Migration matrices for MEMPHYS

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Reminder: main signals and backgrounds

- For super-beam

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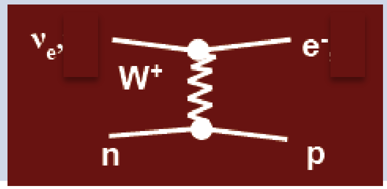
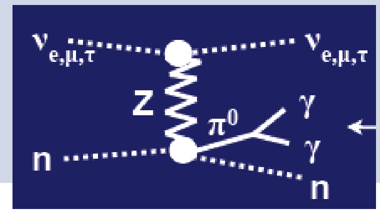
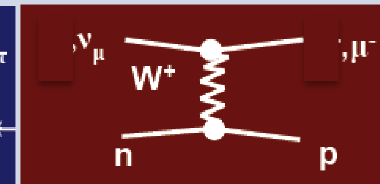
<tr><th></th><th>Signal</th><th colspan="2">Backgrounds</th></tr>
<tr><td>nu-e appearance</td><td>
</td><td>
</td><td>
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- For beta-beam

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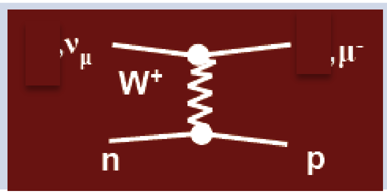
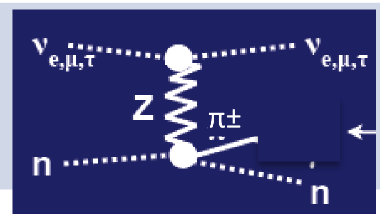
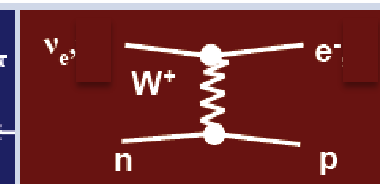
<tr><td>nu-mu appearance</td><td>
</td><td>
</td><td>
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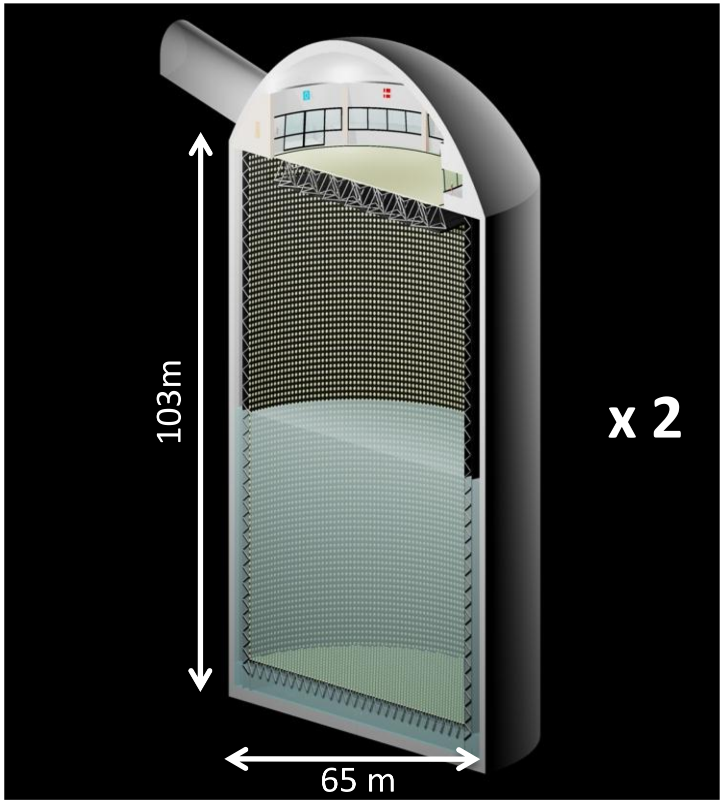
=> need 4 migration matrices (which may be split according to interaction process)

The MEMPHYS detector

"good, old" Water Cherenkov

Fiducial Mass: ~20x SuperKamiokande



Latest baseline design (LAGUNA):

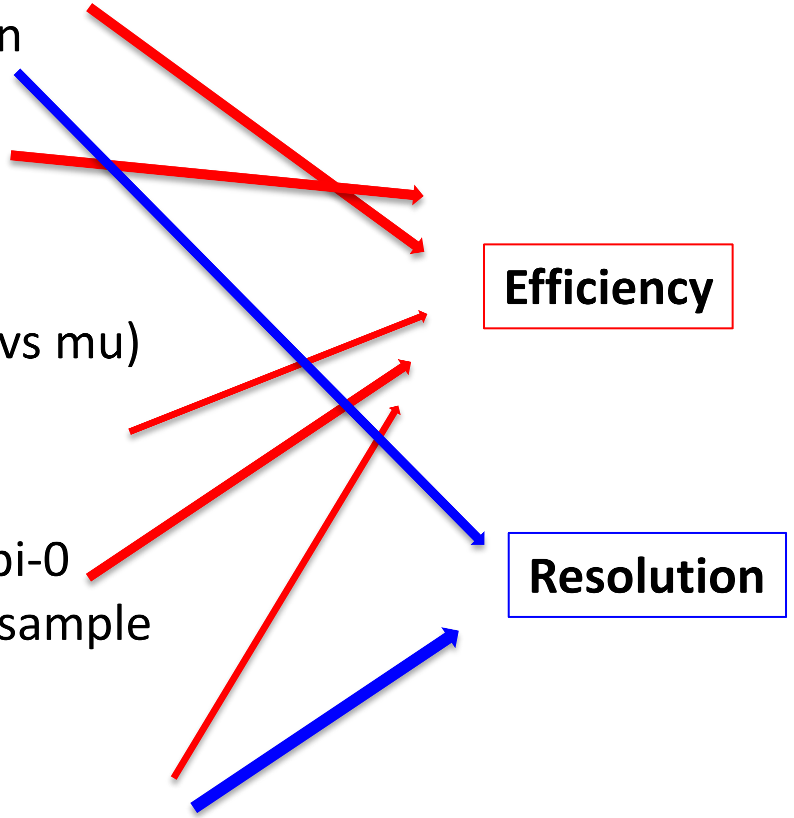
2 cylindrical cavities,
65m diameter x 103m height
⇒fiducial mass = 500 kton

