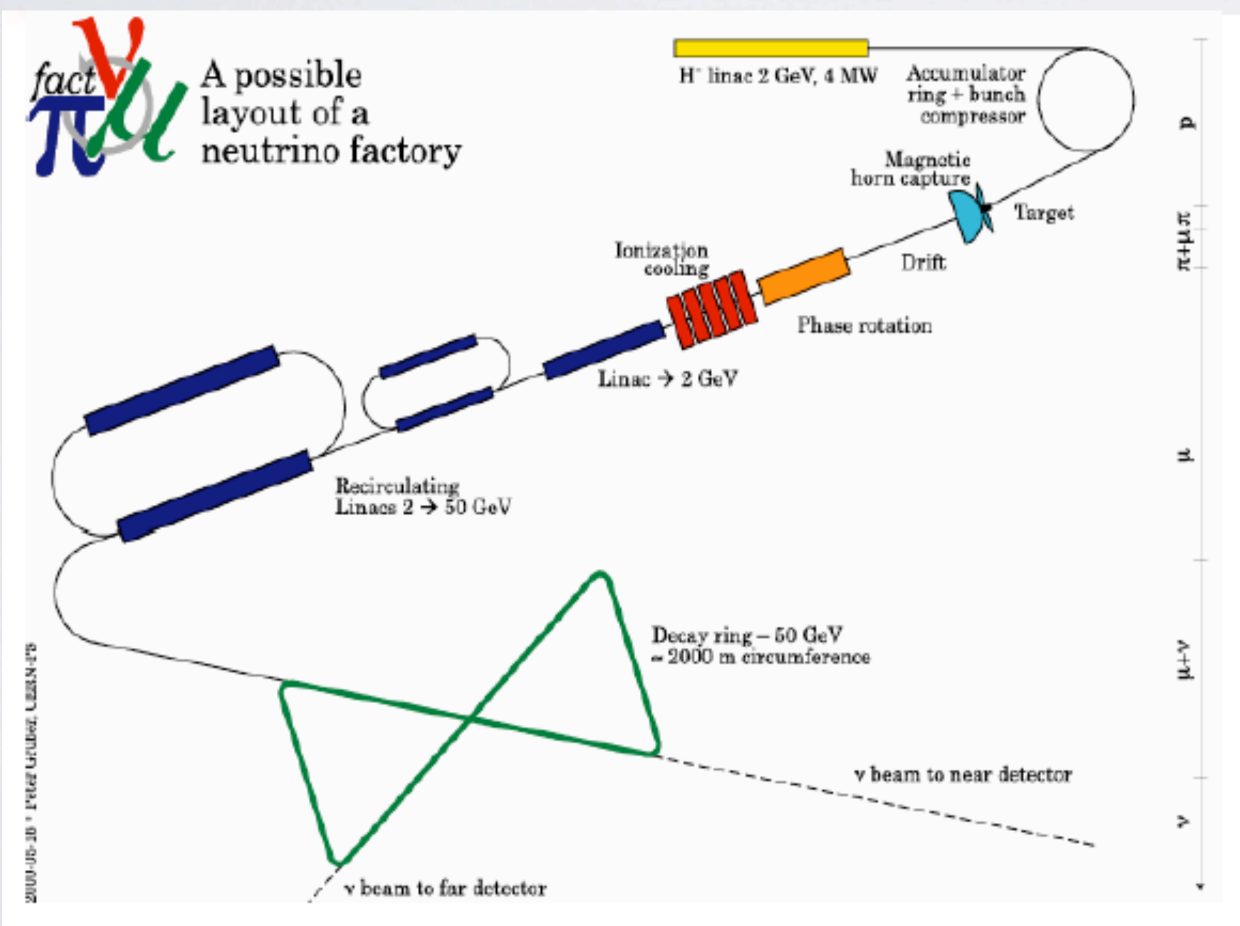
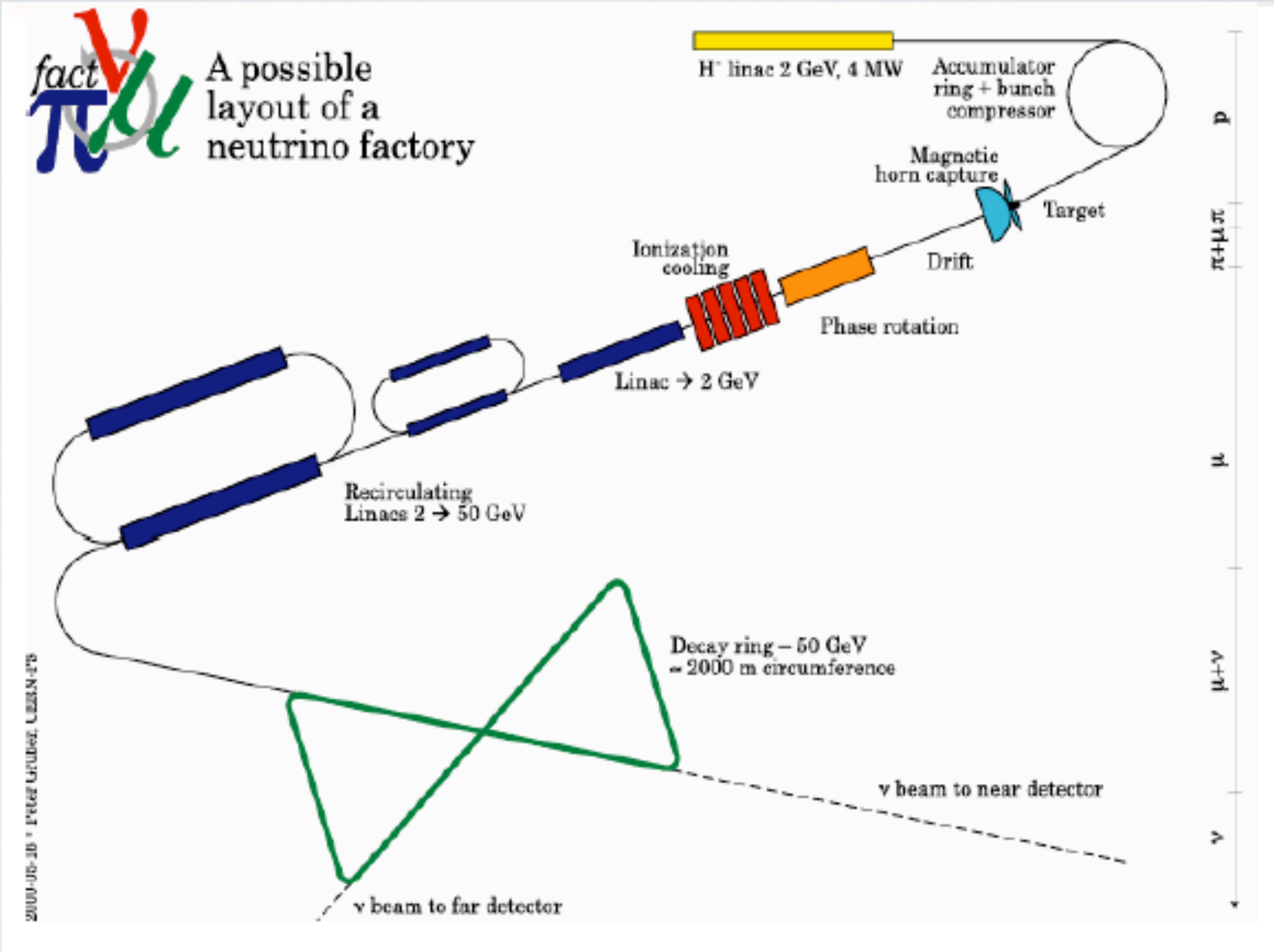
PHYSICS OF THE NEUTRINO FACTORY (AND FRIENDS)



