction of off-center protons and compare with neutrino flux at of off-center beams

$$P(\mu_x, \mu_y) = \int_{-\sqrt{R^2-x^2}}^{\sqrt{R^2-x^2}} \int_{-R}^{R} \left(\frac{1}{2\pi\sigma_x\sigma_y} e^{-\frac{(x-\mu_x)^2}{2\sigma_x^2} - \frac{(y-\mu_y)^2}{2\sigma_y^2}} \right) \times \left(1 - e^{-\frac{2N\sqrt{R^2-x^2-y^2}}{\text{interaction length}}} \right) \text{dxdy}$$

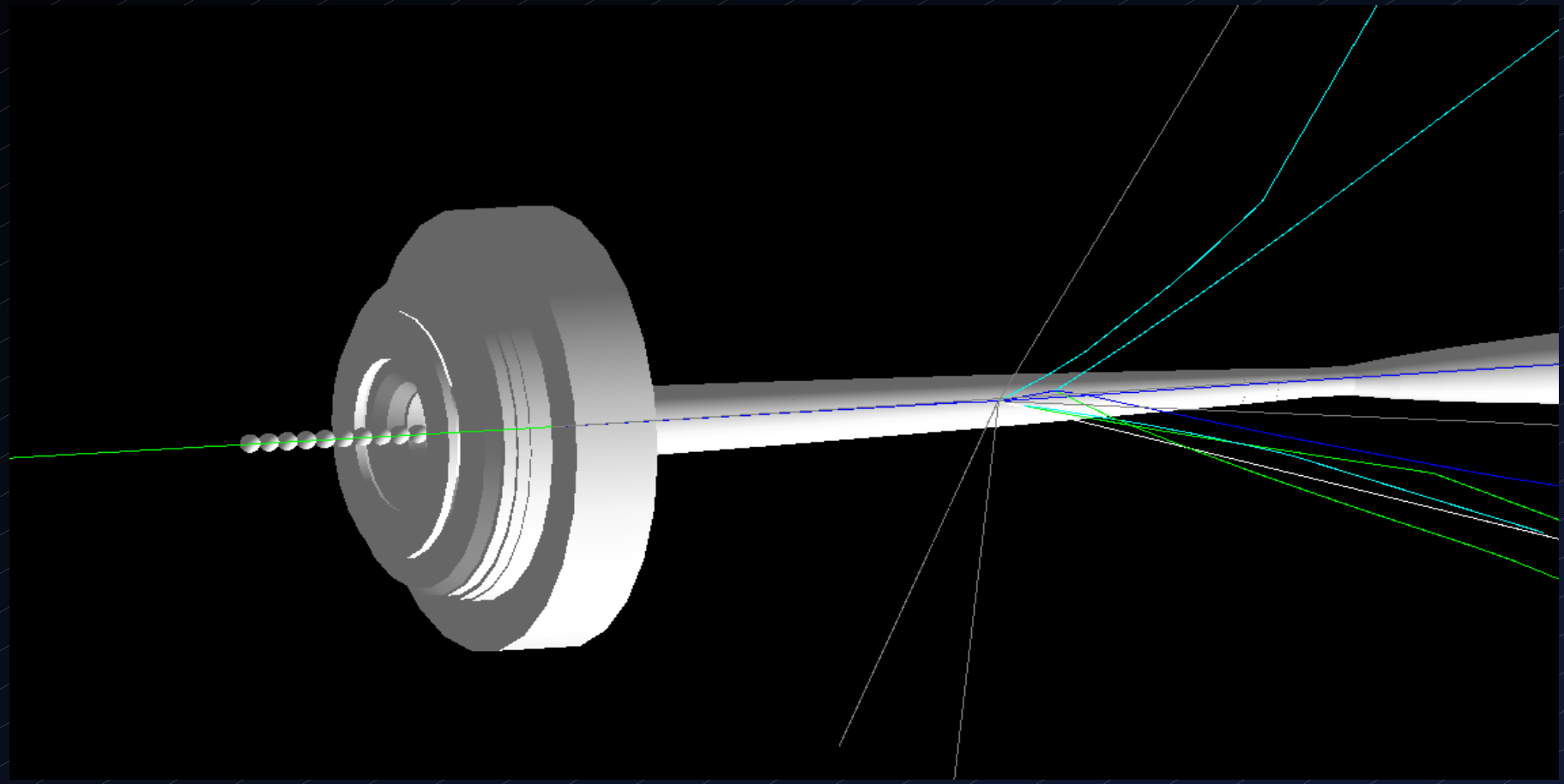
Numerical Integration in python (Thanks Todd) gave

Beam offset (mm)	0	0.05	0.1	0.2	0.4	1	2	3
Probability of interaction (%)	85.043%	85.042%	85.04%	85.02%	84.95%	84.47%	82.63%	79.27%
Ratio to on-centre beam	1	0.99998	0.99993	0.99973	0.99893	0.99320	0.97163	0.93215

TABLE II. Probability of interaction of protons hitting the target at different offset from the target center

Simulation of Target and Horn1 with 1 Proton on Target (POT)

-



MONTE CARLO (g4lbne v3r2p4)

- 500 runs of 100,000 POT for each configurations:

