Update on the BNL VLBL Study

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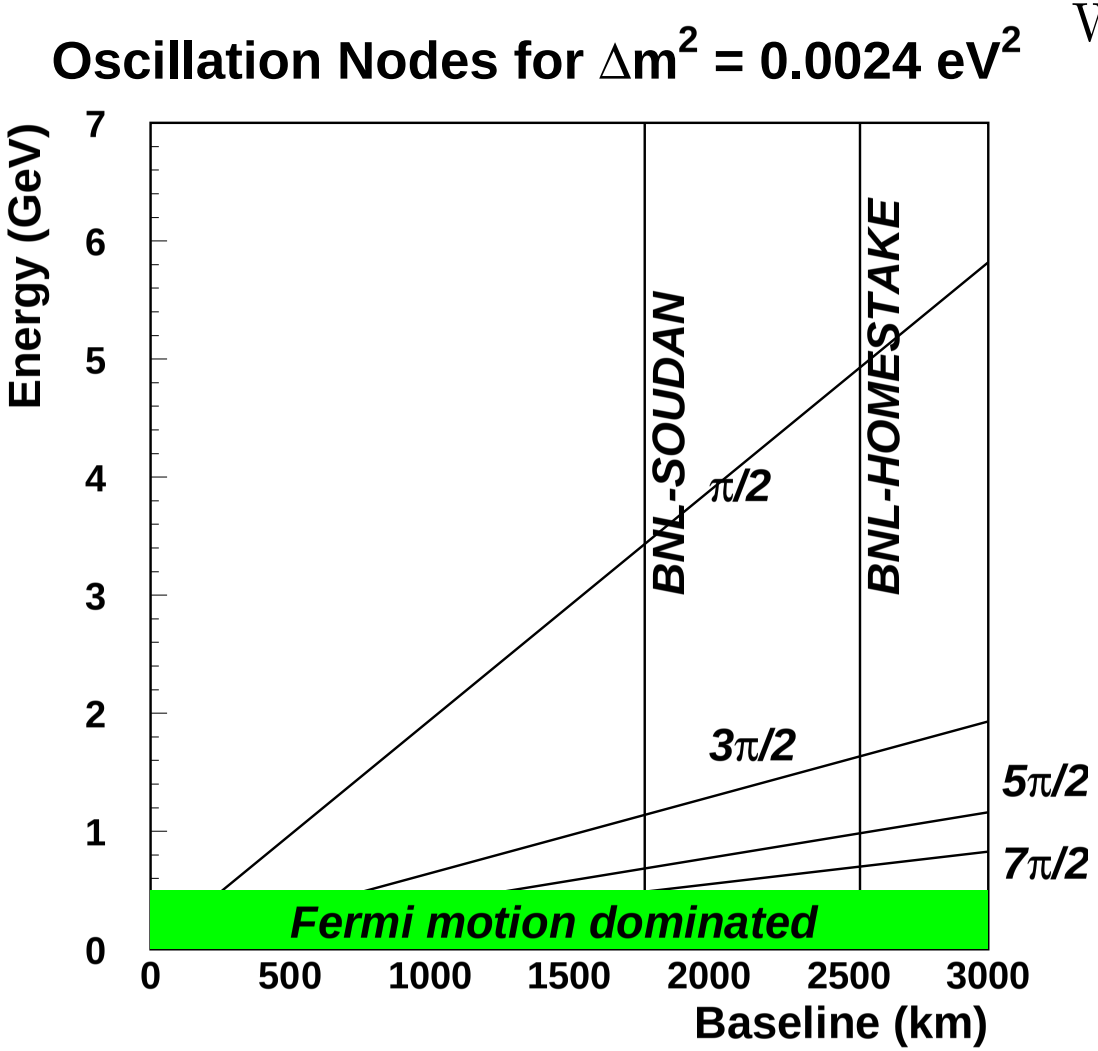
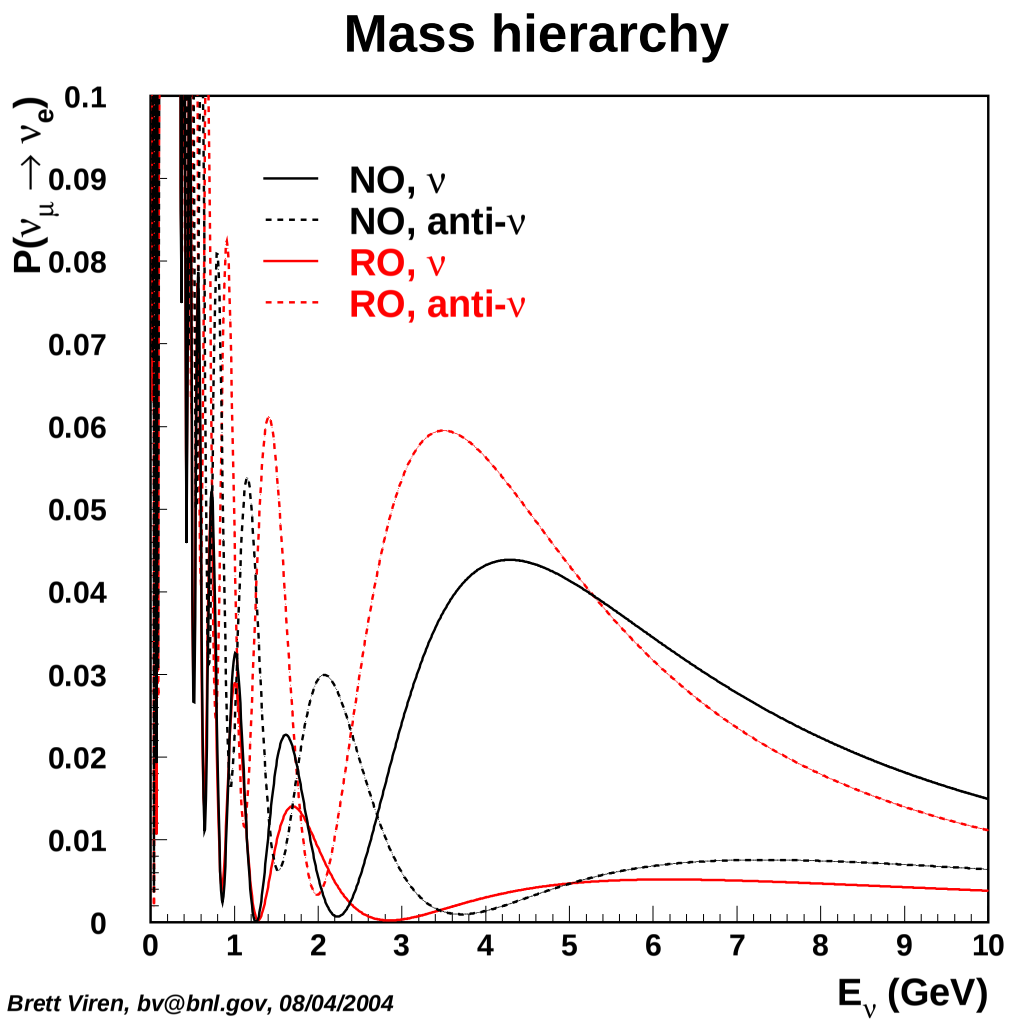
- Brief (re)introduction to the BNL VLBL concept
- Proton beam study update
  - Summary of current “baseline” design
  - New ideas for improvements
- Direction Sensitive Photo-Sensor work



With very long baselines:

- Multiple oscillations visible, increased resolution, decreased normalization systematics
- Osc. at energies where:
  - Cross sections are higher
  - Fermi motion less dominant
  - Different physics at different energies
- SK says, need > 2000 km