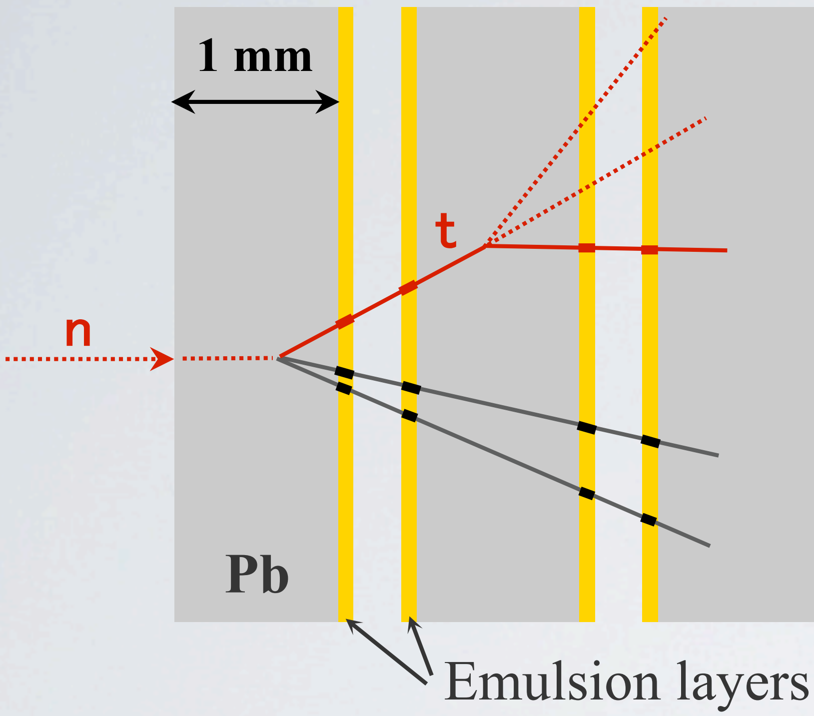
J.J. Gómez Cadenas
IFIC (CSIC-UV)