(excavation less expensive than in the old design with 3 smaller modules)

Readout:
~120000 8"or 10" PMTs per module
(optical coverage 30%,
nPEs equivalent to SK)

Steps towards MM

1. Reconstruction of interaction vertex and track direction
2. Ring edge finding
3. Particle identification (e vs mu) from ring “fuzziness”
4. Ring counting (to reject pi-0 background) in electron sample
5. Lepton momentum reconstruction

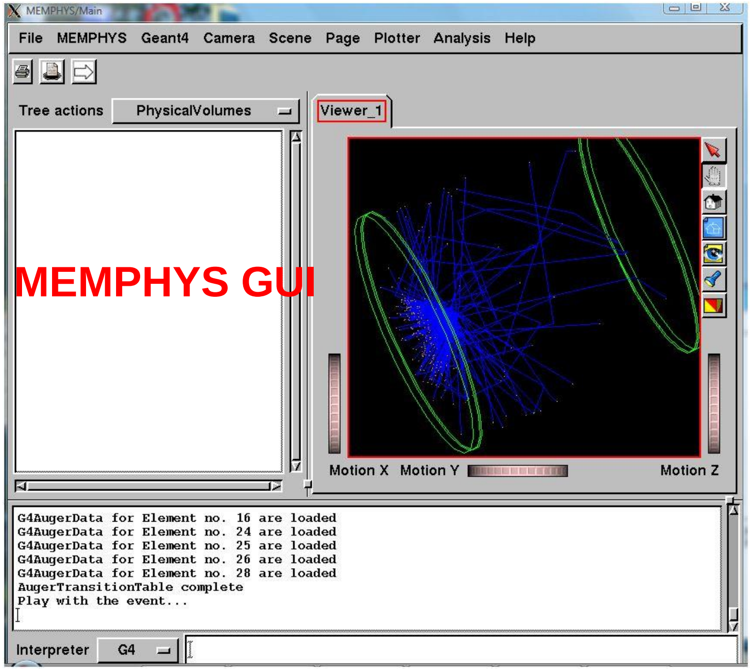


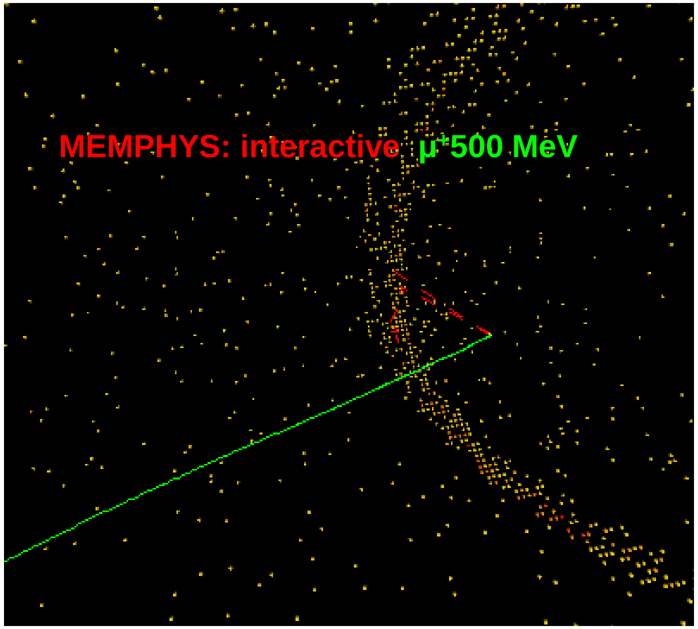
Tools

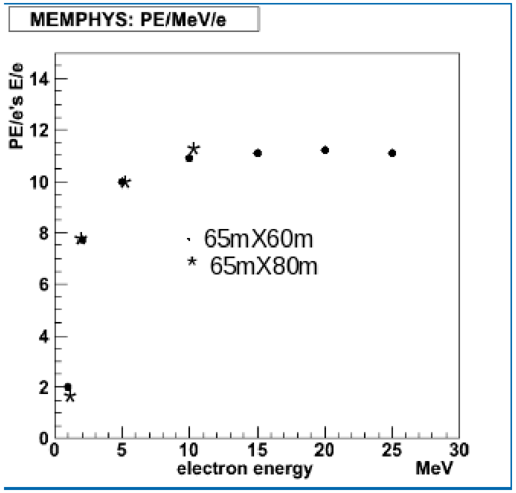
- Full simulation of the MEMPHS detector
  - originally developed by J.E.Campagne and Guy Barrand at LAL
  - extensively tested and developed by N.Vassilopoulos
  - used to define realistic detector performance – for the first time with a full simulation !
  - full and realistic reconstruction and analysis algorithms developed
  - extraction of MM is now done (up to now, the ones by SK were used)