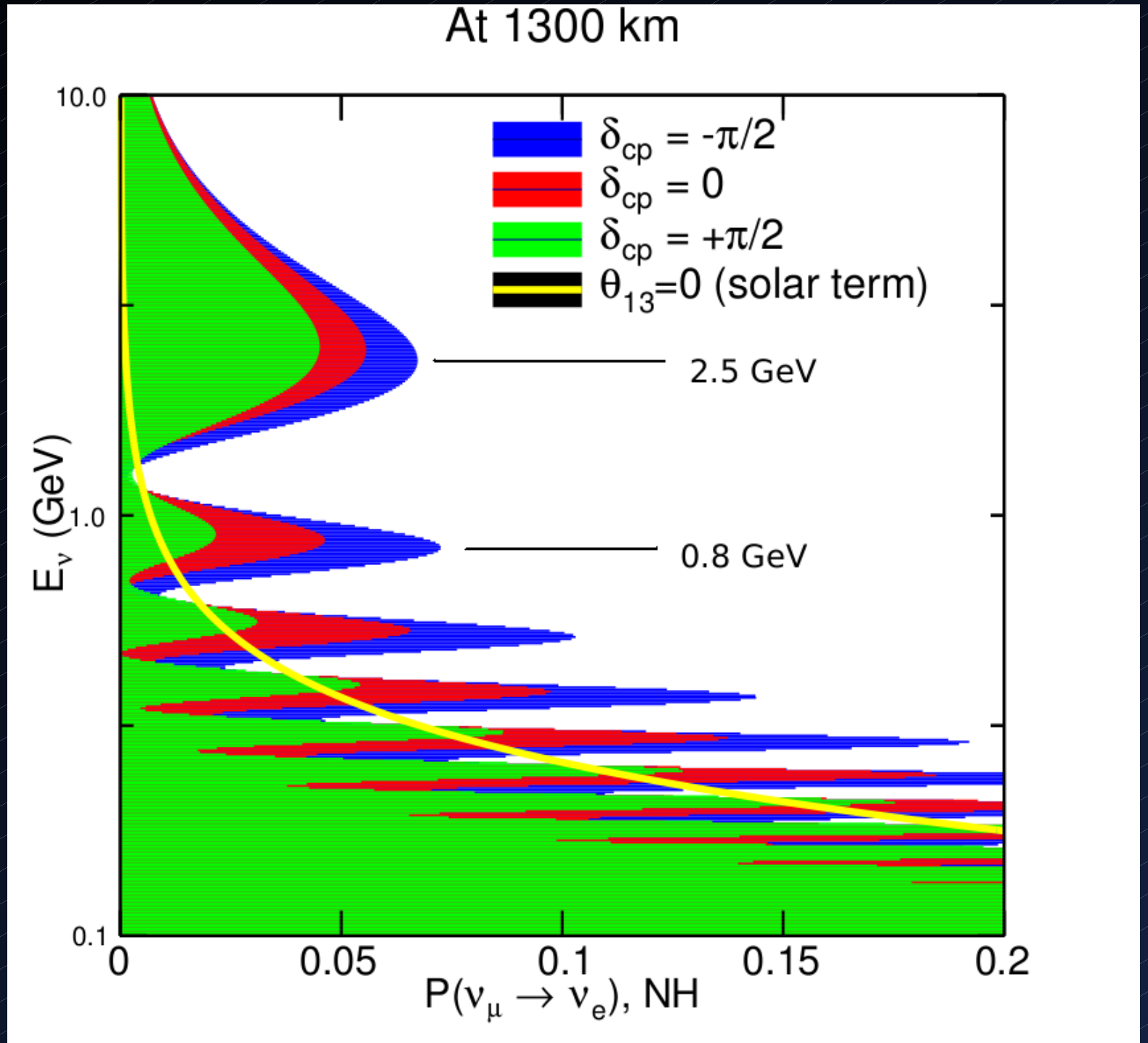
- Ø17mm, beam σ = 2.83mm, 969 mm target, target position varies