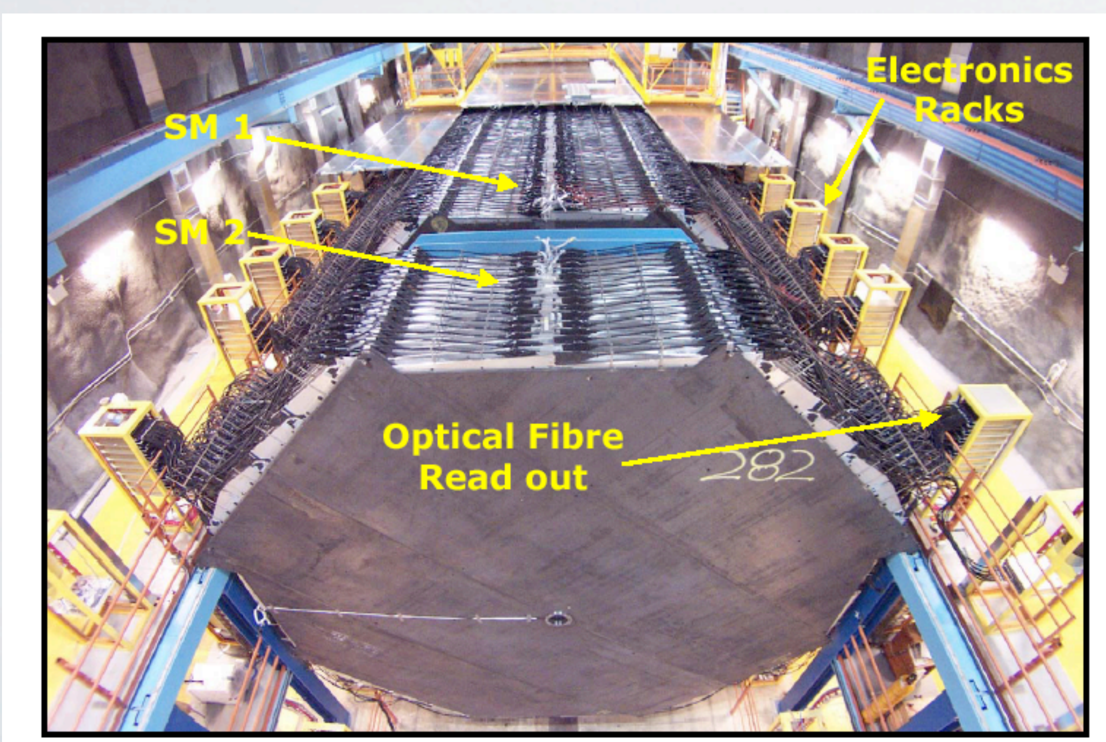
Lecture IV

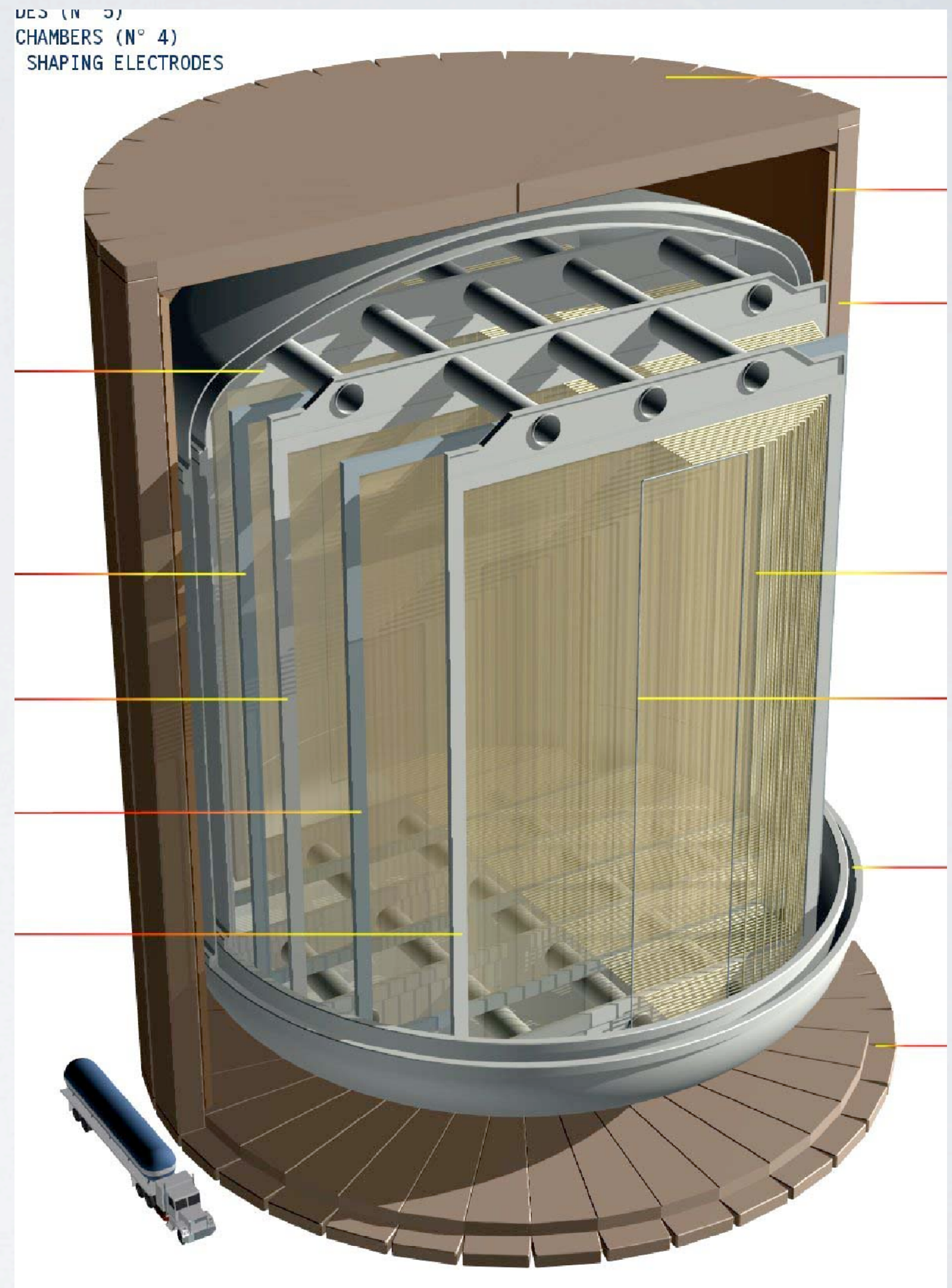
THE HE NEUTRINO FACTORY



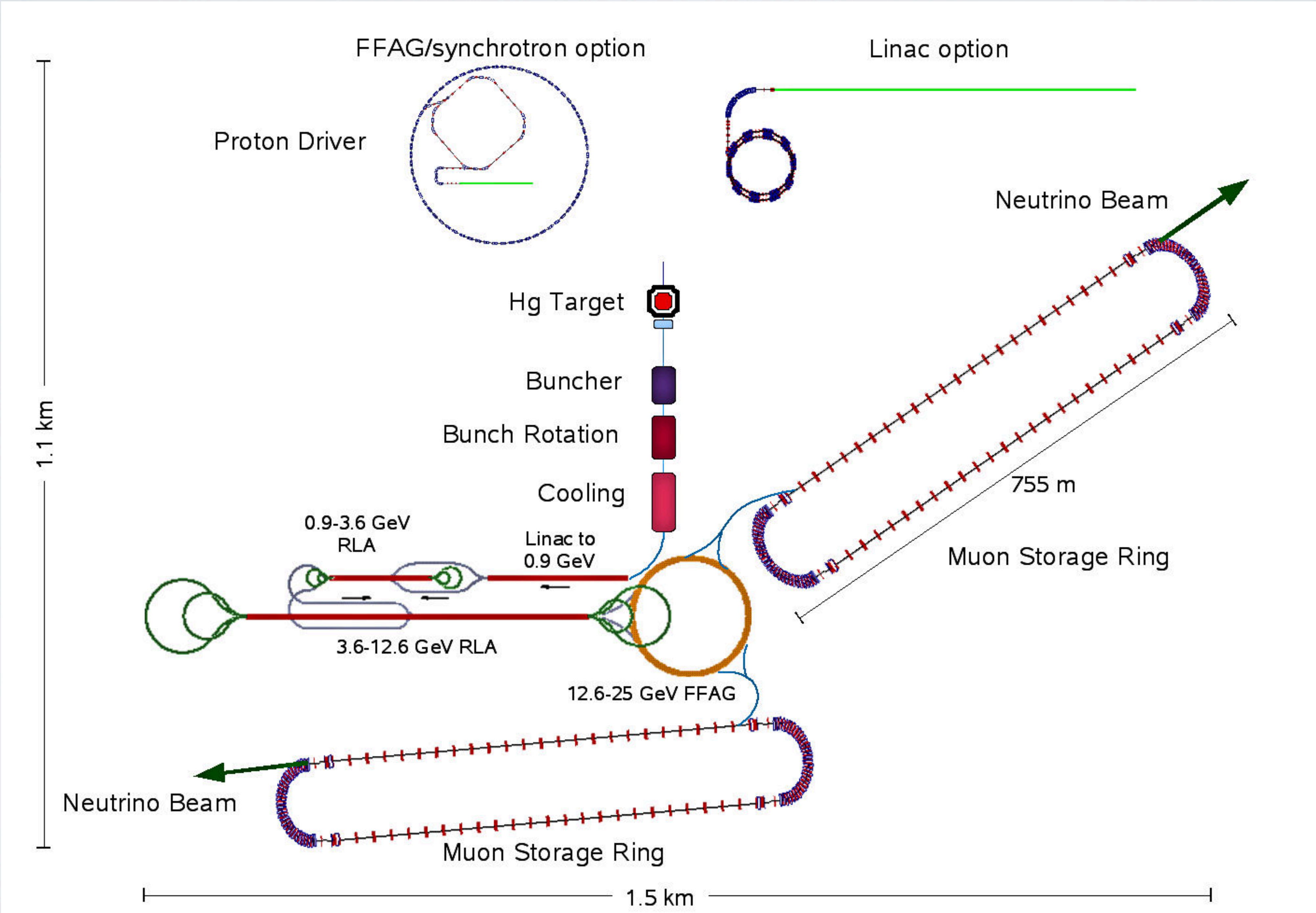
DETECTORS FOR HE NUFACT



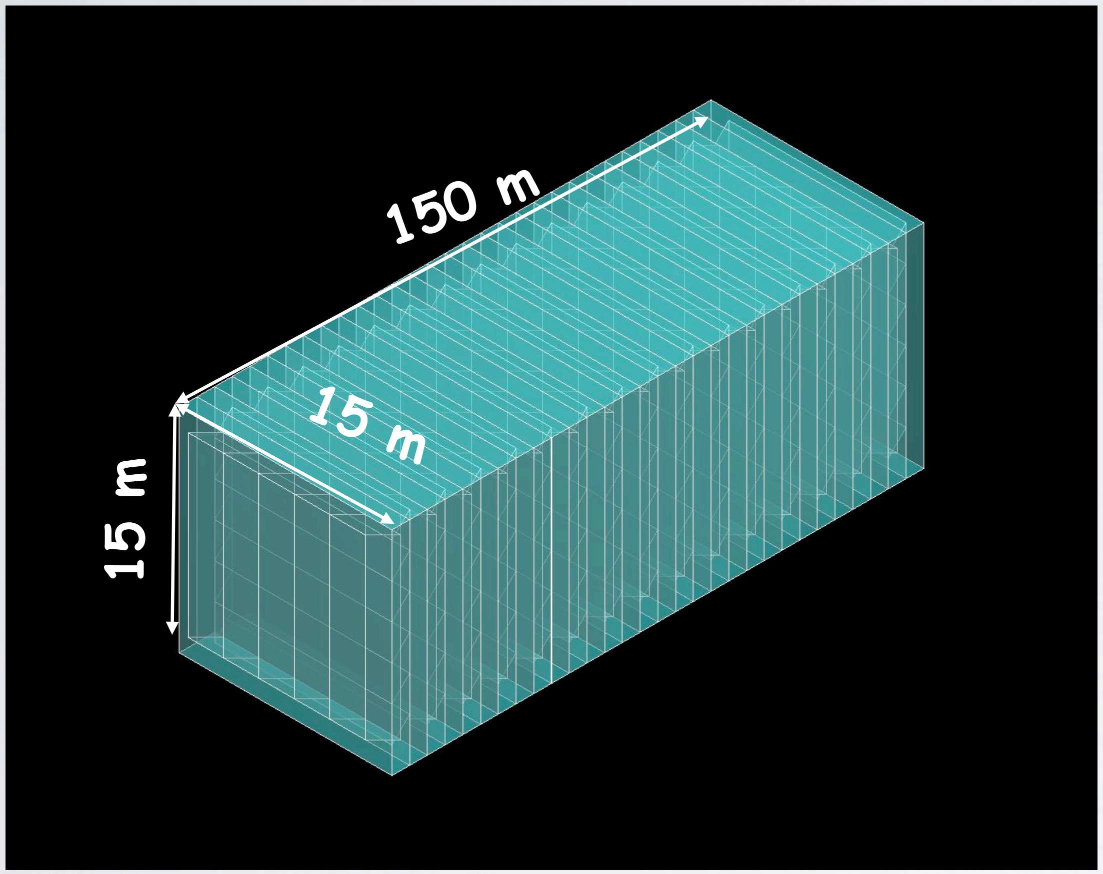




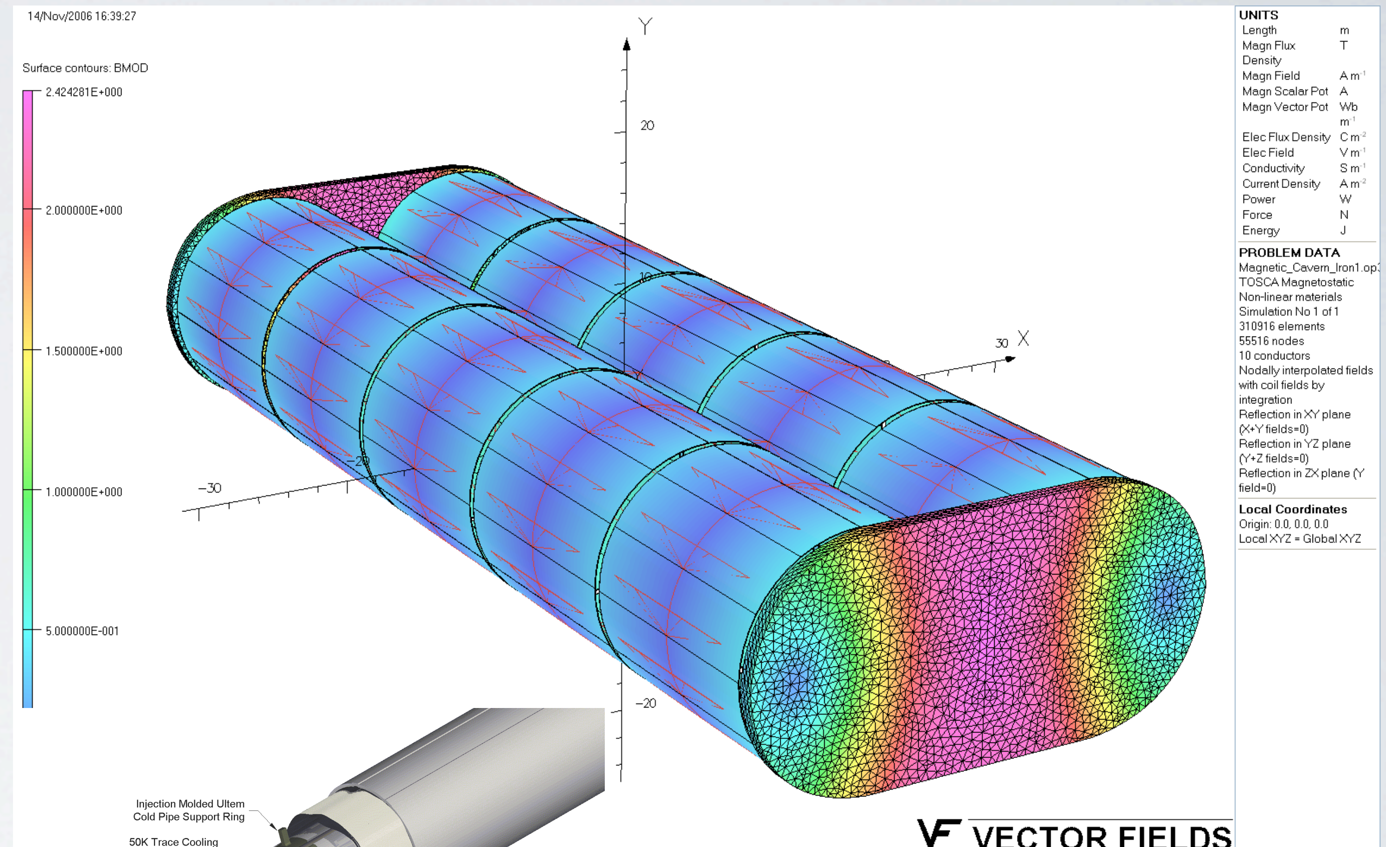