Need wide band, high energy ν beam and a long baseline $\longrightarrow$

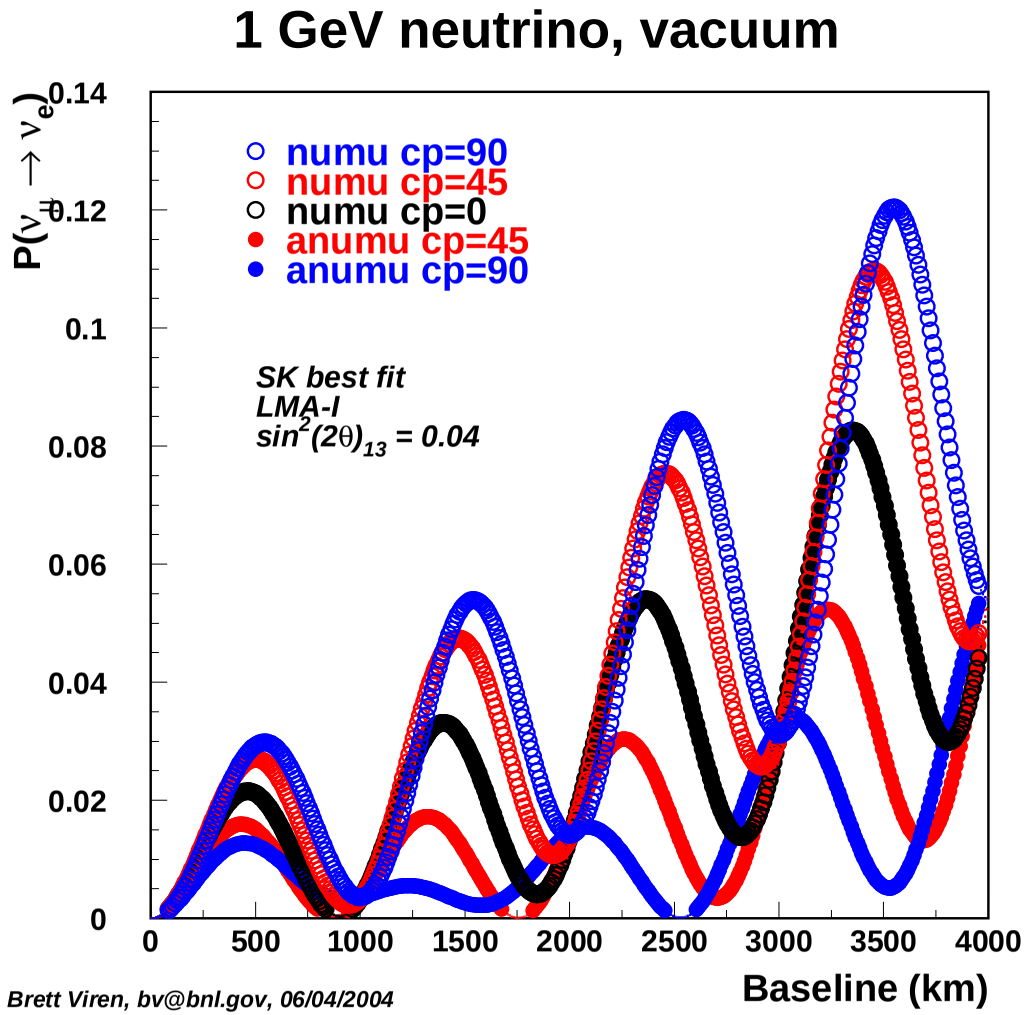


With a very long baseline:

- Large enhancement of ν_e appearance in first oscillation due to matter effect
- Clear sign(Δm^2) measurement

Marciano (hep-ph/0108181):

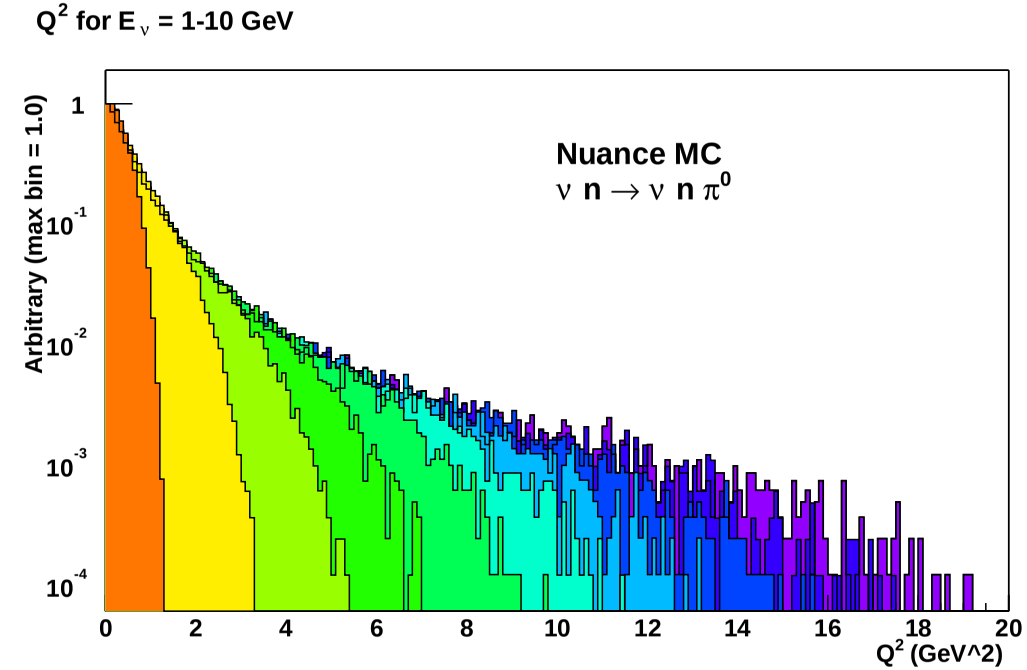
- Flux goes as $1/L^2$
- **CPV grows w/ L**
- **FOM** $= \mathbf{A^2 N_\nu/(1\text{-}A^2)}$

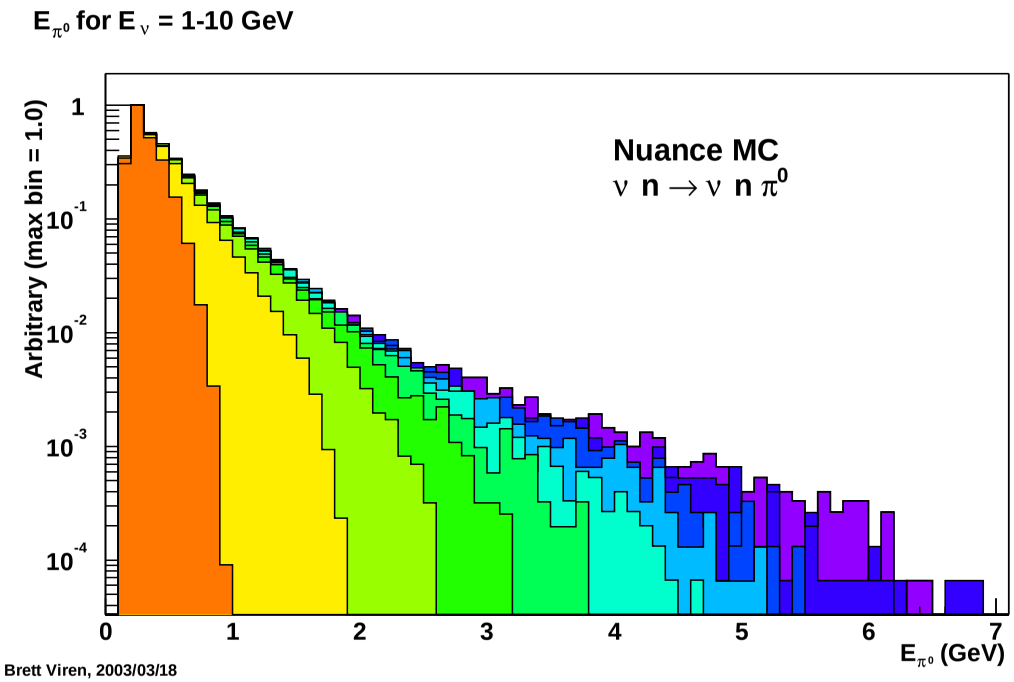


CPV FOM ~independent of baseline for same beam power and detector mass

Not everything is rosy:

- Q_2 (top) and E_π (bottom) for single-π^0 NC events
- Each color band: mono-energetic neutrinos 1-10 GeV in 1 GeV steps
- Pileup below 2 GeV a major difficulty
- **Above 2 GeV, > 50x suppression, natually**