- Ø17mm, beam σ = 2.83mm, 969mm target, beam position varies

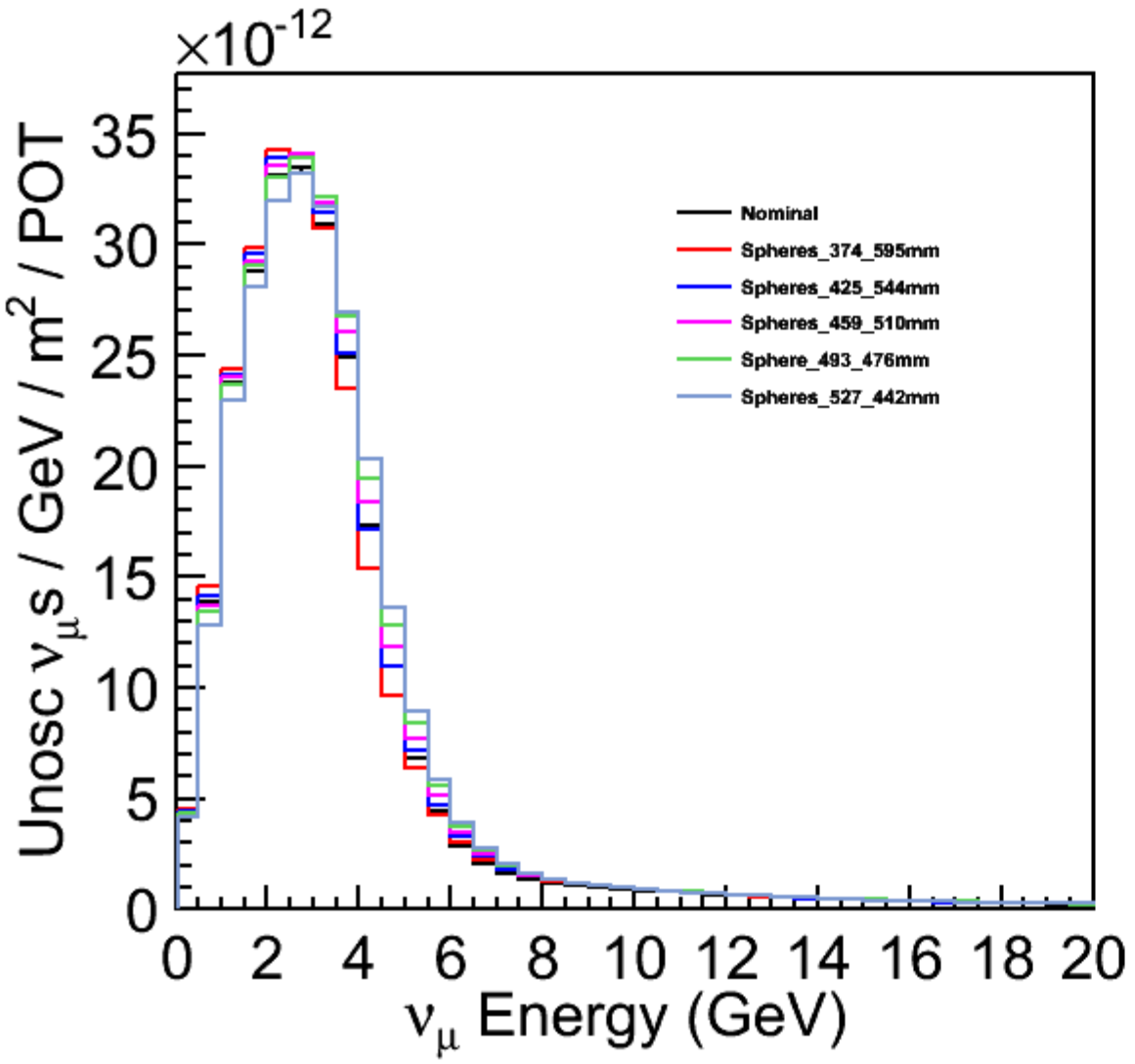
- Ø17mm, beam σ = 1.7mm, 969 mm target, position varies