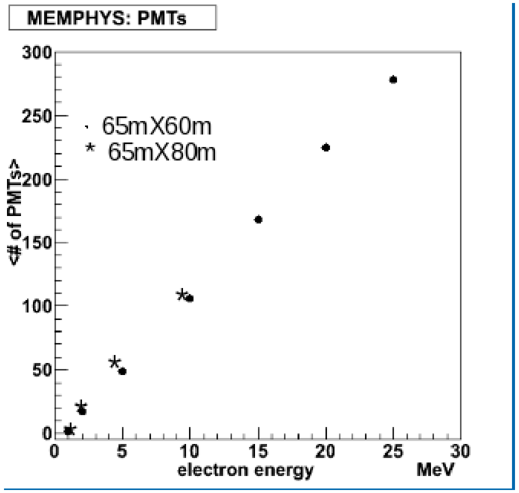
- Some technical details
  - Neutrino interactions in water simulated with **GENIE**
  - Geant-4 detector simulation, with AIDA and OpenScientists used for ntuple production
  - Detailed detector description, easy to modify. We have implemented the new layout with **65x103 m** tank [NEW]
  - The detailed simulation of light propagation in water is very slow: huge work of scripting for production of large samples

Illustrations of simulation and results





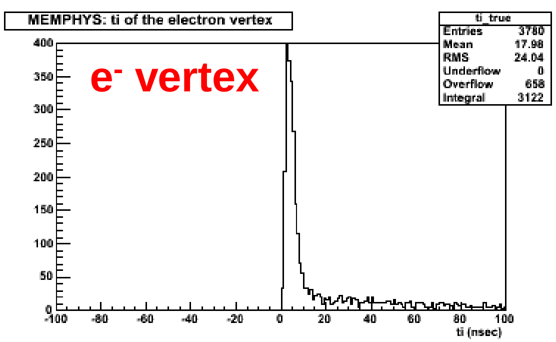


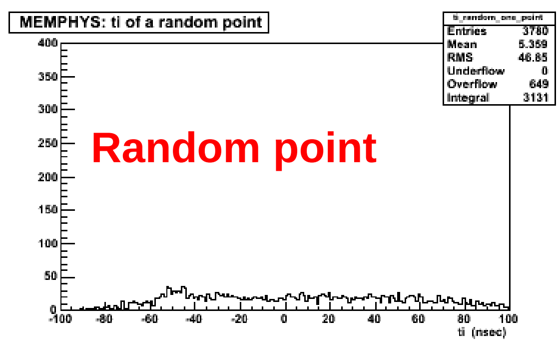


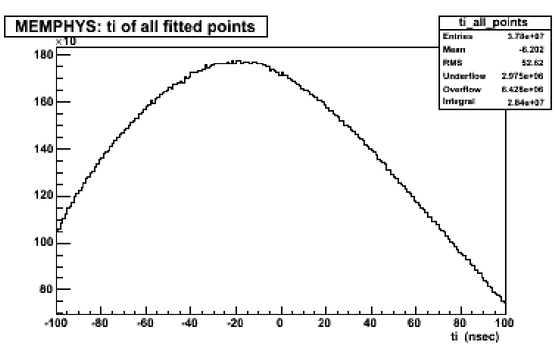
1. 2. Primary vertex fit, direction and ring edge

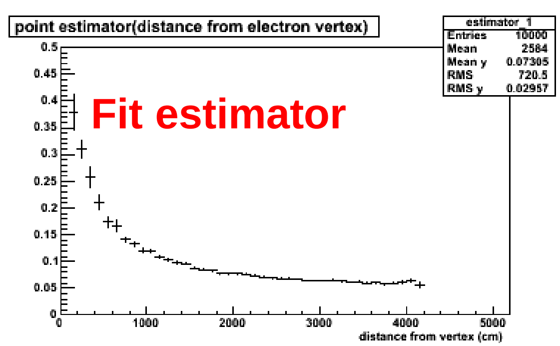
- **Electron ring primary vertex fit**
  - Based on PMT timing: $t_{i\,PMT} = t_i + TOF_i$ $\quad TOF_i = (n / c) \times D$
  - Maximize estimator E:

$$G_P = \frac{1}{N}\sum_i \exp\left(-\frac{(t_i - t_0)^2}{2(1.5\times\sigma)^2}\right)$$