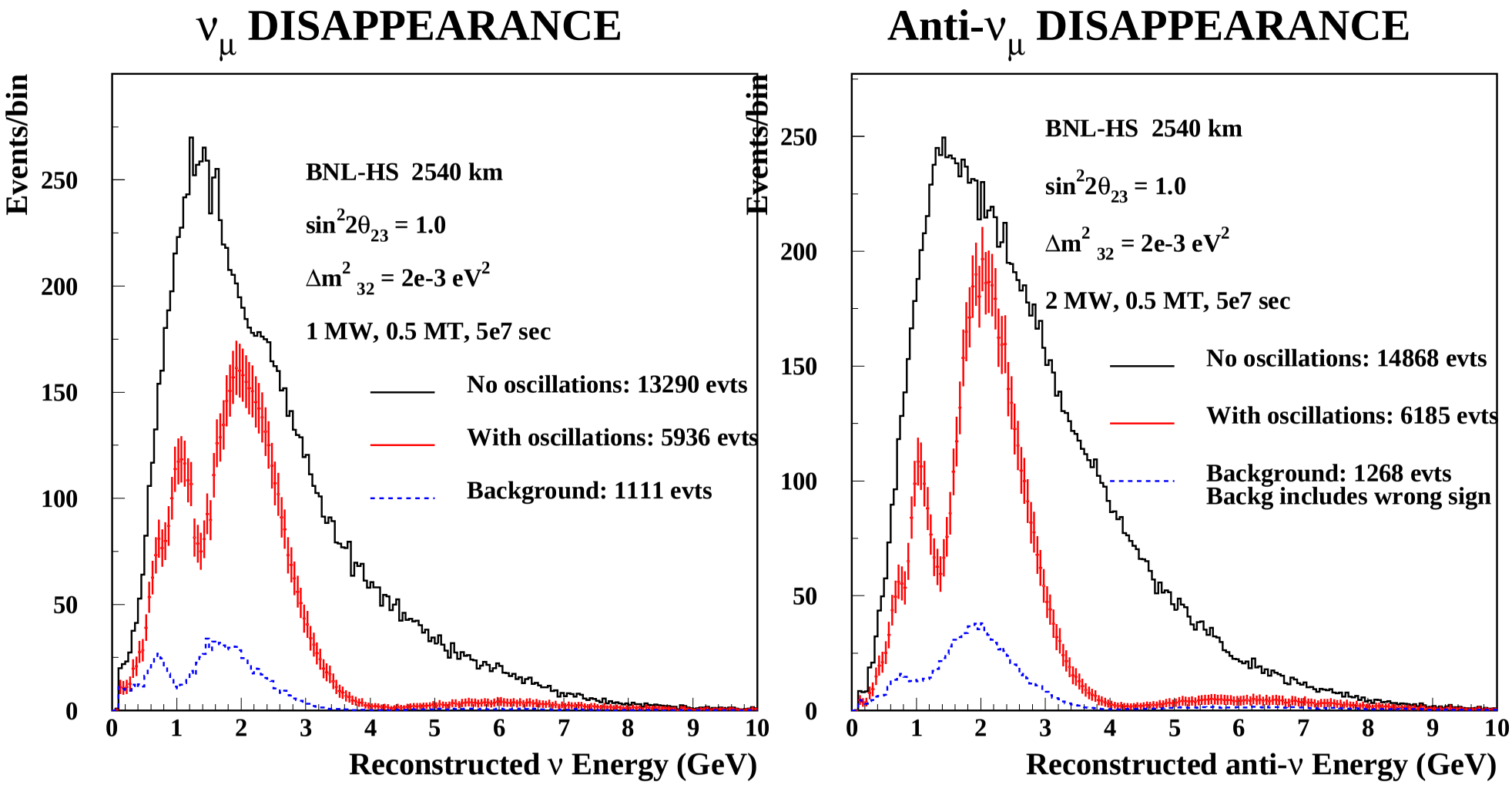




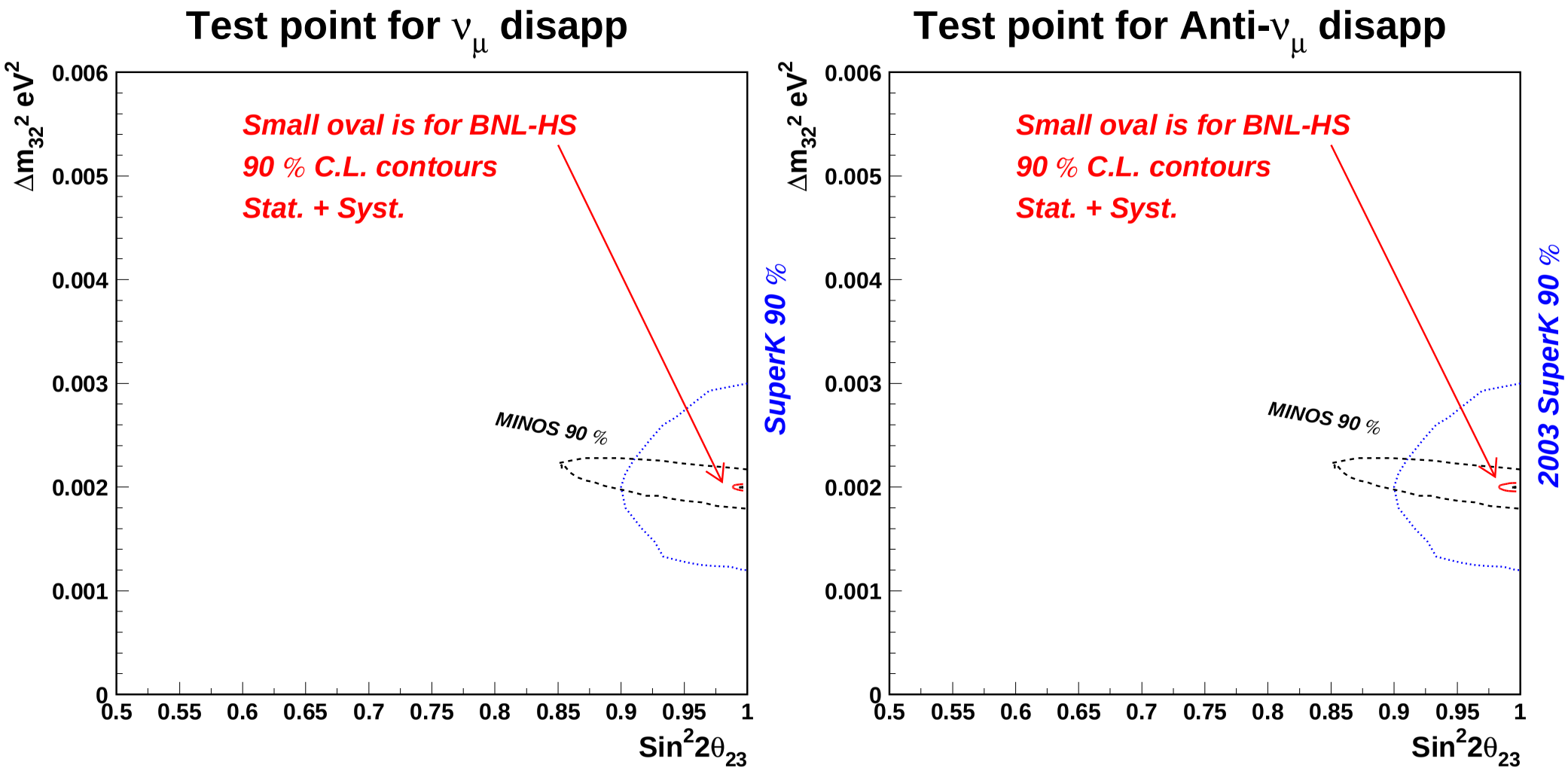
Brett Viren, 2003/03/18

Plots generated assuming:

- 2540 km (BNL-Homestake) baseline. BNL-Henderson (2767) a little better, oscillation features pulled to slightly higher energy.
- Oscillation parameters around SK best fit point and KamLAND's LMA-I, $\sin^2 2\theta_{13} = 0.04$
- 5x10^7 seconds, 1 MW neutrino running
- 5x10^7 seconds, 2 MW anti-neutrino running
- 500 kTon fiducial mass UNO-like detector
- Better than SK e/π^0 separation, (not yet shown to be possible, but we are hopeful)