- Ø17mm, beam σ = 1.7mm, 901 mm target, position varies

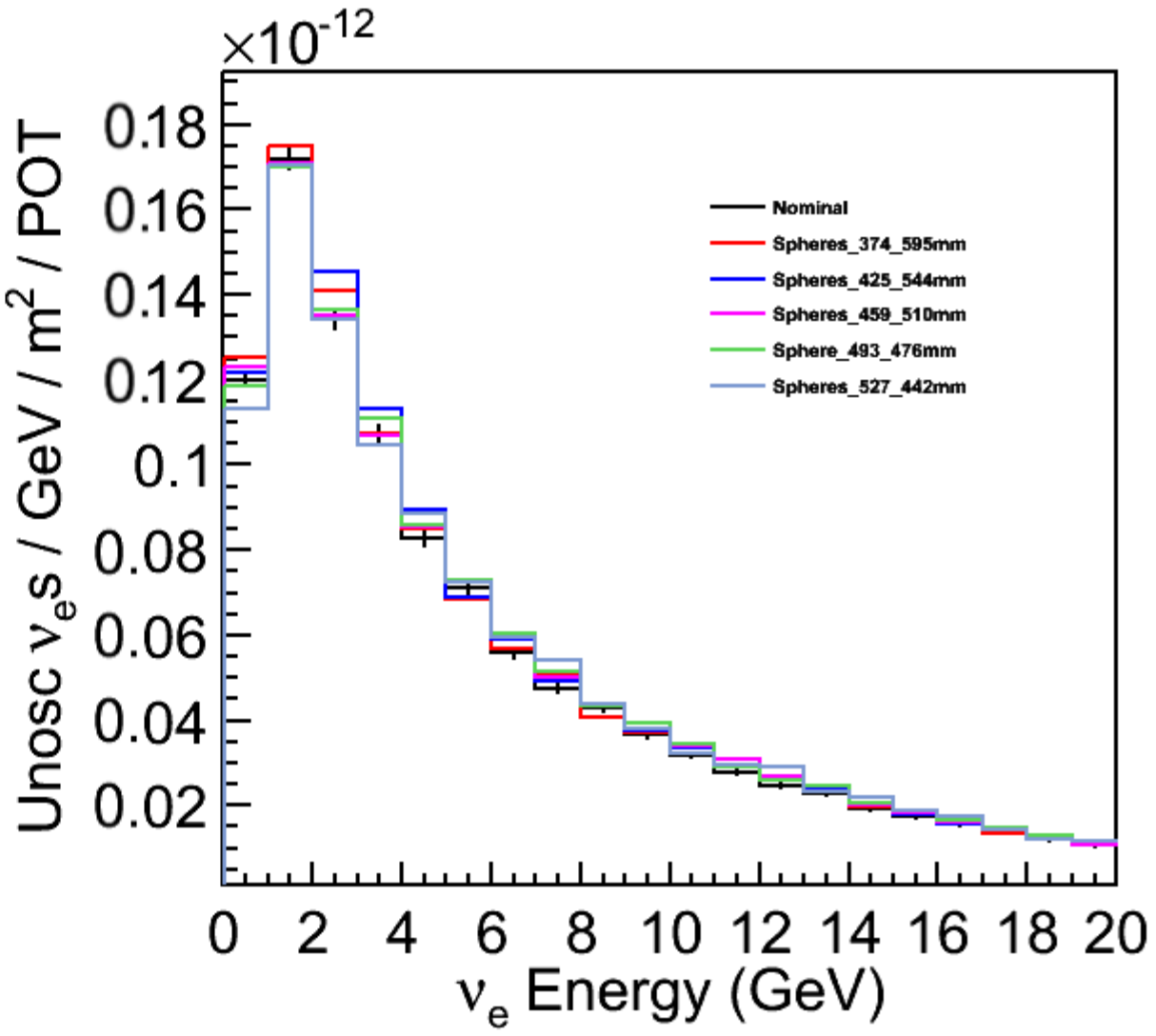
- Ø13mm, beam σ = 2.16mm, beam position varies