THE LE NEUTRINO FACTORY

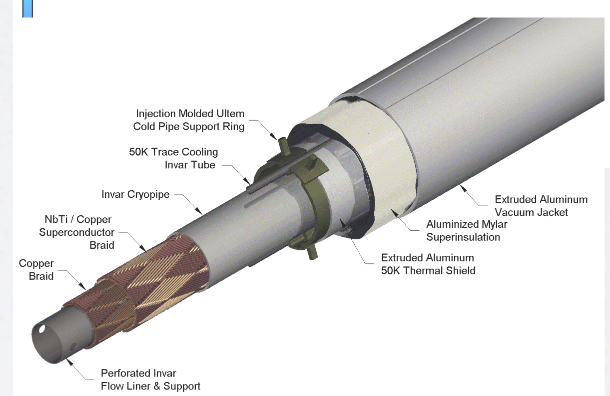


DETECTORS FOR LE NUFACT



B = 0.5T

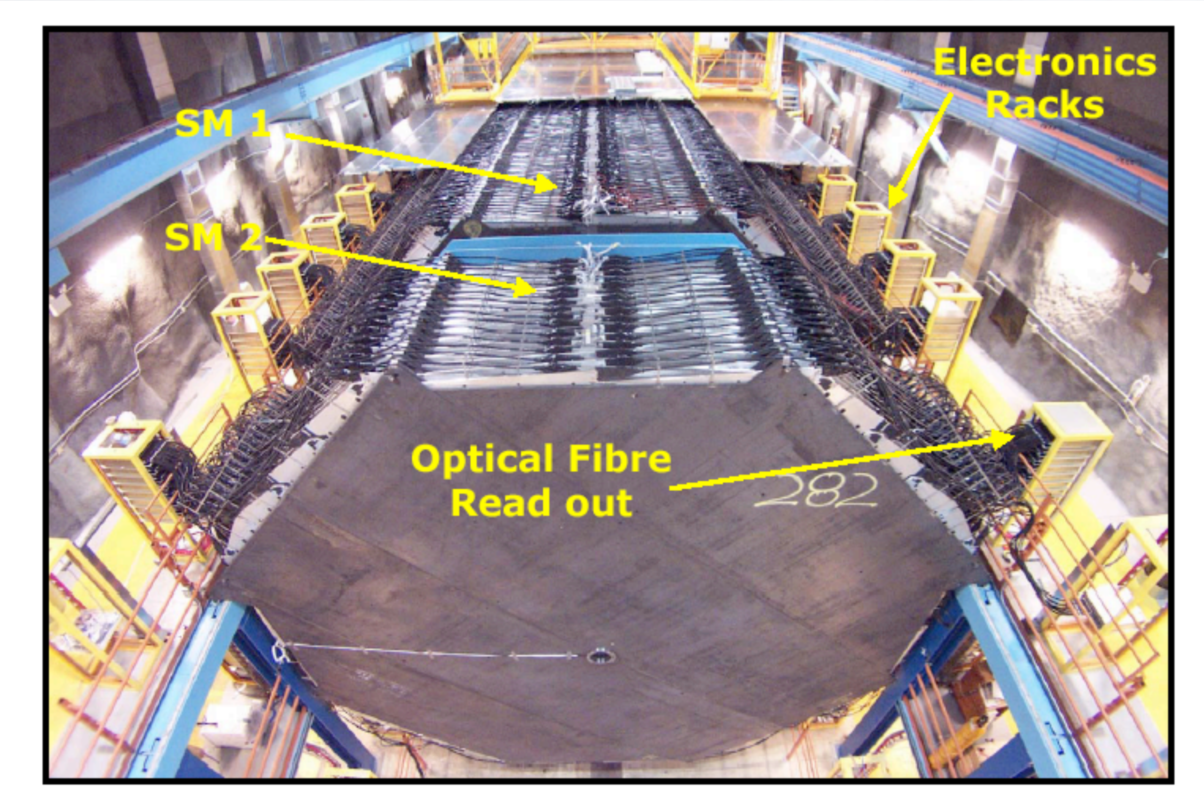




CONVENTIONAL OPTION FOR NUFACT

MIND YOU

$$\mu^+ \longrightarrow e^+ + \bar{\nu}_\mu + \nu_e$$