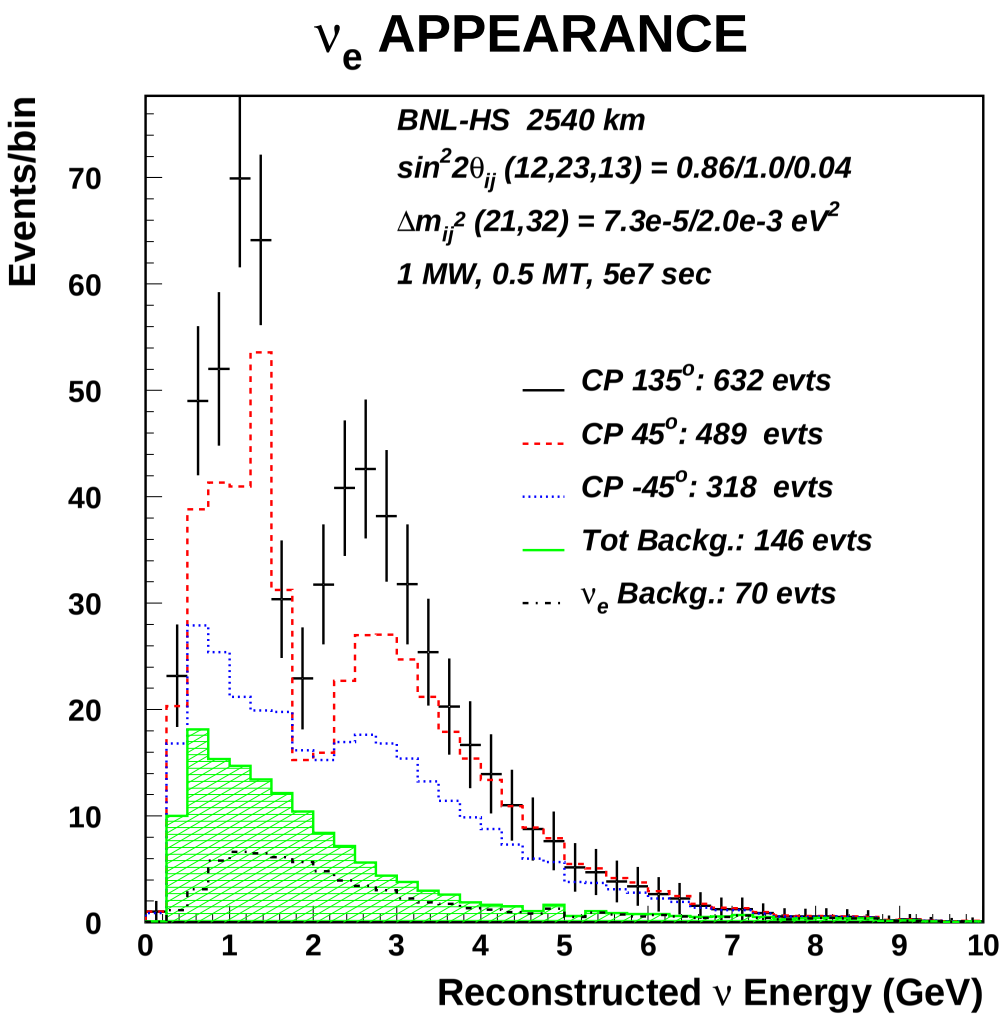


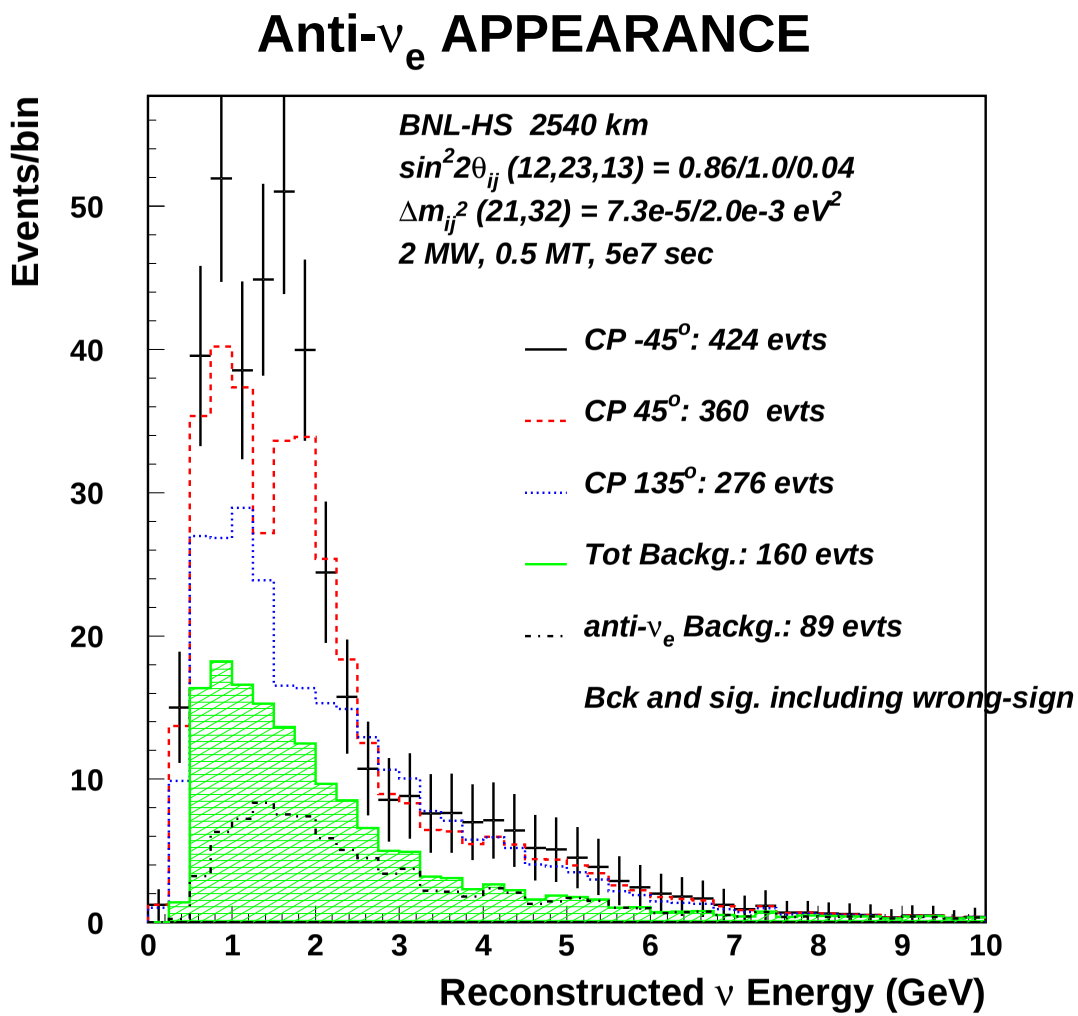
Node pattern provides high Δm^2 resolution. Energy calibration is very important. Flux normalization not important for measurement of $\sin^2 2\theta_{23}$



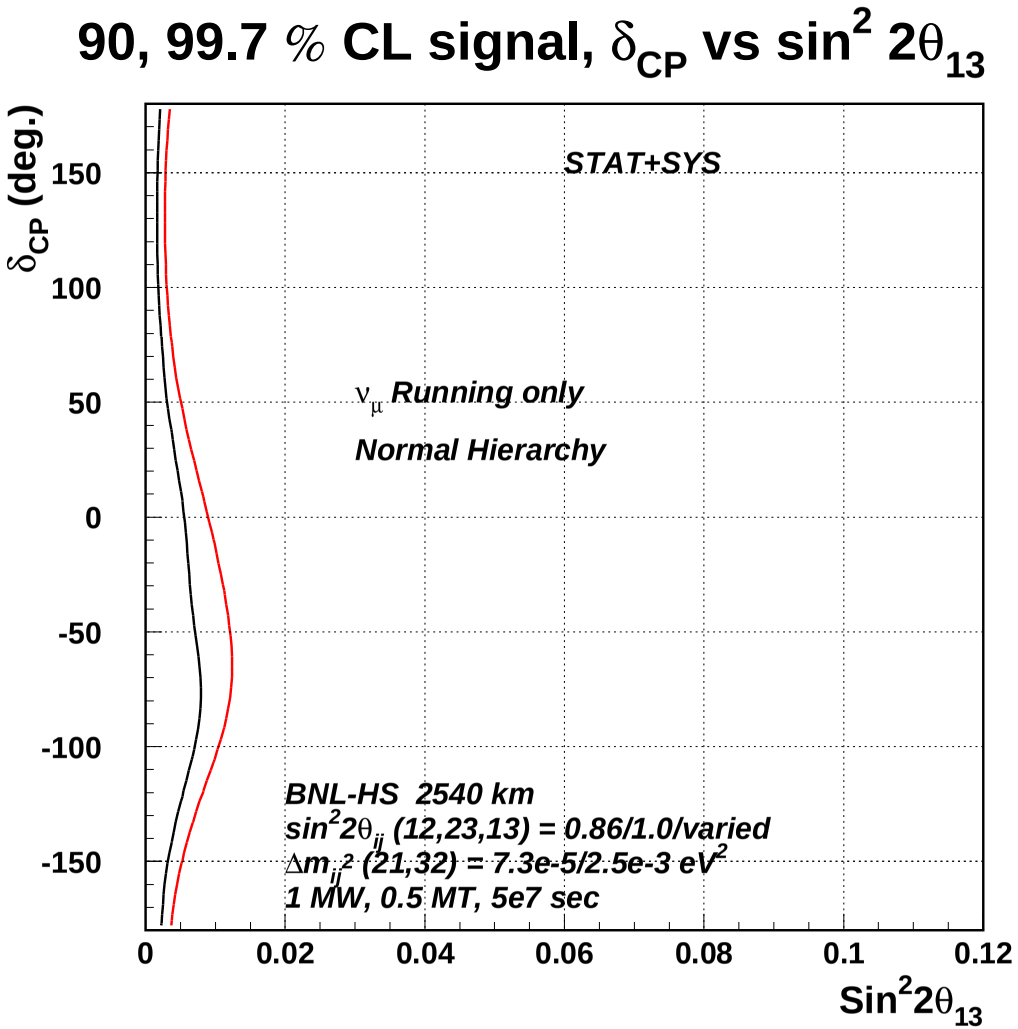
~1% resol. on $\Delta m^2{}_{32}$ and $\sin^2 2\theta_{23}$ over broad range if we can understand detector energy scale to 1%. Robust against other systematics.