OSCILLATION MAXIMA

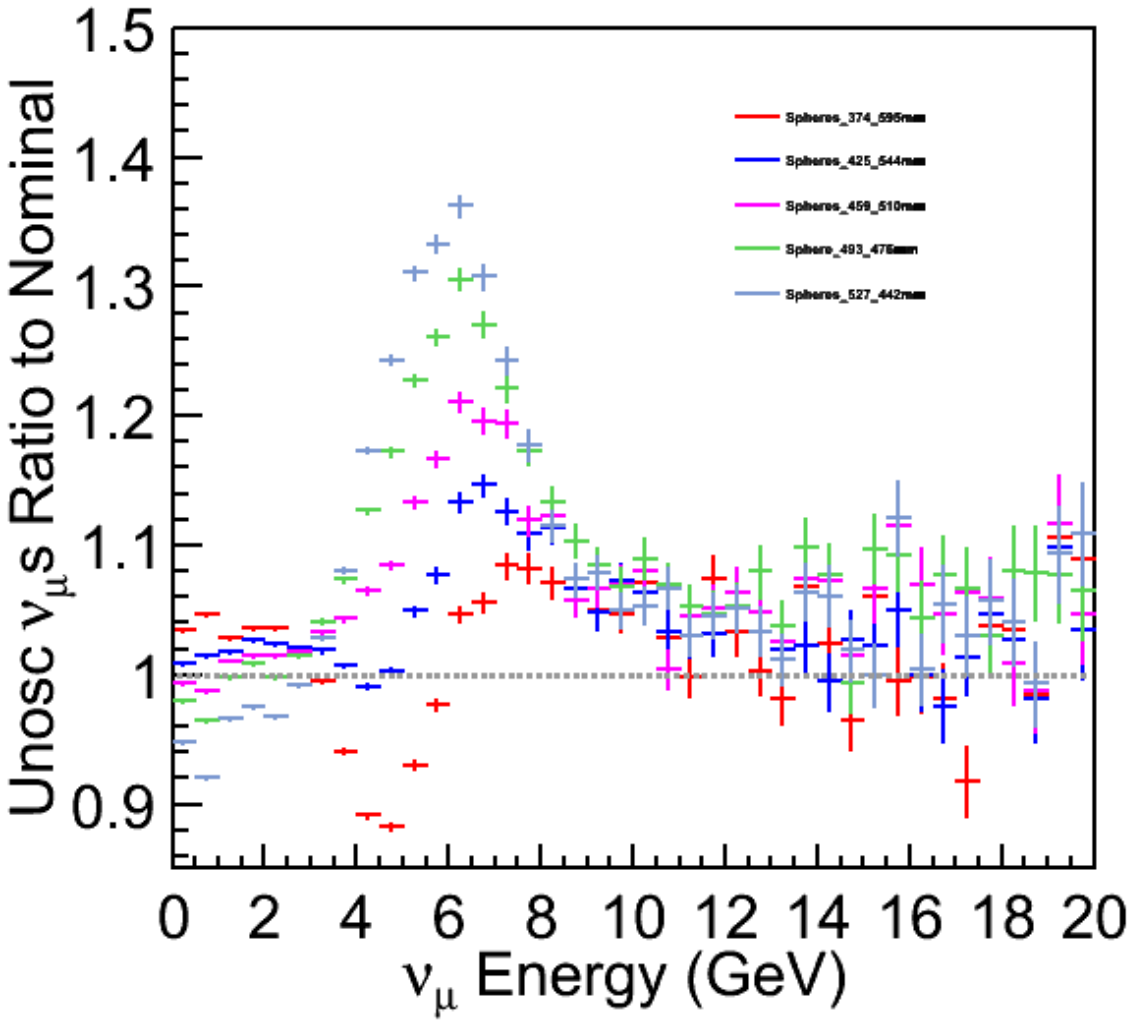


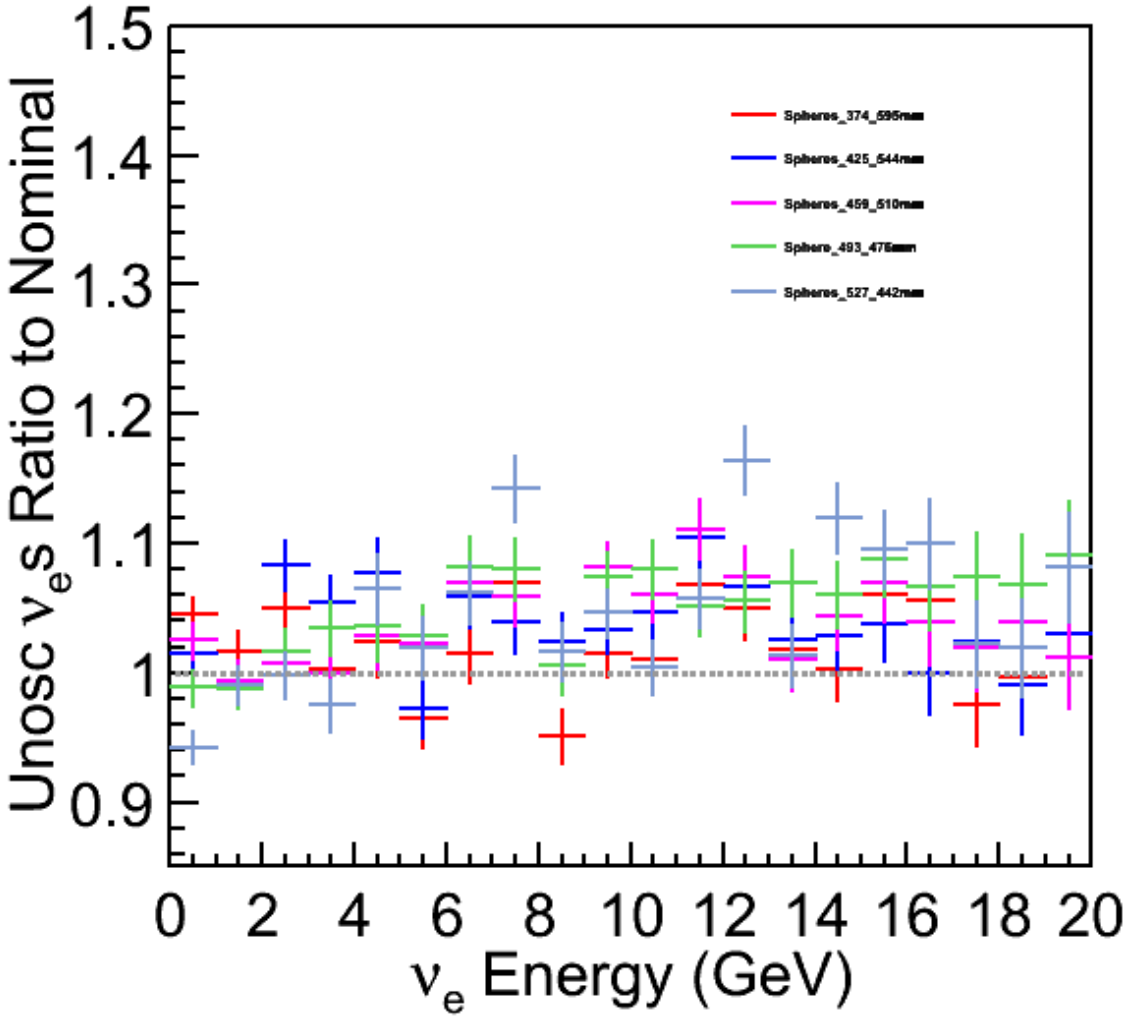
MOVE TARGET. Spheres Ø17mm, beam σ = 2.83mm, 969 mm target, target position varies, Far Detector





MOVE TARGET. Spheres Ø17mm, beam σ = 2.83mm, 969 mm target, target position varies, Far Detector