$$\bar{\nu}_\mu + N \longrightarrow \boxed{\mu^+} + X \qquad \text{CC}$$

right sign muon

$$\bar{\nu}_\mu + N \longrightarrow \bar{\nu}_\mu + X \qquad \text{NC}$$

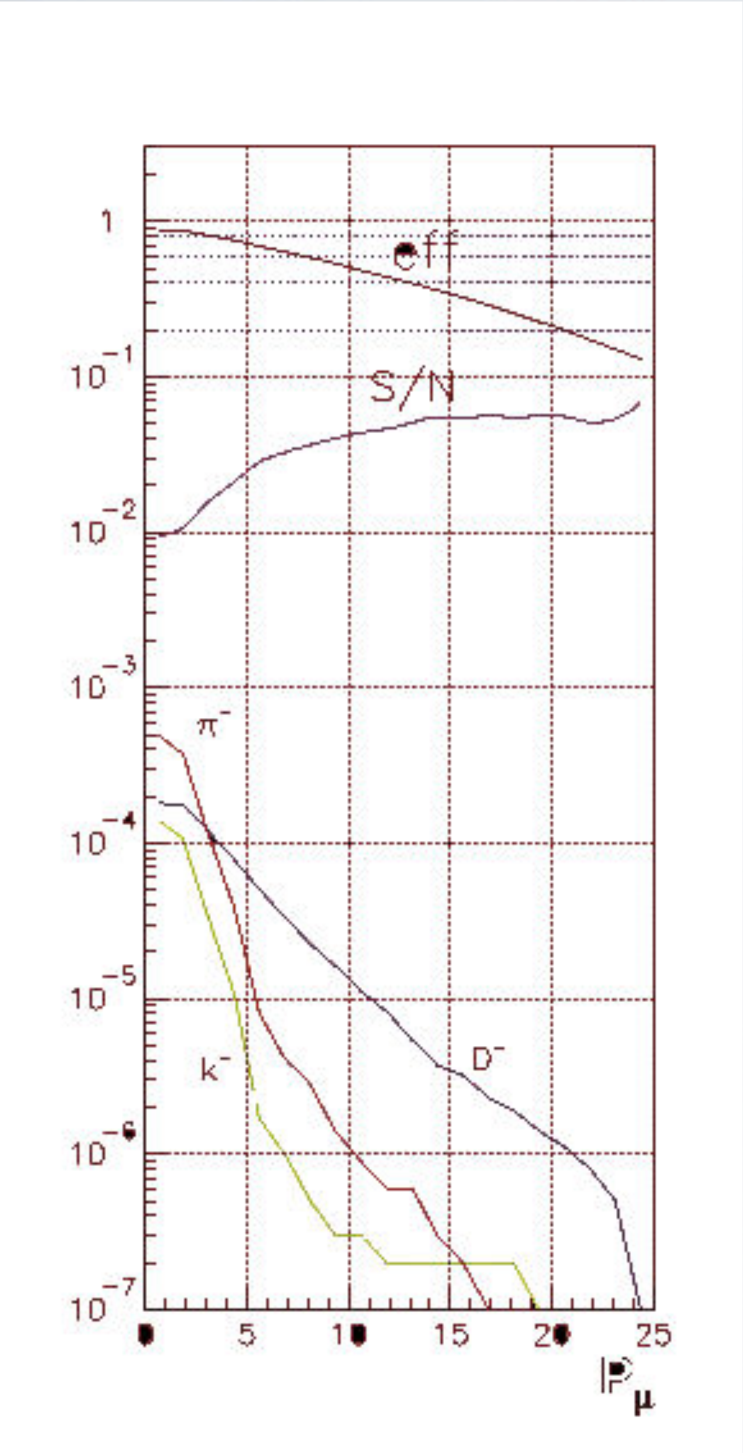
$$\nu_e \overset{\text{osc}}{\sim} \nu_\mu$$