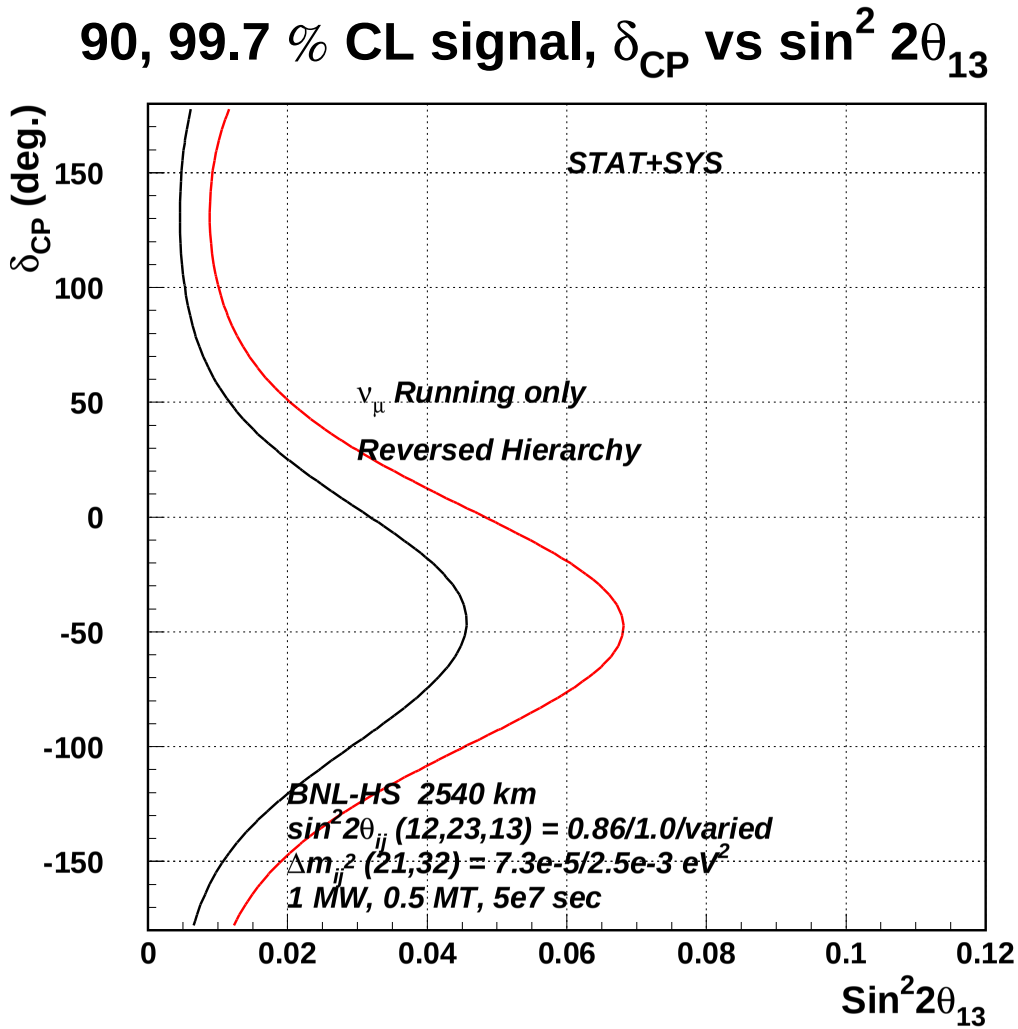
9/22 – Expected Appearance Spectra (strong background rejection)



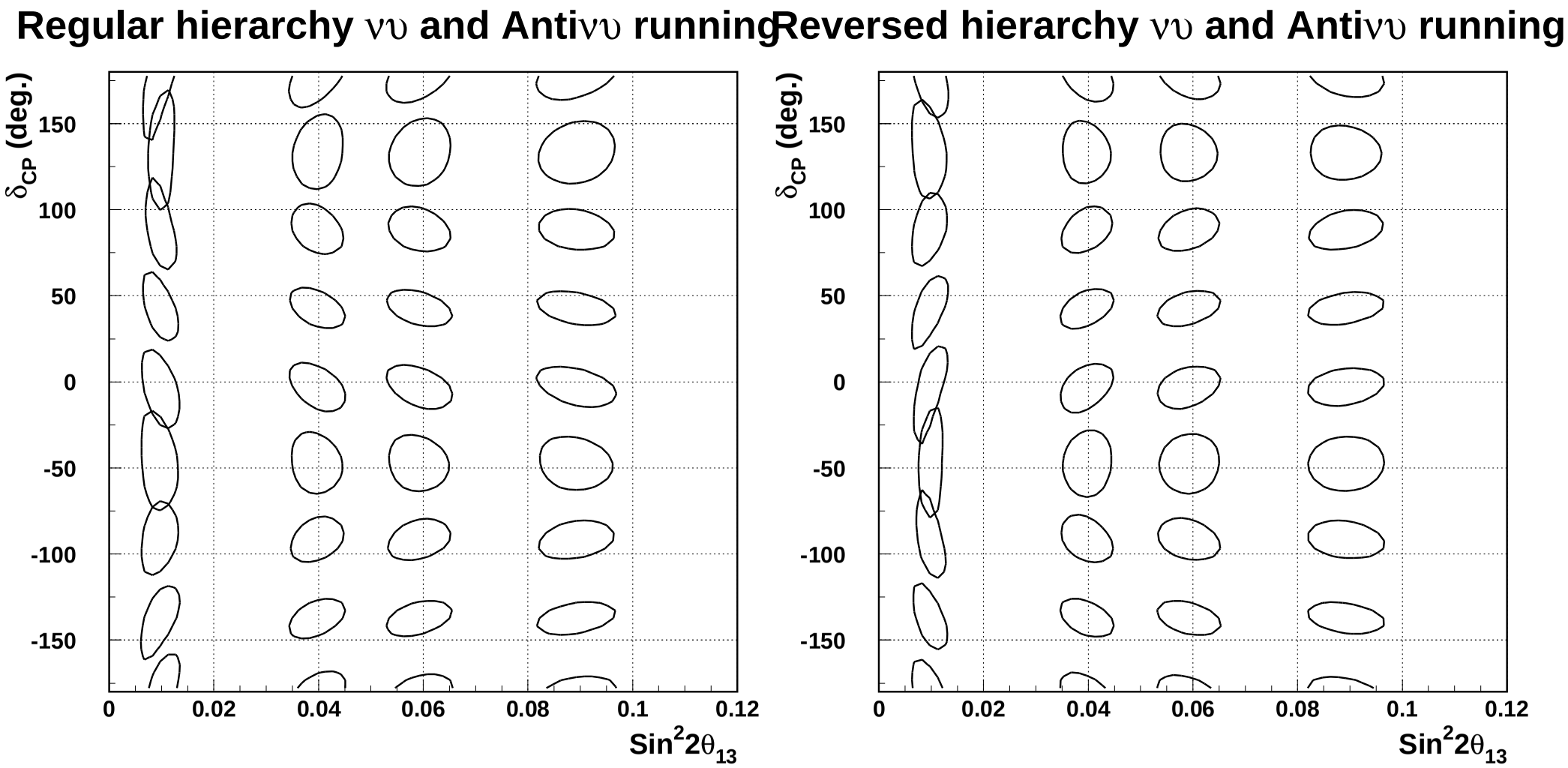


Normal hierarchy. R.H. essentially flips the two

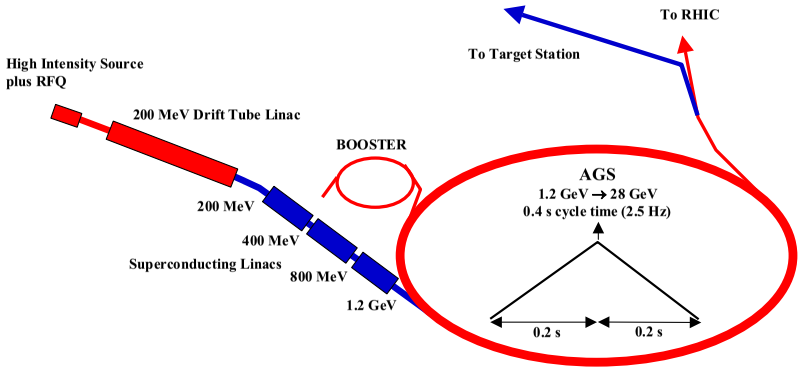




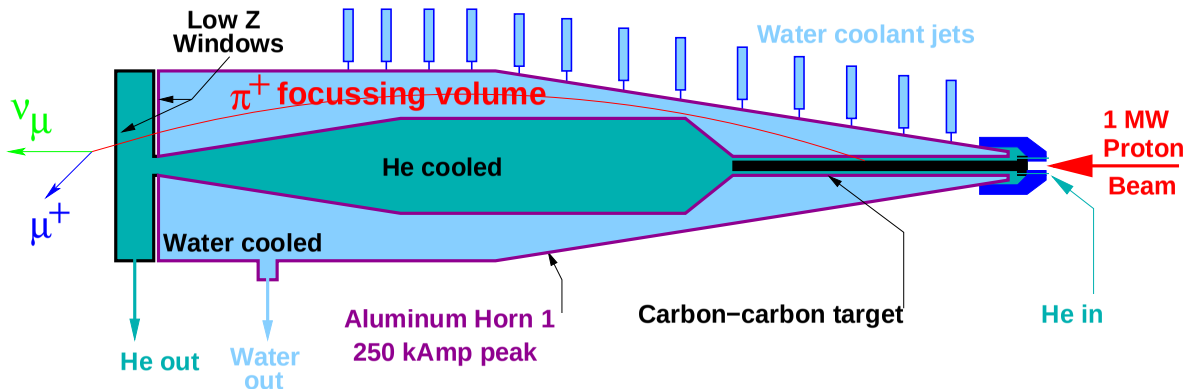
$\sin^2 2\theta_{13} < 0.015$ or better if normal hierarchy. O.w. need anti-ν running to reach that limit.