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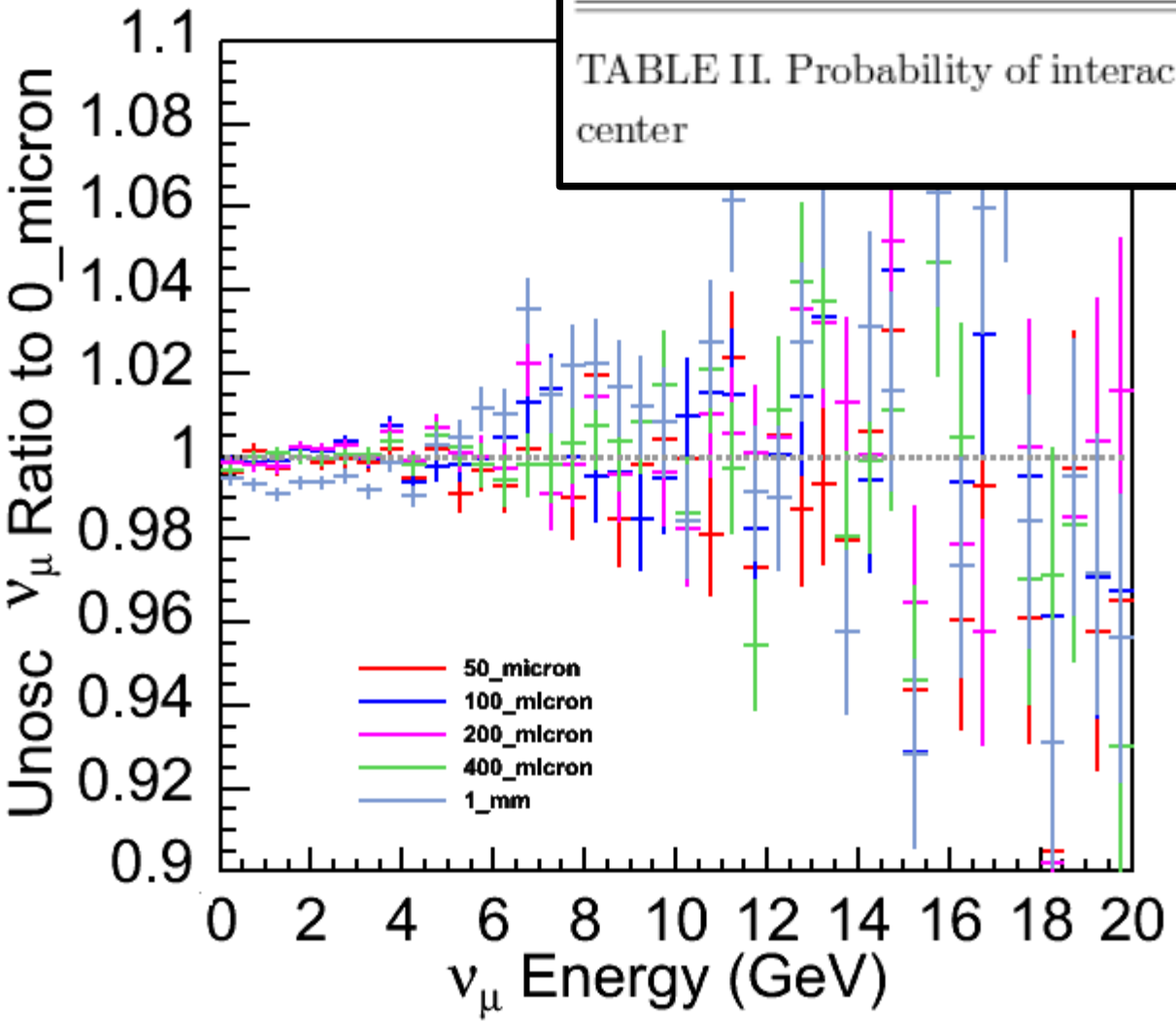