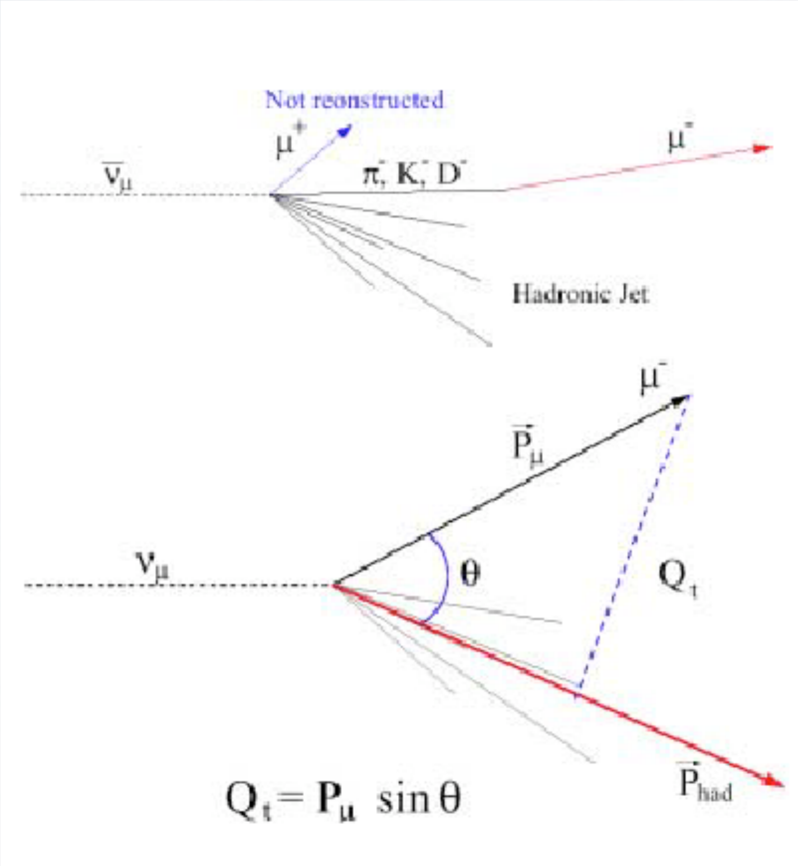
$$\nu_\mu + N \longrightarrow \boxed{\mu^-} + X \qquad \text{SIGNAL}$$