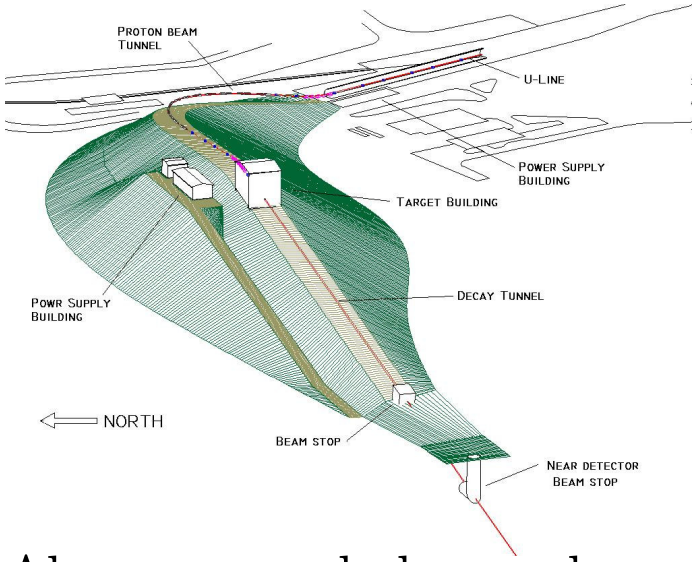
Left: Regular mass hierarchy. Right: Reversed mass heierachy.



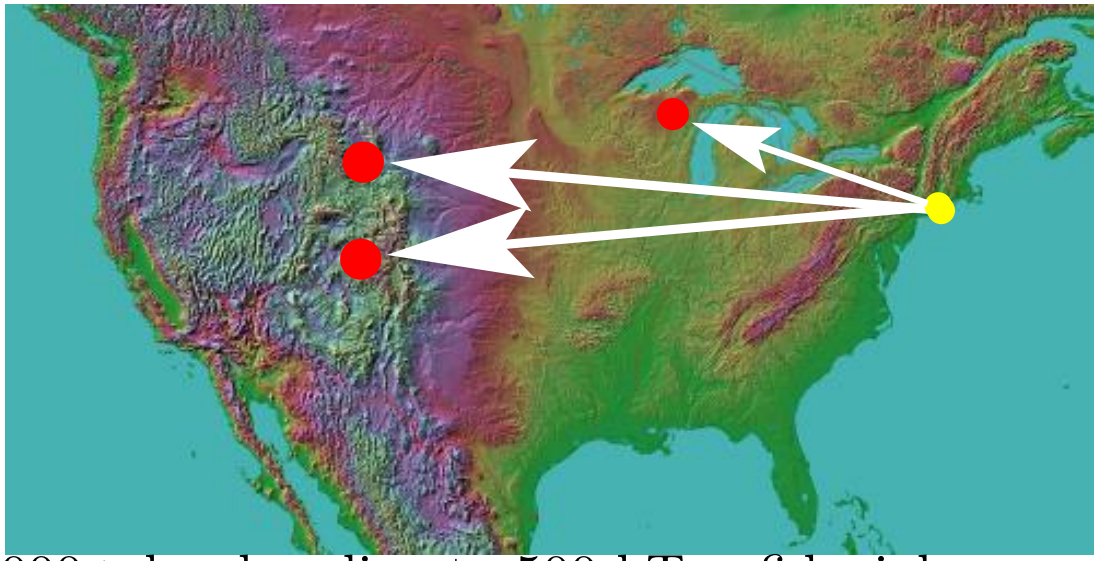
Upgrade AGS to 1 MW, 28 GeV. 5 years of 1e7 seconds running.



80 cm x 6 mm carbon-carbon target, He and H2O cooled, conventional 2 horn focus



Above ground decay channel - The Hill



2000+ km baseline to 500 kTon fiducial WC detector.

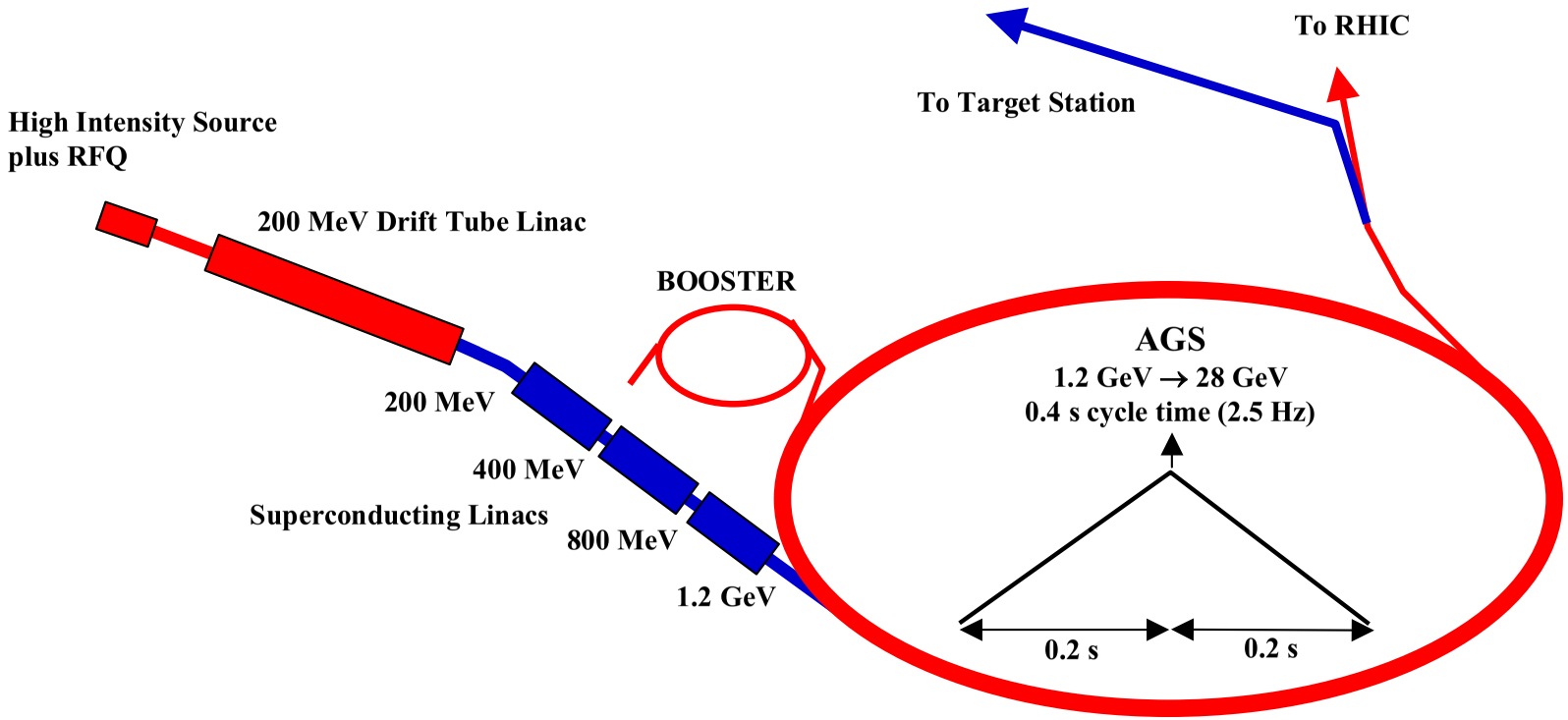
Costs:

- Bottom-up estimate, FY04 dollars
- Direct cost $273.4M direct
- Total (30% contingency, 14.5% BNL overhead) $406.9M

Schedule:

- 3 years R&D
- Construction starts 1 year after R&D starts
- 4.5 years construction, 0.5 year commissioning
- Utilize RHIC shutdown periods work involving existing machines

Based on RHIC and SNS ring and LHC magnet construction



- Existing 200 MeV room temperature Linac
- New 0.2-1.2 GeV superconducting Linac with 0.8/1.6/1.6 GeV sections
- Run AGS at 2.5 Hz rep rate
- Run 10^7 seconds / year. Likely achieve closer to twice this.