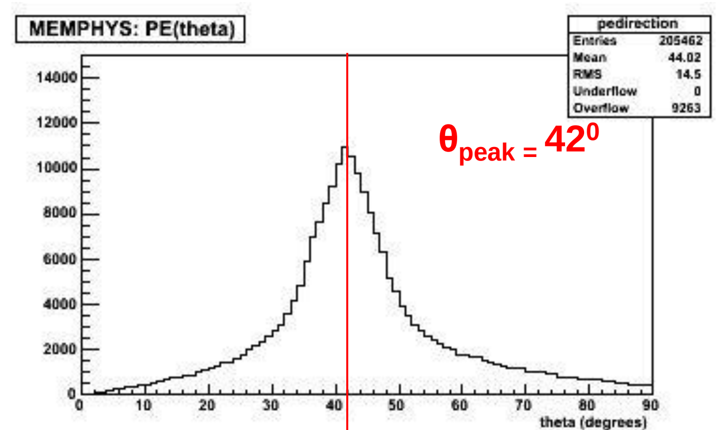


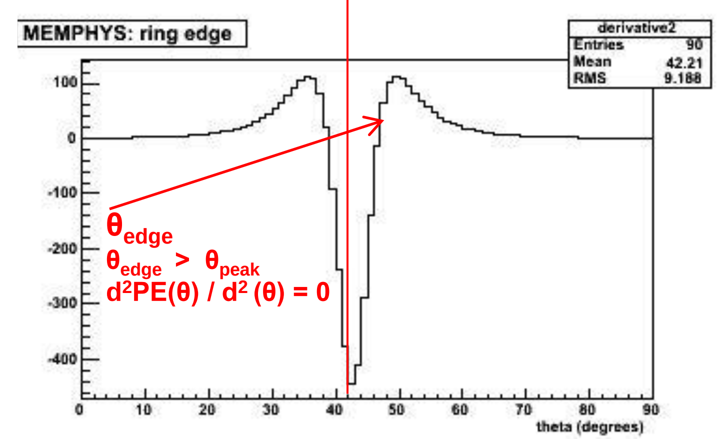




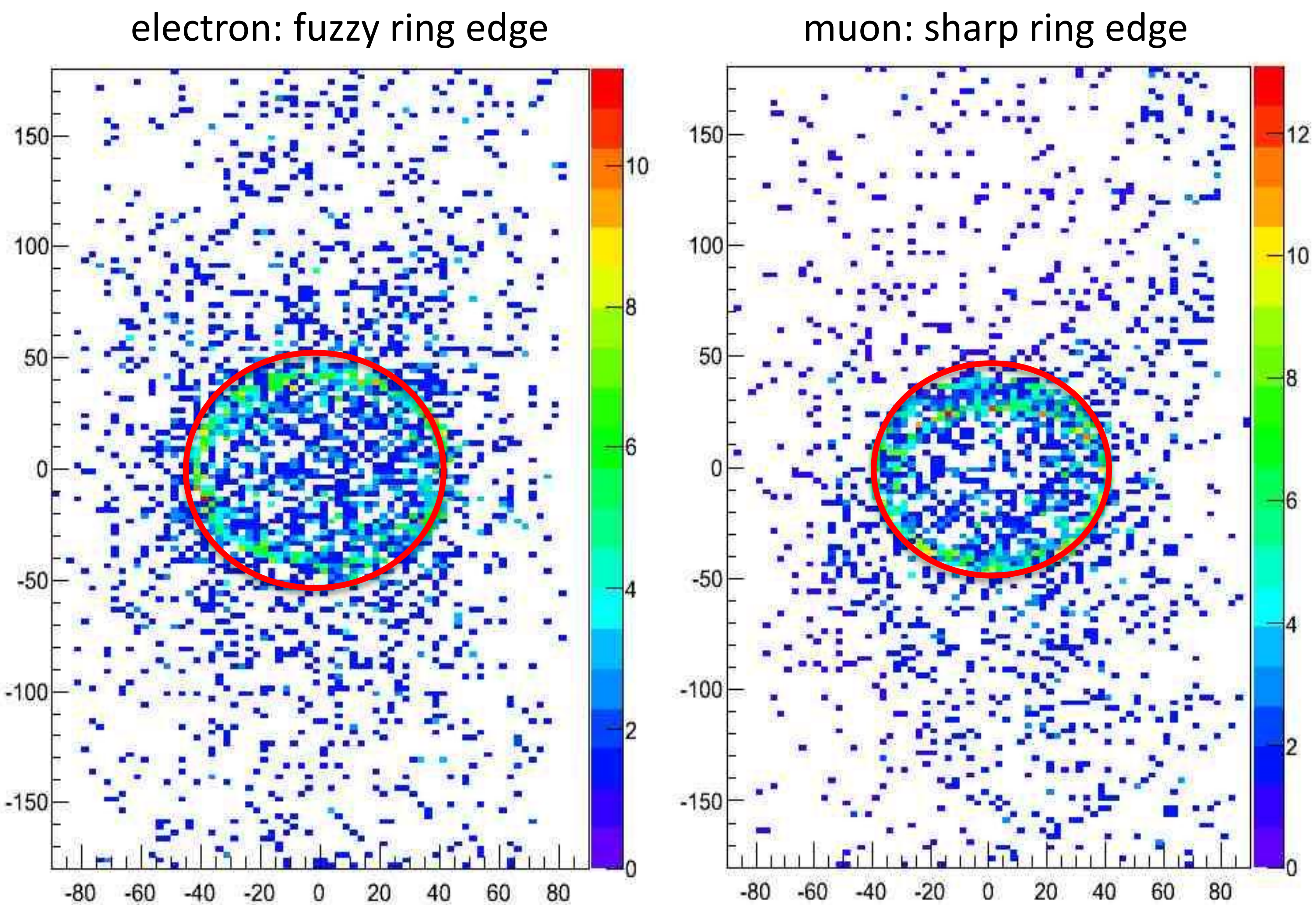
- **Electron direction: 400 MeV e^-**

$$\vec{d}_0 = \sum_i q_i \times \frac{\vec{P}_i - \vec{O}_0}{\left|\vec{P}_i - \vec{O}_0\right|}$$