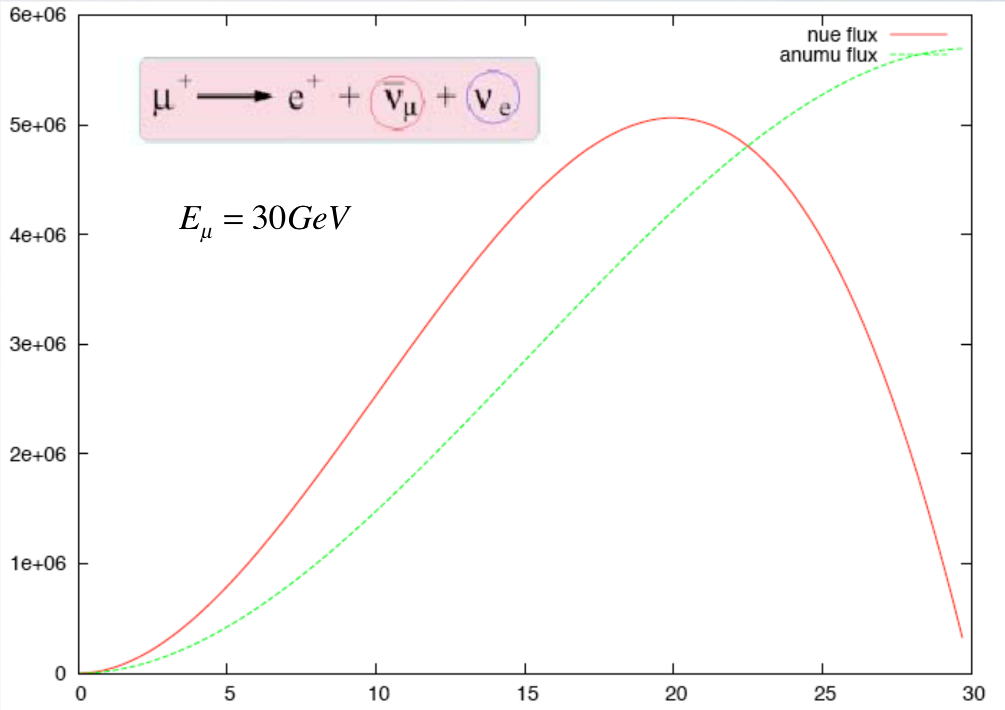
wrong sign muon

10 x MINOS

MIND YOU





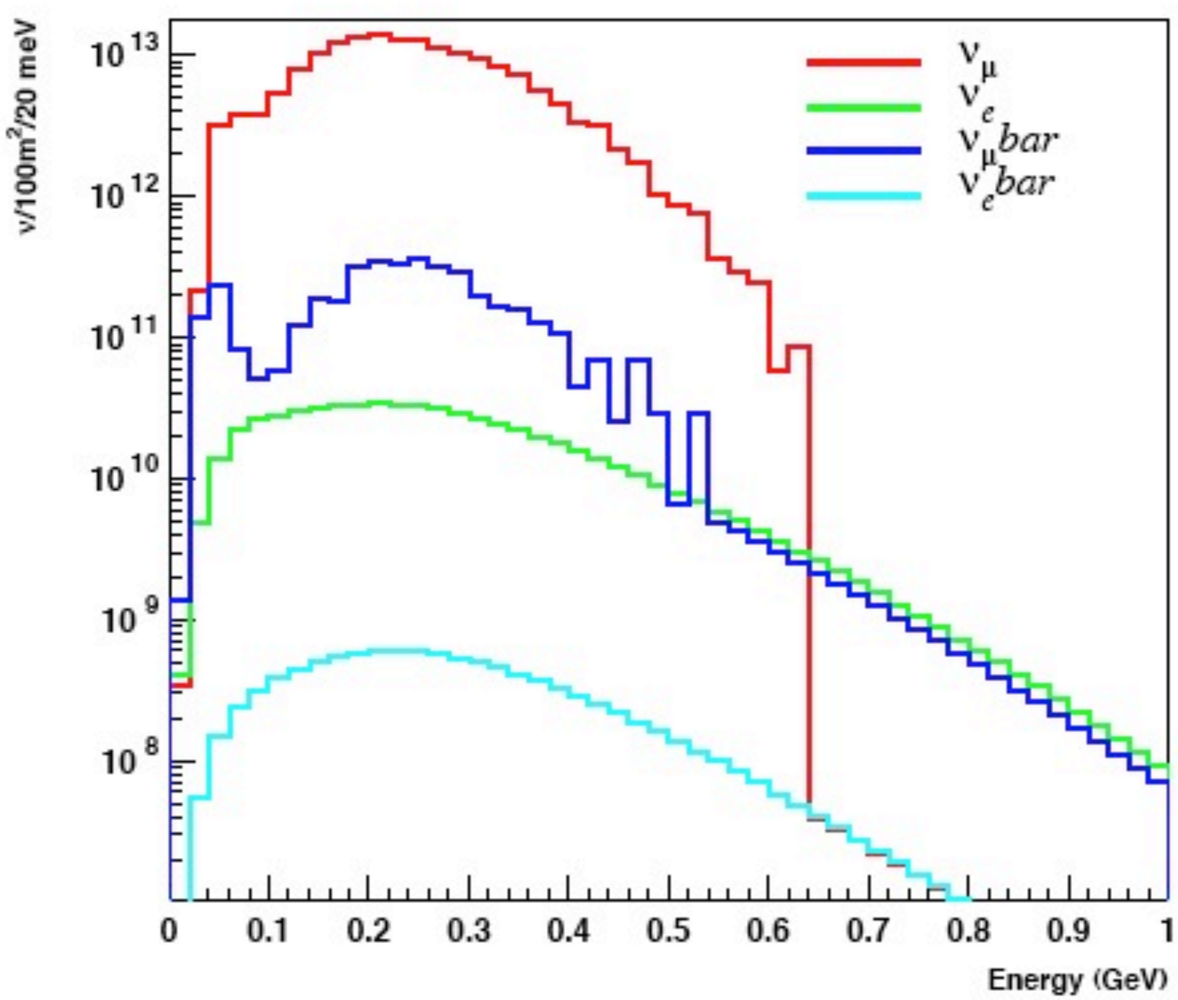


- Iron main problem: Energy threshold. Muons of low energy are not easy to distinguish from pions. Spectral energy analysis suffers a low energy and thus degeneracies.

HOMEWORK

- Here is your program for pinning down al NuFact physics: A HE nuFact of some 20 GeV with two baselines, one shooting at 7,000 km, the other at 3,000. The combination of the two allows to disentangle the true CP from the fake CP (matter effects). You have a large iron detector to carry on your experiment(s)
- But: at L=3000 Km, the oscillation peaks at ~7 GeV. You are badly off-peak!
- No problem! Because you have energy binning, the bins between 1 and 1 GeV will "map the oscillation peak"
- Or not? Is something wrong? Can you use the low energy bins? why?
- Any ideas?

GALLERY OF GREAT IDEAS: SUPER BEAM LE



Flux intensities at 50 km from the target

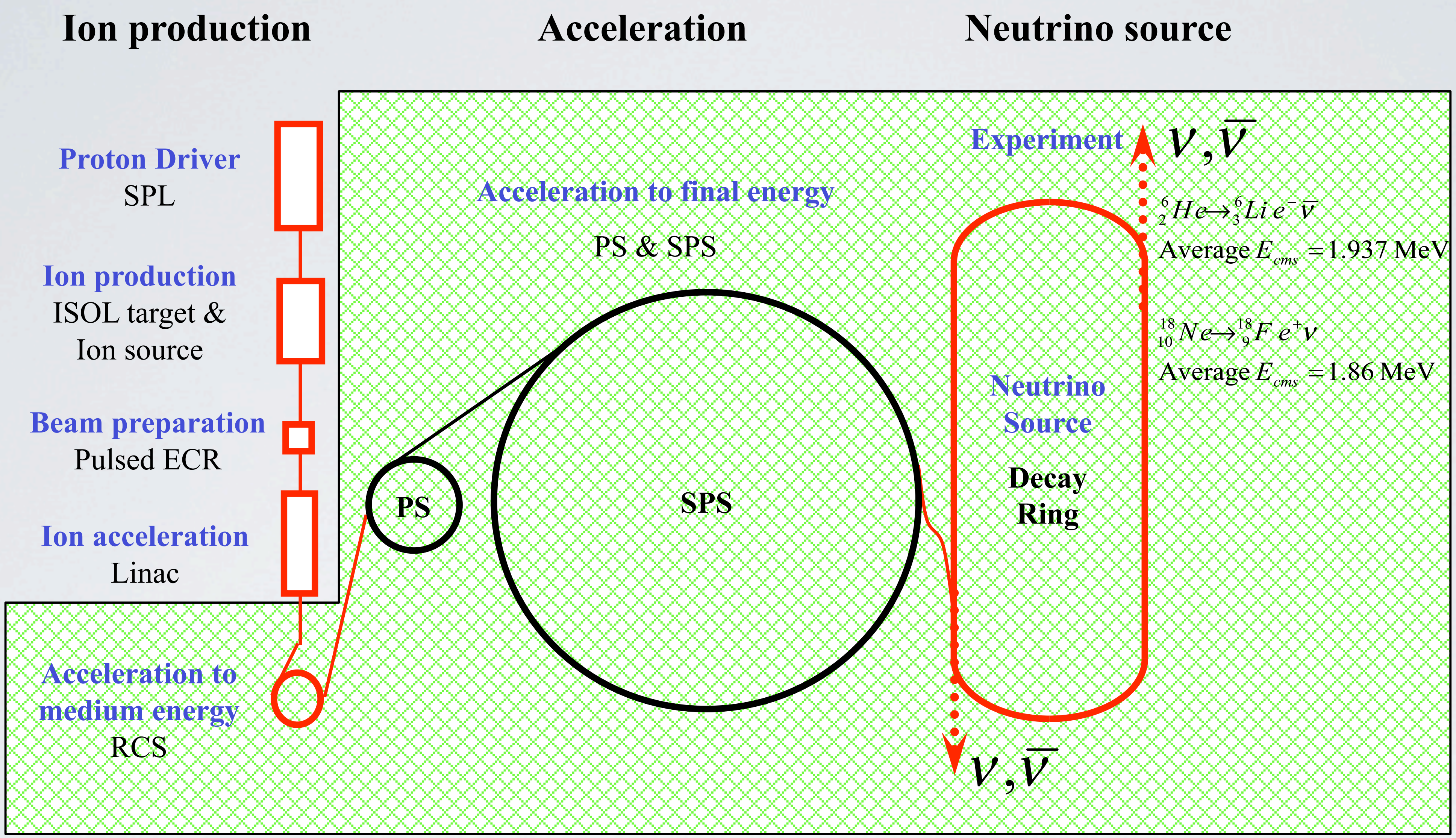
Flavor	Absolute Flux ($\nu/10^{23}\text{pot}/10^2\text{m}^2$)	Rel. Flux	$\langle E_\nu \rangle$ (GeV)
ν_μ	$1.7 \cdot 10^{14}$	1	0.26
$\overline{\nu}_\mu$	$4.1 \cdot 10^{12}$	2.4%	0.24
ν_e	$6.1 \cdot 10^{11}$	0.36%	0.24
$\overline{\nu}_e$	$1.0 \cdot 10^{10}$	0.006 %	0.29