Recently Considered Modifications:

- Room Temp Linac: upgrade 200 to 400 MeV by copying the 1993 FNAL Linac upgrade
- Superconducting Linac: instead of the 1.2 GeV injection using 0.8/1.6/1.6 GHz sections, go to 1.5 GeV using all 0.8 GHz. sections

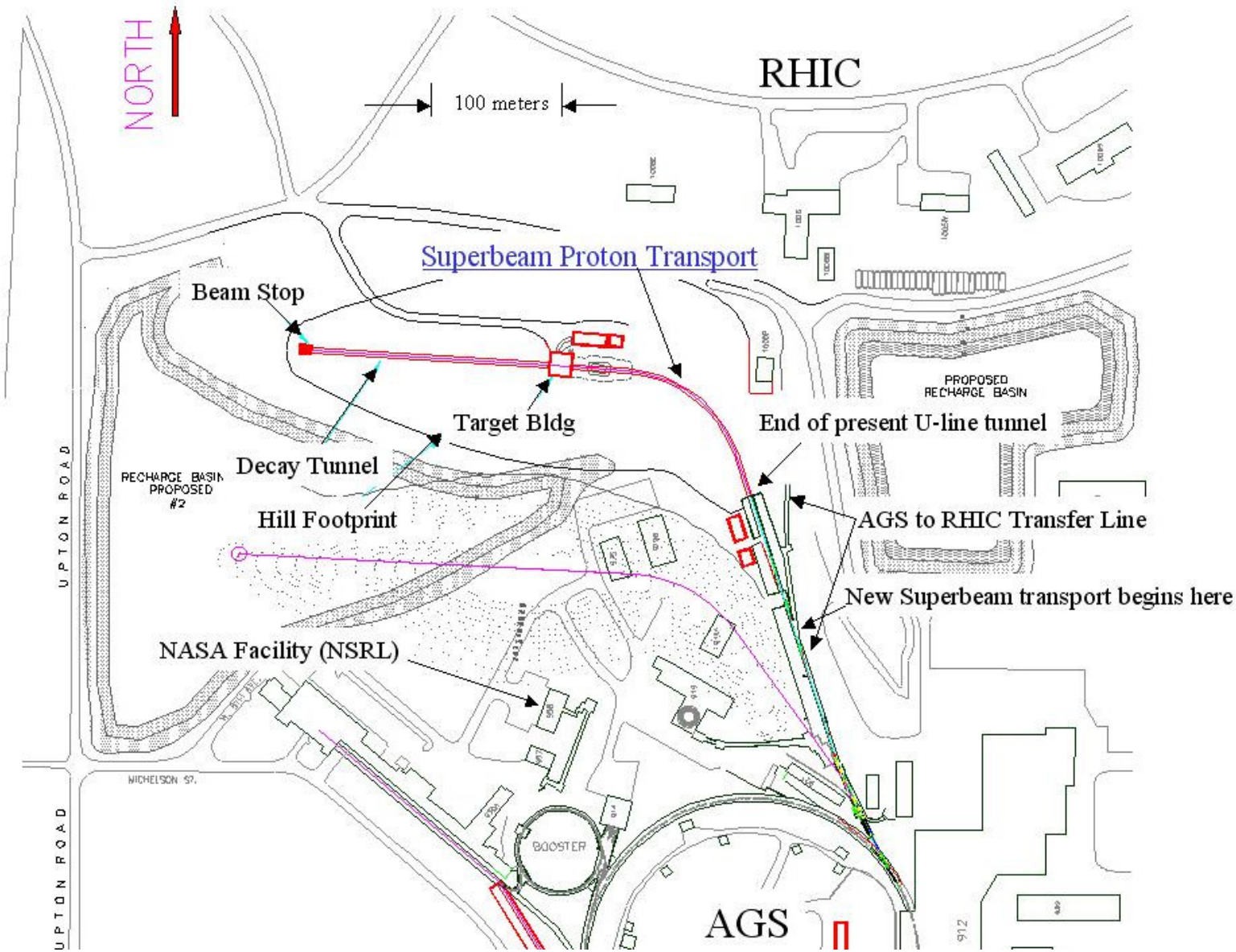
This then,

- uses proven, reliable technology
- less R&D needed, yet get better performance

1.5 GeV injection leaves a straight forward path for **2 MW running**

- **Space charge effect lessened, less losses at injection**
- Would still need double the motor-generator power supplies
- Would need new, redesigned AGS cavities

16/22 – Possibly Longer Decay Tunnel - Not Yet Official

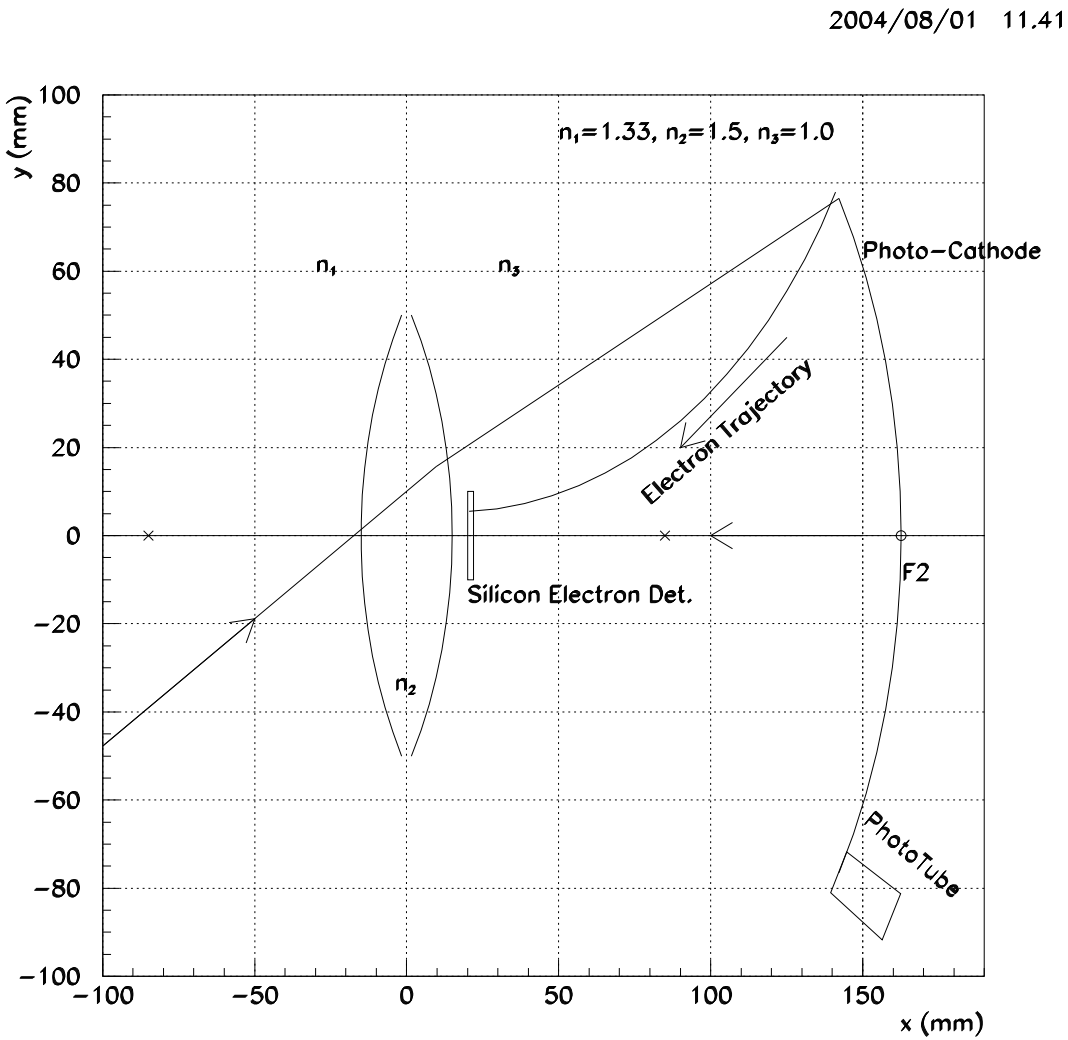


Possible to move hill south, away from RHIC, further from BNL border. 300m decay tunnel possible (thus harden the ν-spectra). Not yet "official", but being look at.

Direction Sensitive Photo-Sensor developments

The idea:

- Record photon direction as well as time may give improved e/π^0 separation.
- Use lens to convert direction to position
- Read out light either by array of PMTs, or hybrid of reflection photocathode and photoelectron steering onto a silicon readout

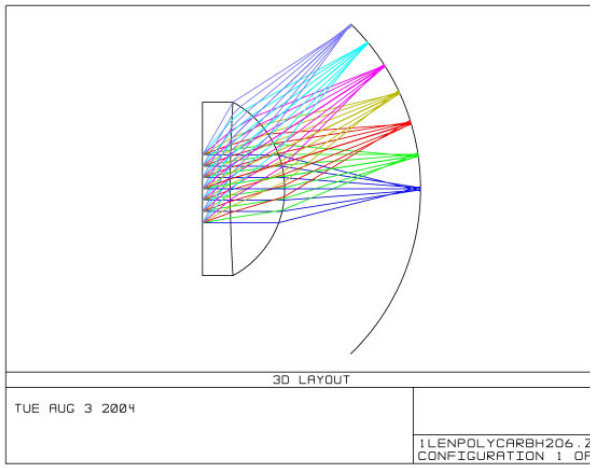


Work most recently done by BNL summer student Zach Parsons of Univerity of South Dakota.