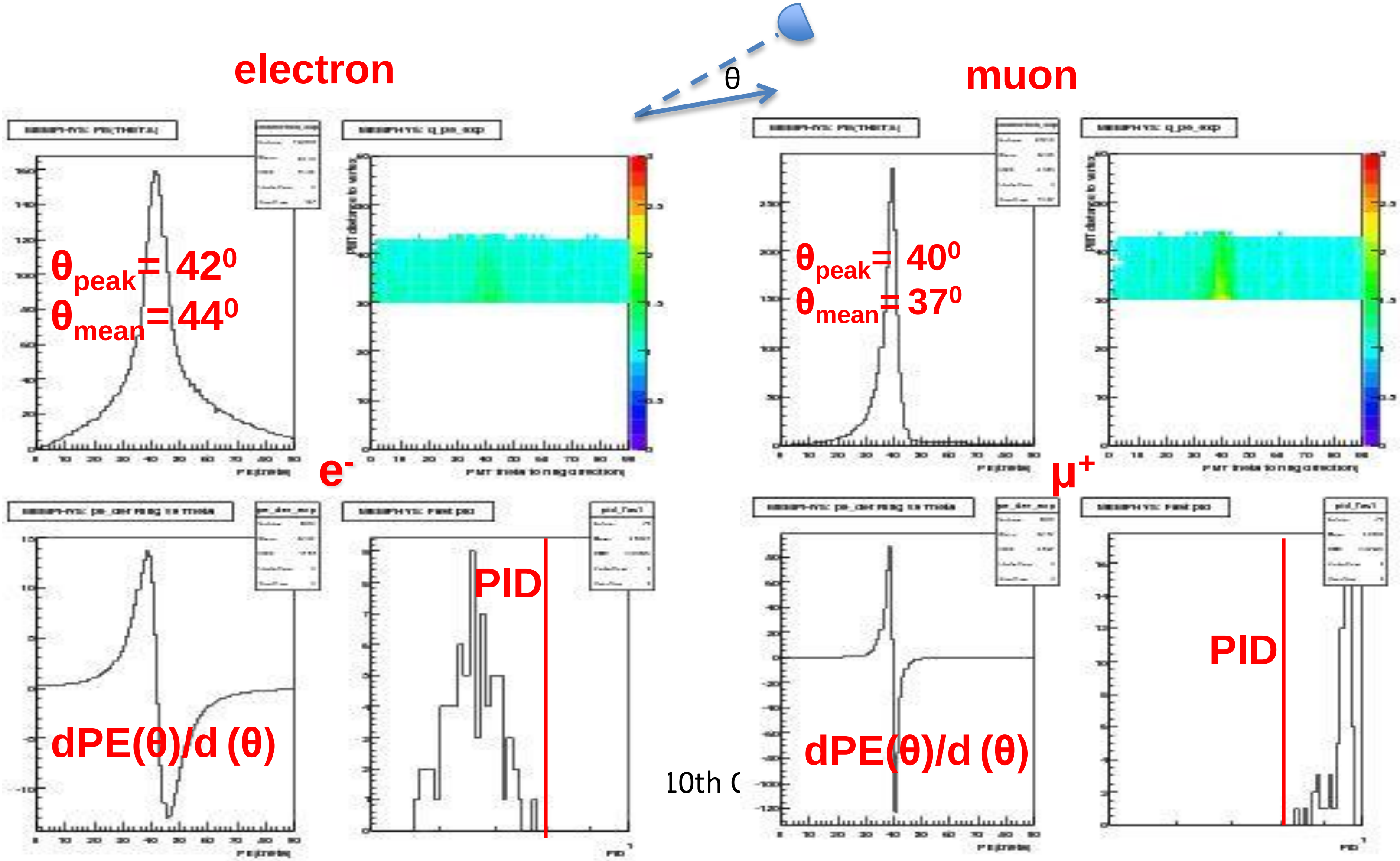
3. Particle ID



phi vs theta, spherical coordinates around fitted vtx and direction
PEs corrected for attenuation length

3. Particle ID

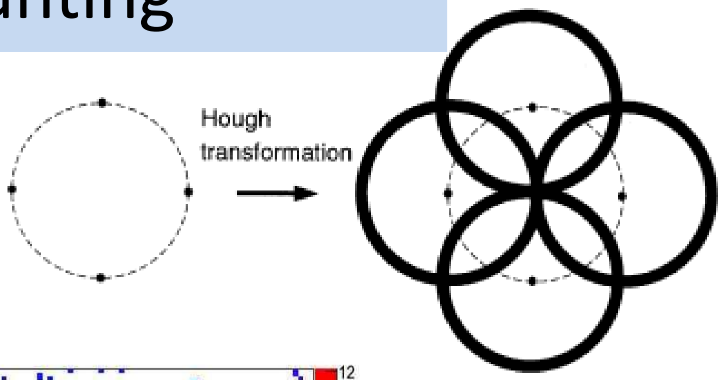
Fraction of PEs within ring edge is used as fast PID