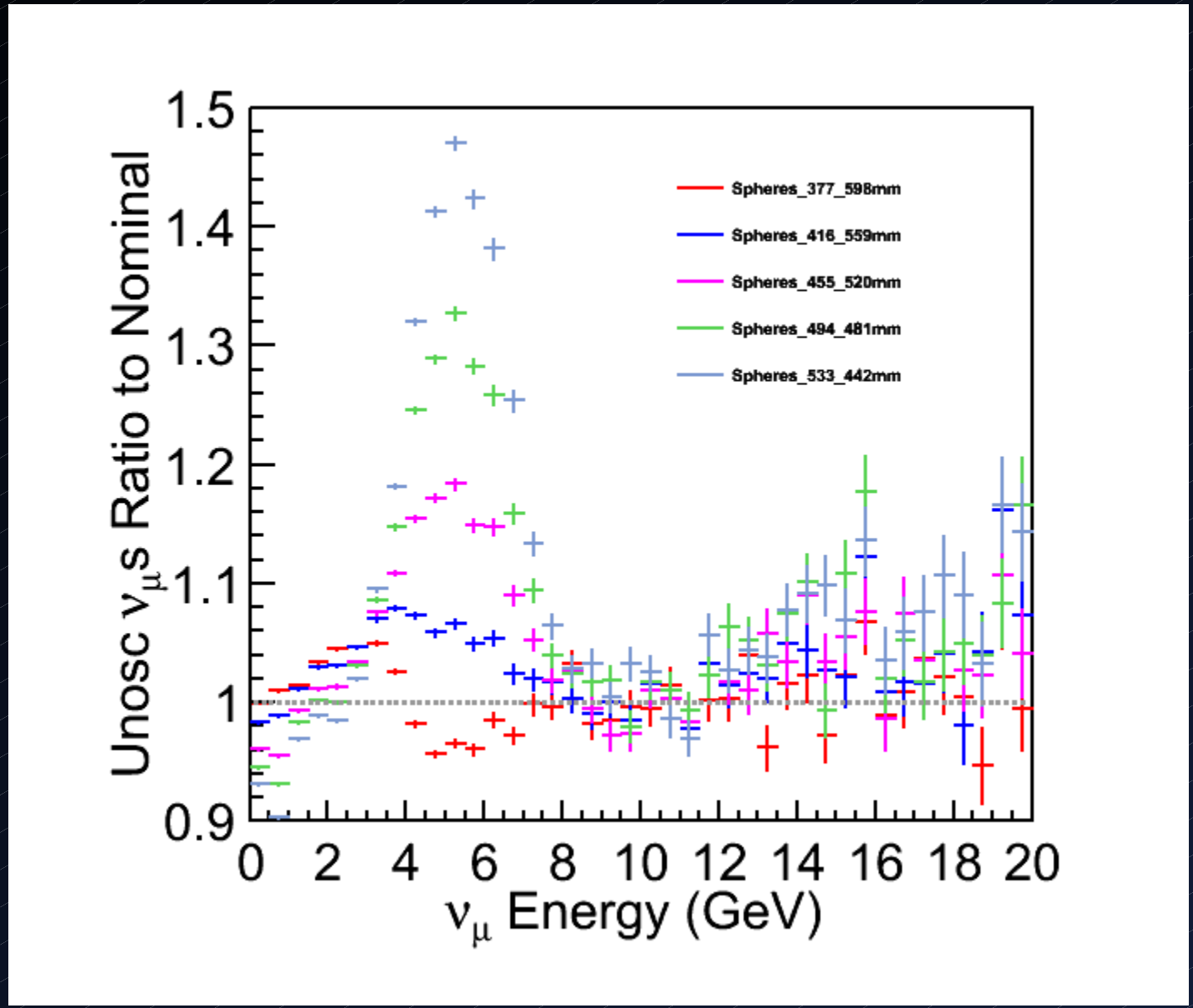
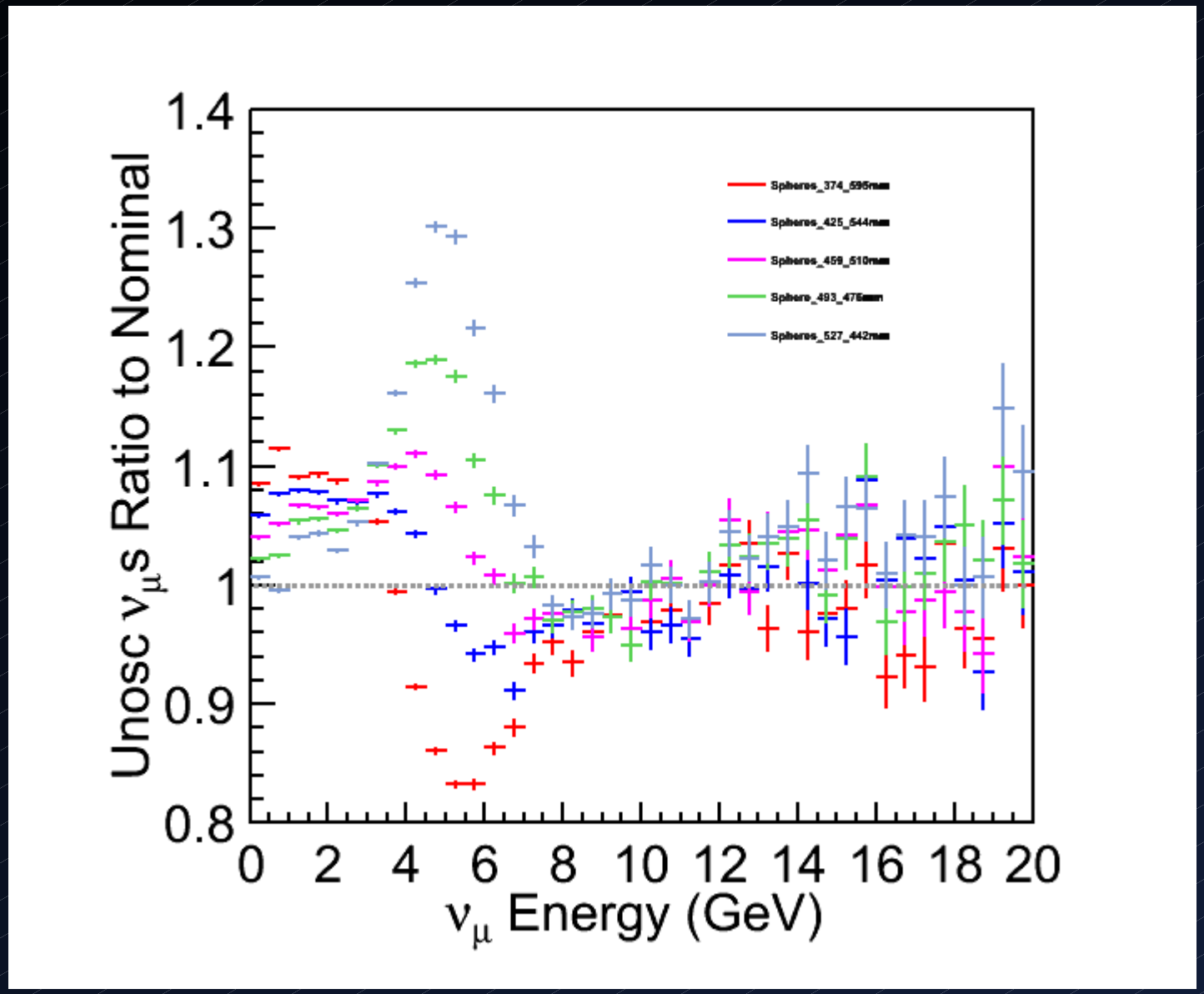