Optimize on:

- $\Downarrow$ Complexity
- $\Downarrow$ Angular resolution = spot size / focal plane radius
- $\Downarrow$ Surface area of image "plane"
- $\Uparrow$ Ratio of lens aperture to total lens diameter
- $\Downarrow$ Absorption (via reduce thickness and/or right material choice)

Used "ZEMAX" program, optical simulator with large catalog of materials.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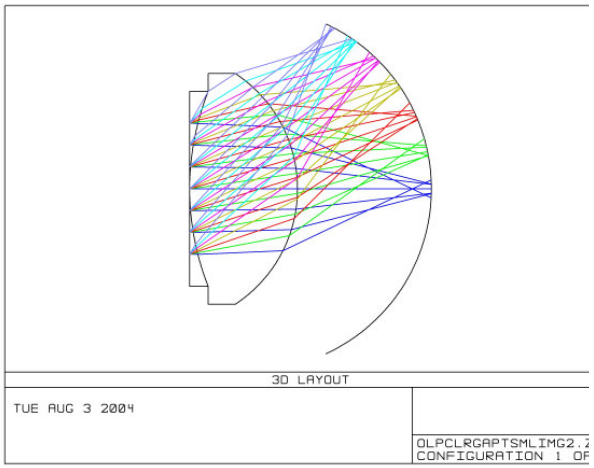
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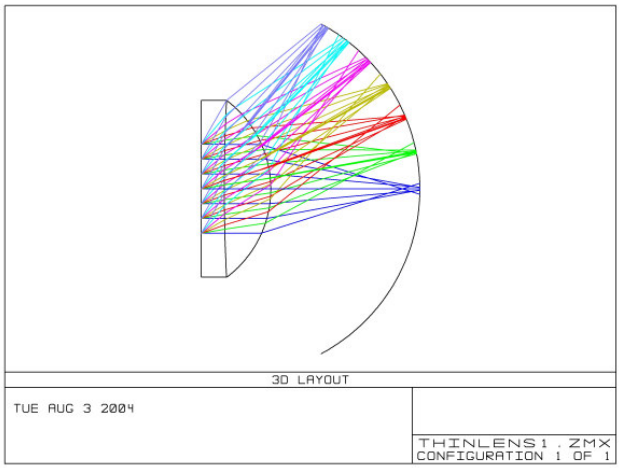
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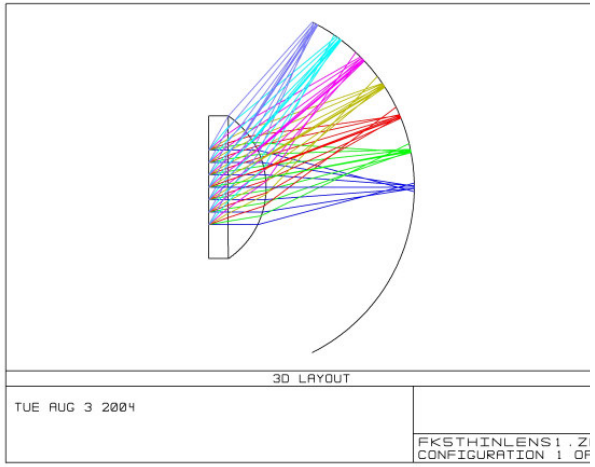
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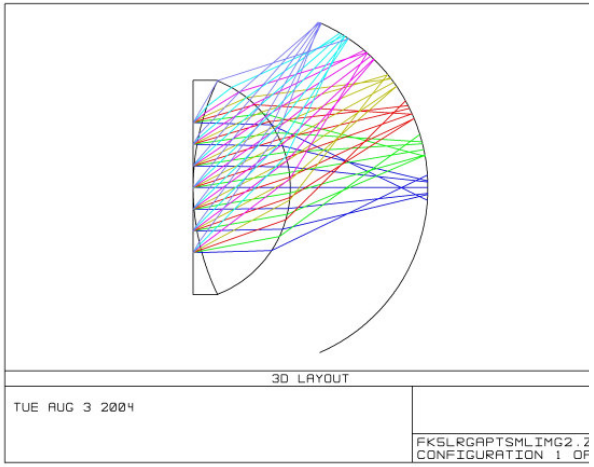
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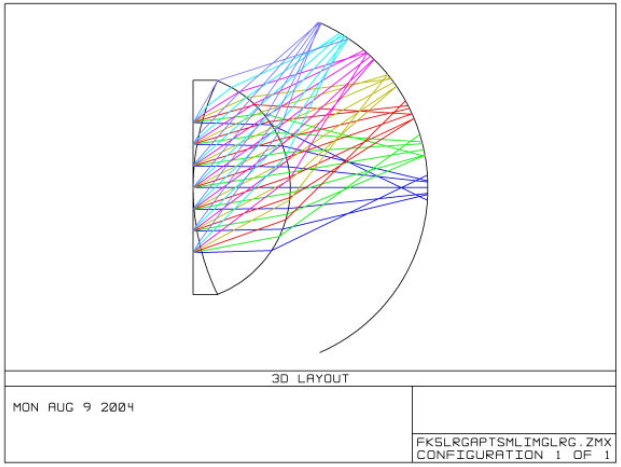
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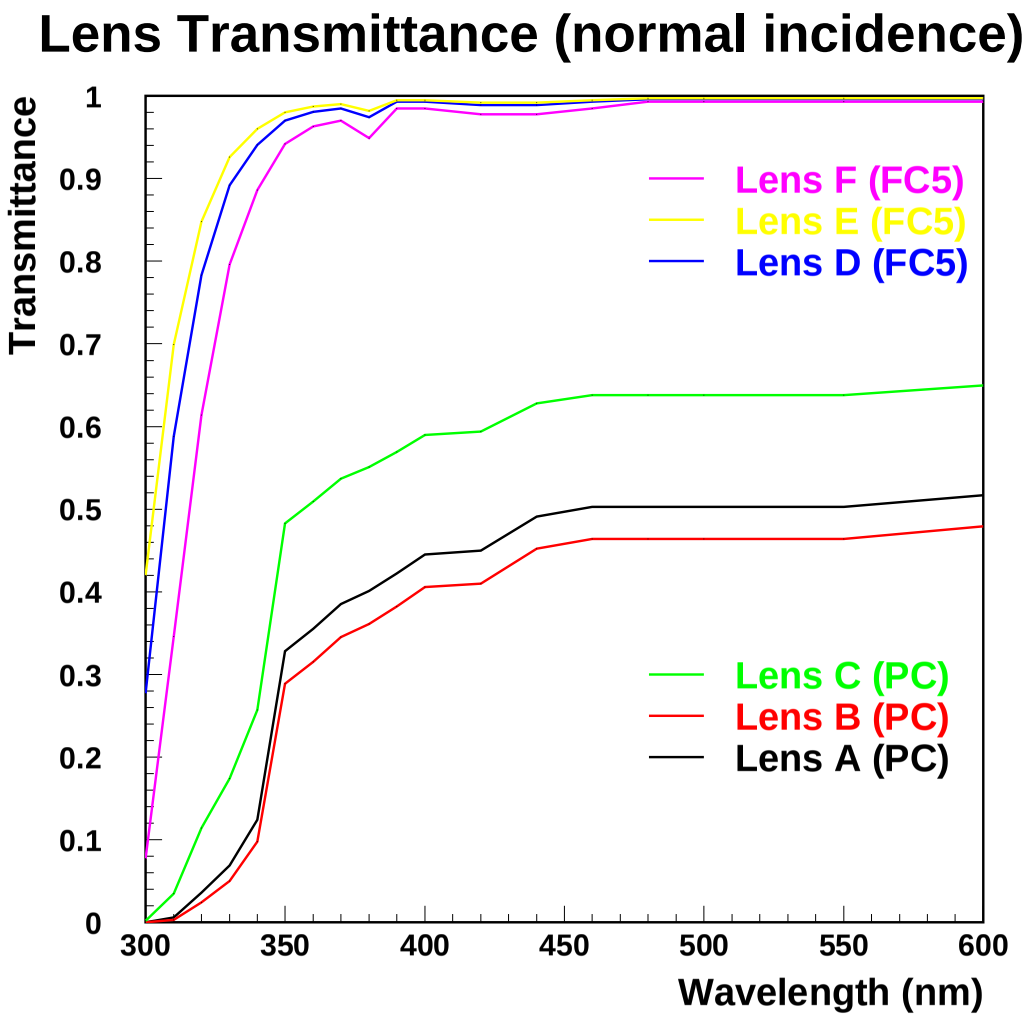

- FC5 is a special high transmittance glass.
- PC is simple polycarbonate

Not yet strongly considering costs

Beam:

- A bottom up cost and schedule estimate has been done for
- Design solidifying, some recent new improvements
- "AGS Super Neutrino Beam Facilty Report"
  `http://raparia.sns.bnl.gov/nwg_ad/`

DSPS:

- Summer student pushed development a bit further
- His report is available from: `http://nwg.phy.bnl.gov/preprints.php`

Some expected future work at BNL:

- Put DSPS into UNO MC, test for e/π^0 separation
- Use Chiaki's work on SK efficiencies to looked at VLBL/UNO through use of GLoBES software. Allow quick evaluation of different beam setups
- Push ahead UNO MC and reconstruction work
- $10K+10K for computing - increase existing Opteron cluster