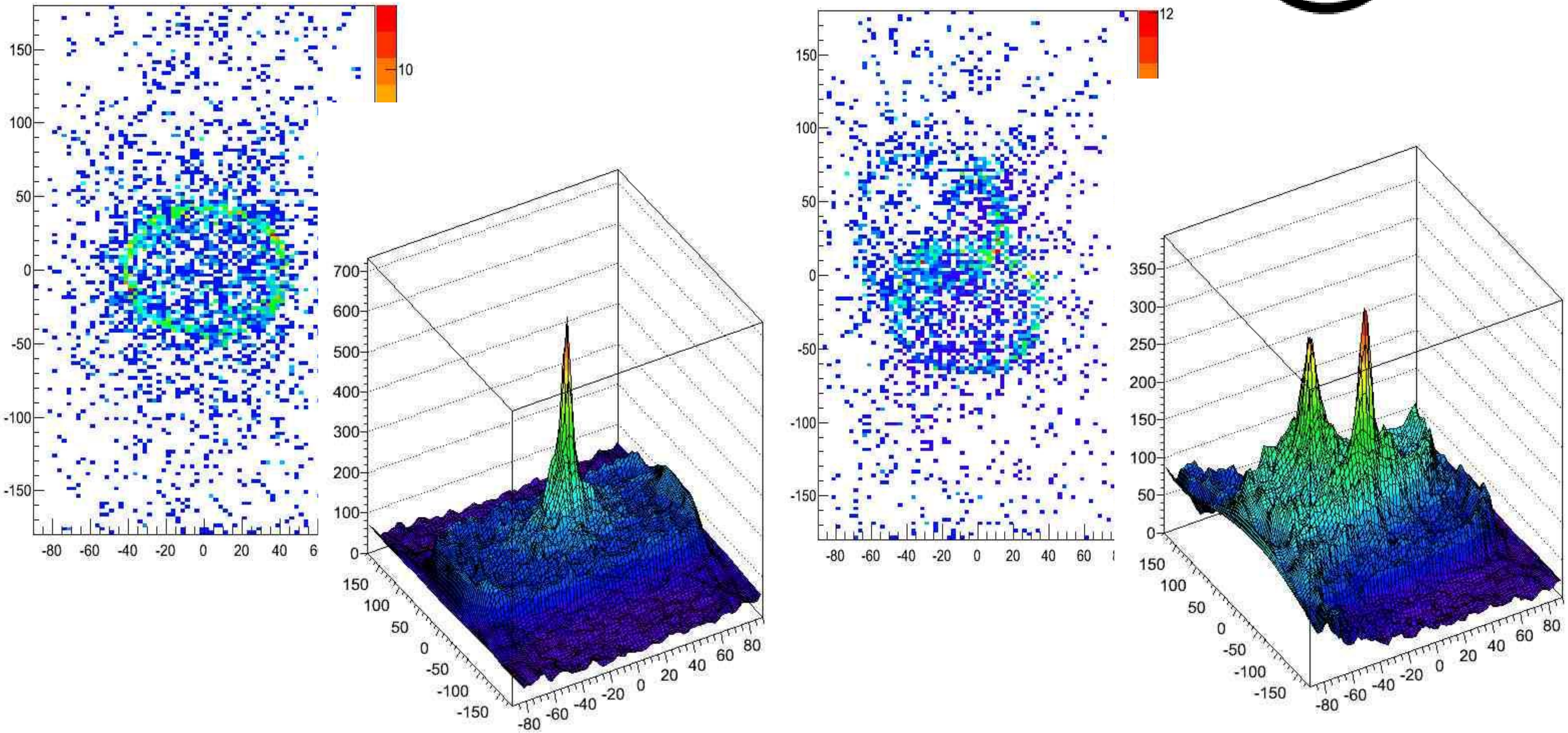


4. Ring counting

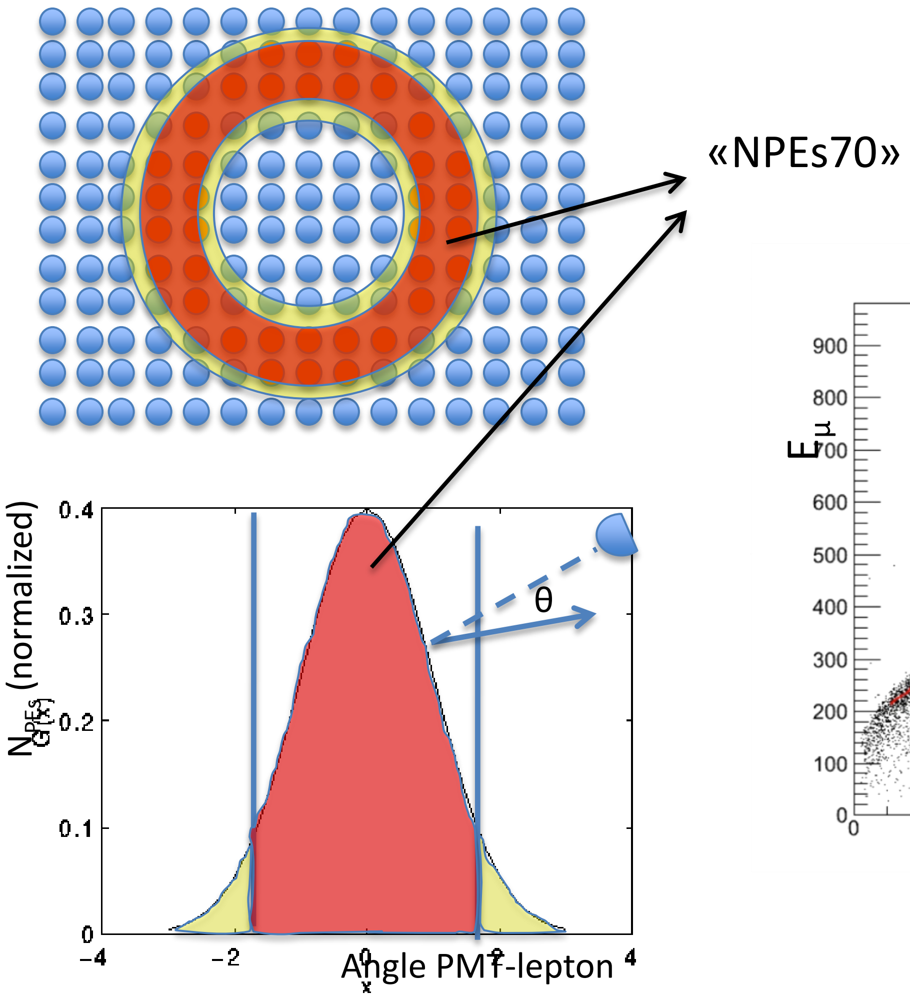
Hough Transformation:

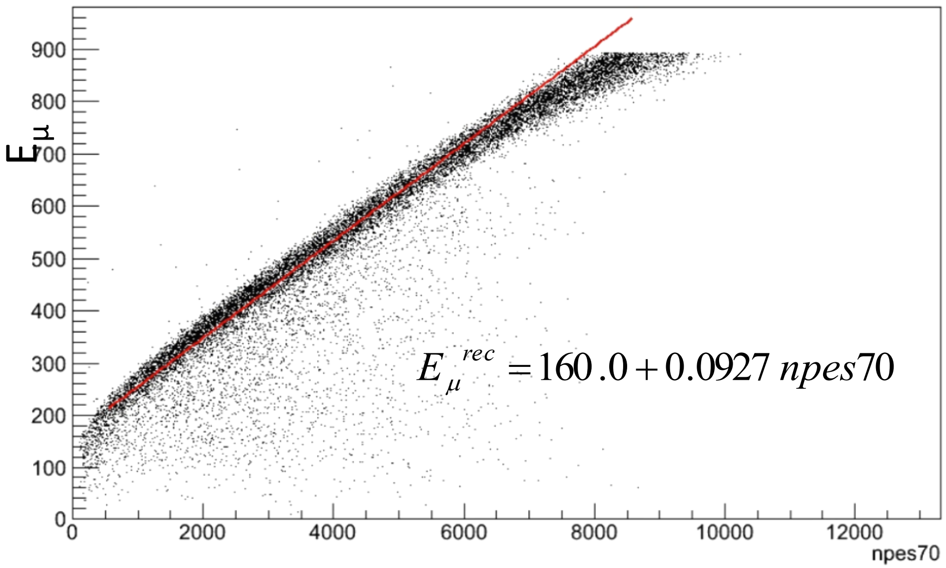
– Turn rings into peaks,
  then use simplified peak counting