MOVE BEAM OFFSET.
Spheres Ø17mm, beam σ = 2.83mm, 969mm target, beam position varies, Far Detector

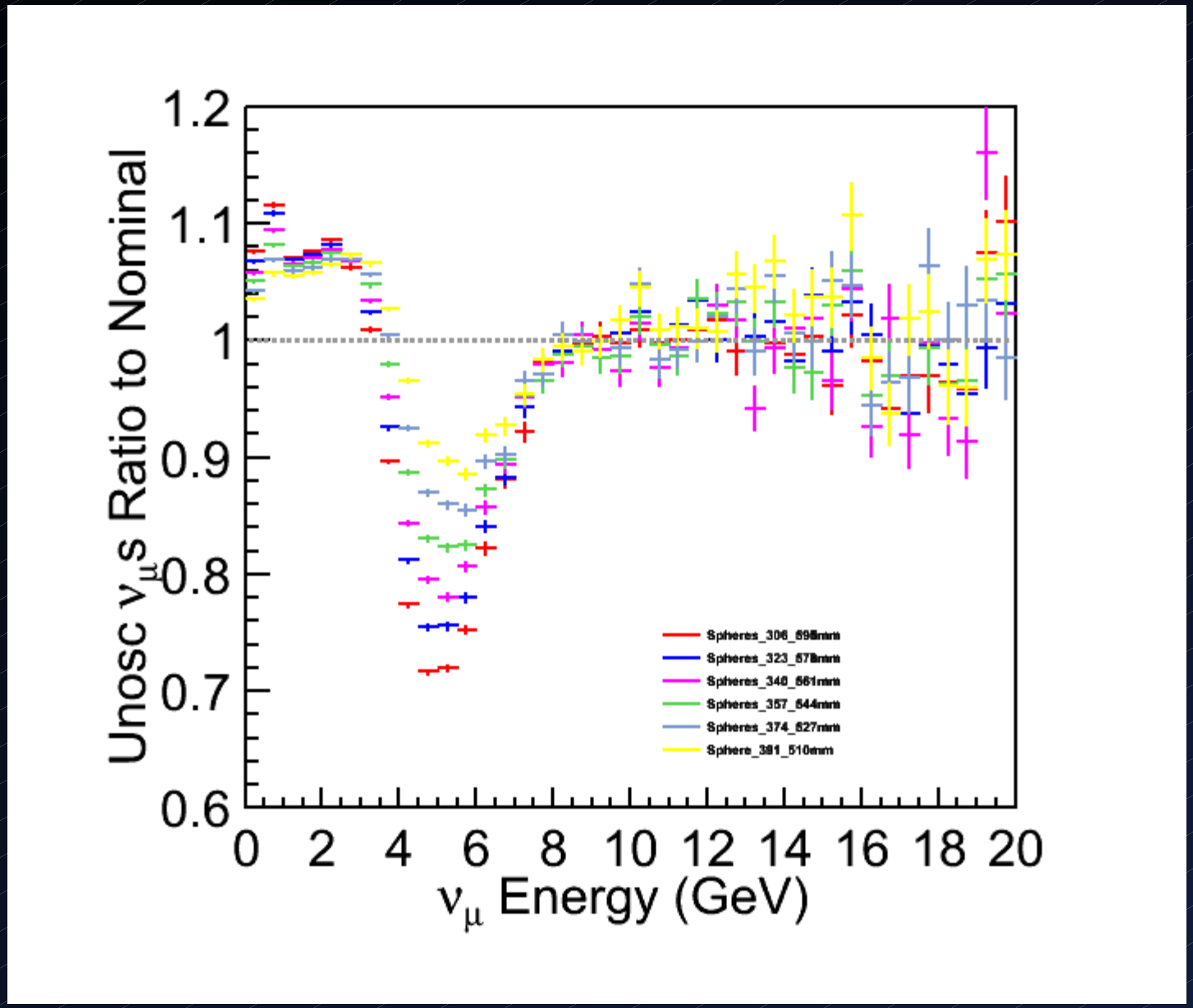
SMALLER TARGET. Spheres Ø13mm, beam σ = 2.16mm, beam position varies, Far Detector



THINNER BEAM: Spheres Ø17mm, beam σ = 1.7mm, 969 mm target, position varies, Far Detector



SHORTER TARGET. Ø17mm, beam σ = 1.7mm, 901 mm target, position varies, Far Detector



CONCLUSION AND FURTHER STUDY

- Spherical array target besides favorable mechanical properties also promises higher neutrino flux

- Short target (less than two interaction length) and thin beam (sigma < R/3) gives higher flux in 0-3.5 GeV and suppresses higher energy tail

Further work:

- More engineering study on the strength of spheres target under thin beam (sigma < R/3)

- Engineering study on more accurate dimension of cooling can

- Upgrade the source code to move the target to any arbitrary position

ACKNOWLEDGEMENT

I am grateful to

Dr. Alberto Marchionni for many interesting physics problems and advise &

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Dr. Eric Prebys for mentoring, tours and a nice house party &

Ms. Tanja Waltrip for making sure I got my stipend &

Dr. Erik Ramberg and Dr. Roger for interesting talks

And all my friends

Back up slides

QUYNH
NGUYEN

Parameters:

- Material: Beryllium
- First try Ø17mm and try to reduce further to ~ Ø10mm
- Target length: two “effective” interaction lengths
- Beam size 3σ; beam power 1.2MW
- Try different material ?