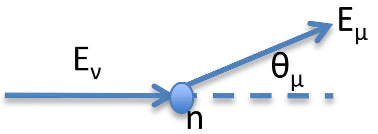
- Lepton momentum is reconstructed from summed charge in the ring (N.V.)



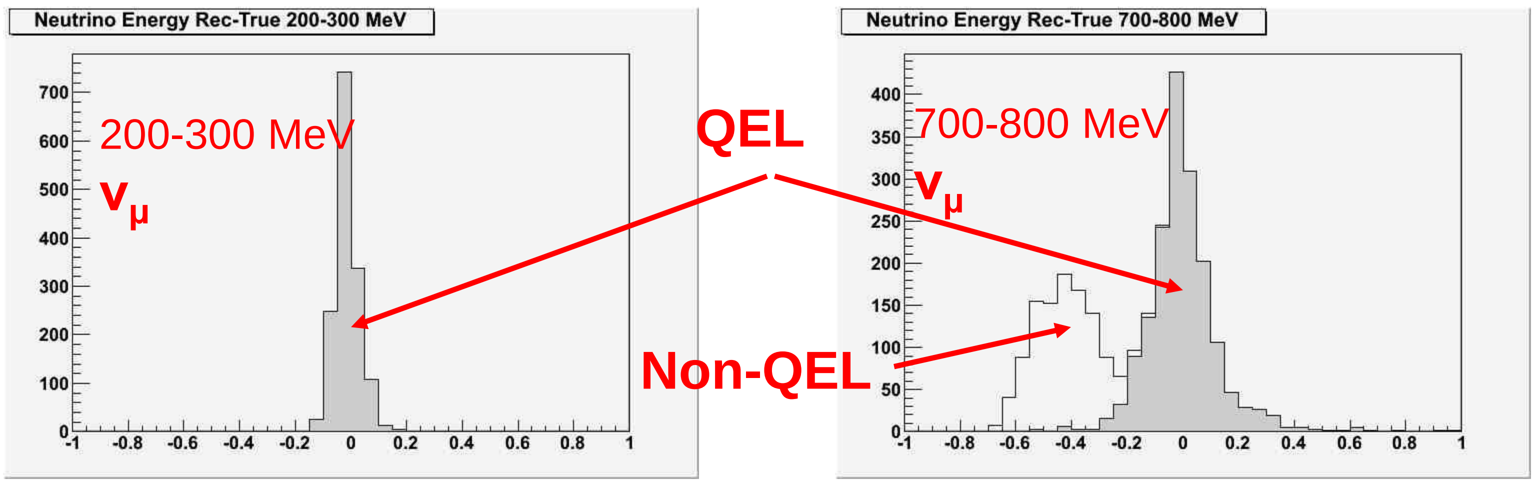


5. Energy reconstruction (2)

- Neutrino momentum is derived from lepton energy and direction, assuming a 2-body process



$$E_\nu = \frac{m_n E_\mu - m^2_\mu / 2}{m_n - E_\mu + p_\mu \cos\theta_\mu}$$

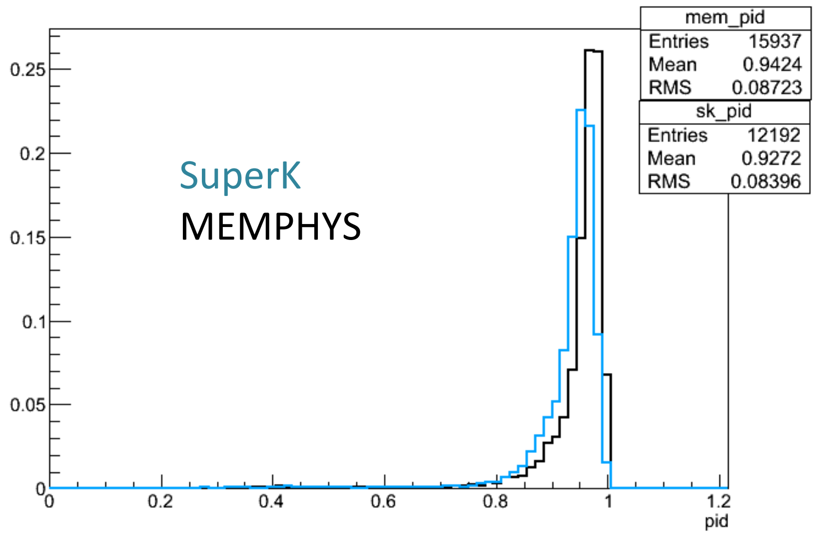


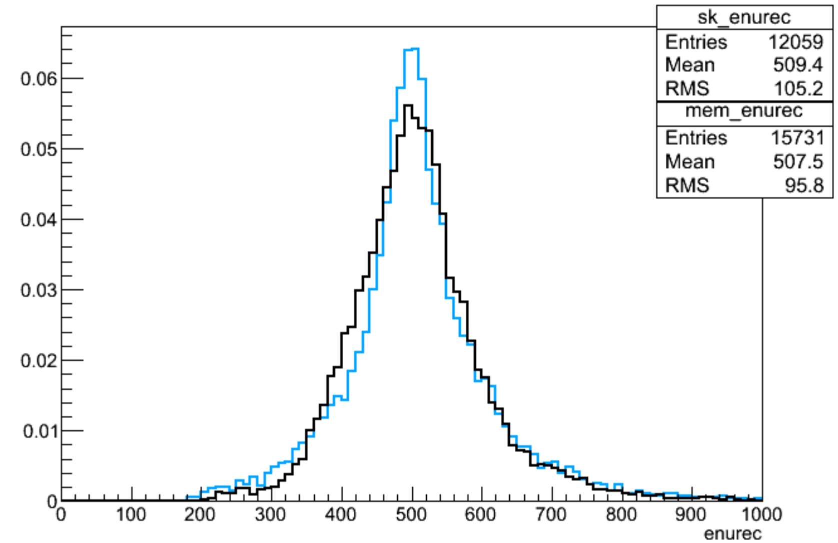
"Fast" simulation

- OK for CC-QEL events, with smearing due to Fermi motion
- in non-QEL, some energy is taken away by other interaction products, whose effect is more important at high energy

Comparison with SuperKamiokaNDE

- The simulation has been run with the SK geometry
  (40m radius, 40m height, 20-inch PMTs, 40% optical coverage)
- Detector performance can be directly compared

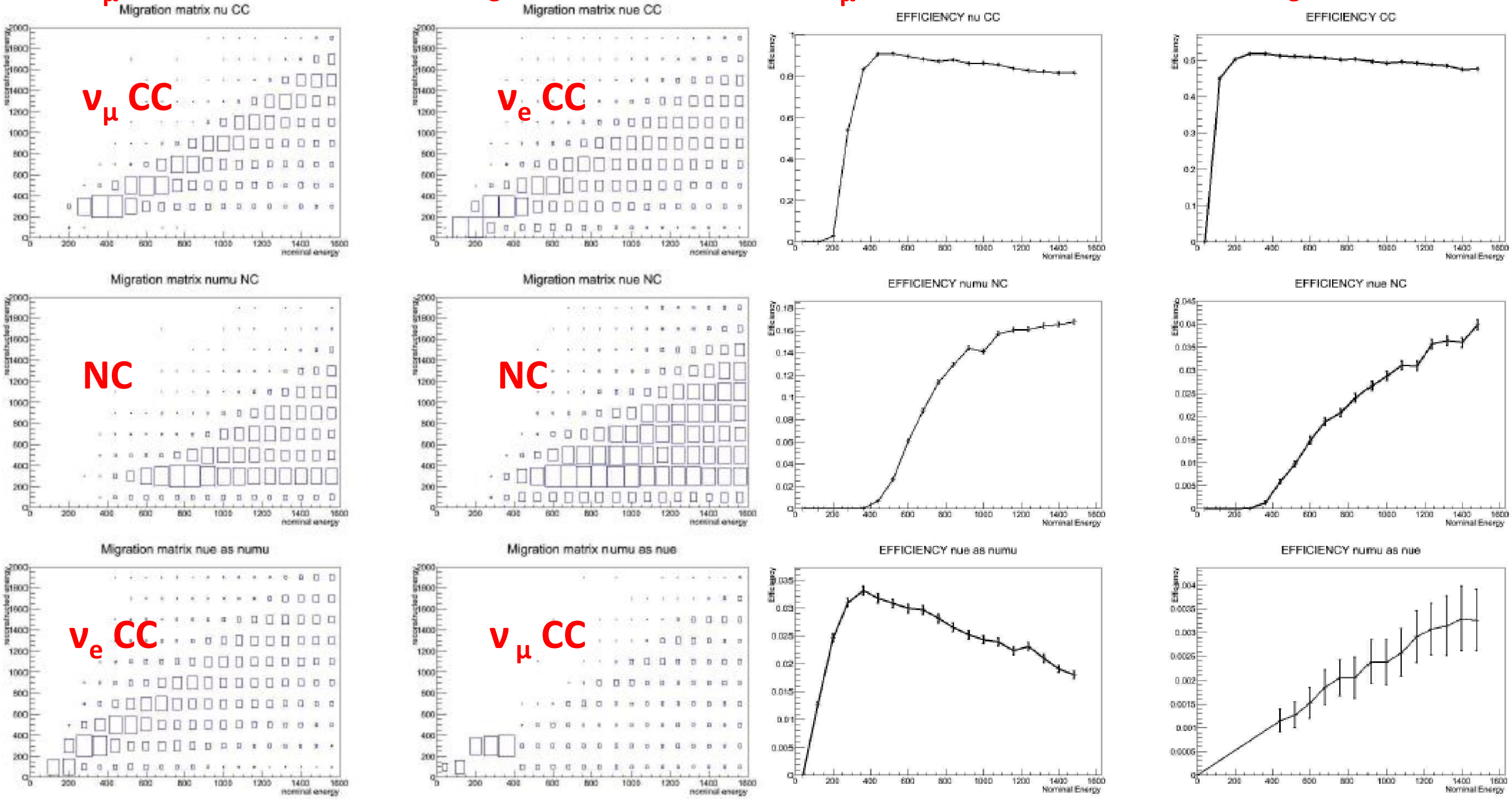




-> This allows us to rescale our efficiencies, to account for losses due to simplified algorithms

MM for MEMPHYS

ν_μ selection | ν_e selection | ν_μ selection | ν_e selection



MM

selection efficiencies for different neutrino events

Summary and outlook

- A full Geant-4 simulation of MEMPHYS is available
- We have all the ingredients to make performance studies
  - optimization of geometry, photodetection solutions, etc. are possible
- We have (preliminary) Migration Matrices for MEMPHYS

  soon available in note/paper

Thank you