- Selling values: High intensity beam of nμ peak at low energy: Therefore very short distance (< 100 km). No matter effects, great intensity!

THE SKEPTICAL PHYSICIST

- Anything wrong with the LE, high intensity super-beam?
- Give a summary of merits/problems for this option

GGI: BETA-BEAM

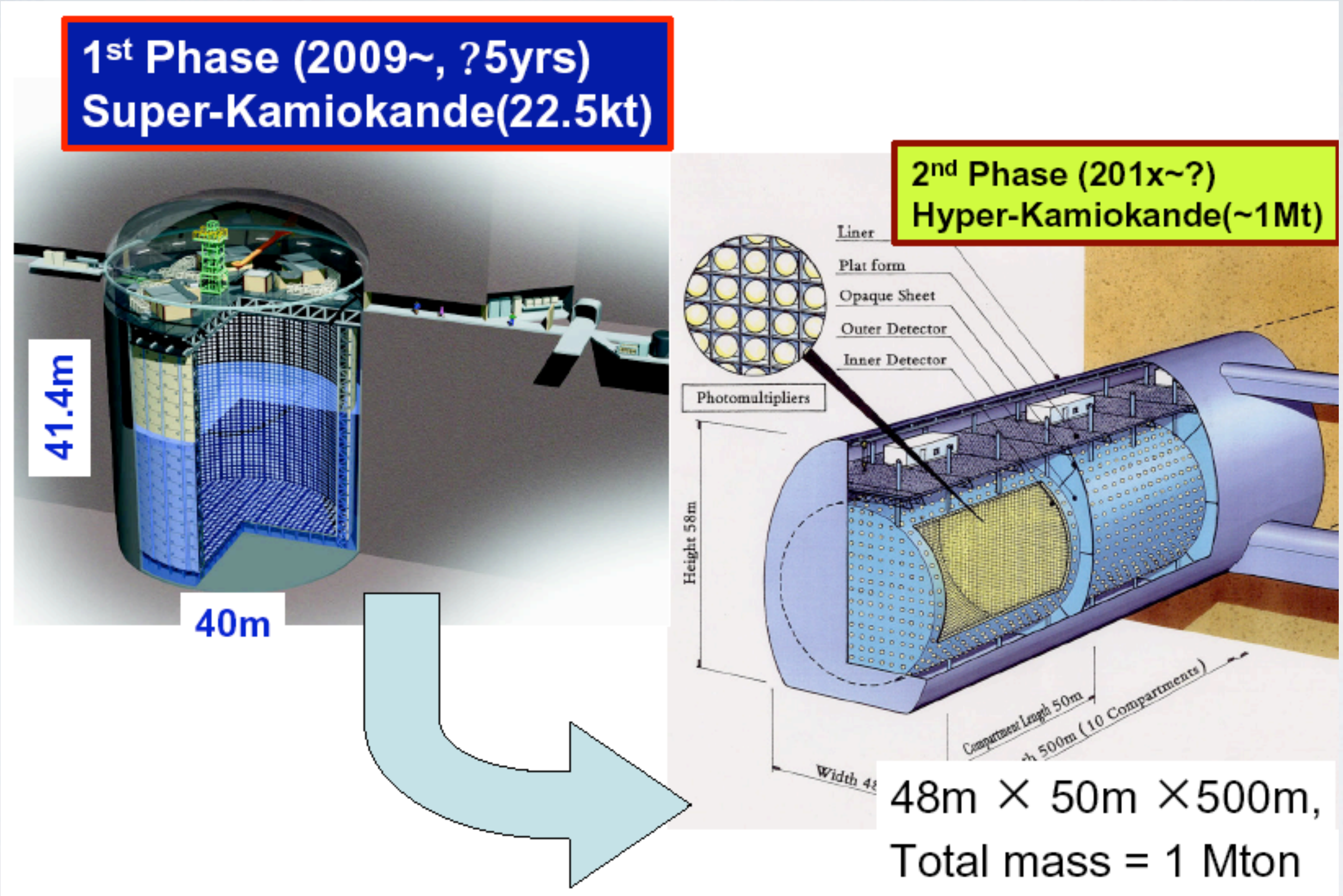


- Selling values: High intensity beam of ne (and antineutrinos) peaks at “QE” energy: Therefore short distance (~ 300 km). Small matter effects, no beam backgrounds, neutrinos and antineutrinos, great intensity!

THE SKEPTICAL PHYSICIST

- This can't be beaten, or can it?
- Give a summary of merits/problems for this option
- Can you go higher in energy (γ>100?) any merit on (γ~300, 1000, 5000?) Assuming that the machine could do it... what would need to change in your detector? Is a good deal?

GGI: MONSTER K



- Selling values: One megaton water detector! Perfect for Eν~1-2 GeV (e.g, the classical beta-beam of γ=100). Lots of interactions!

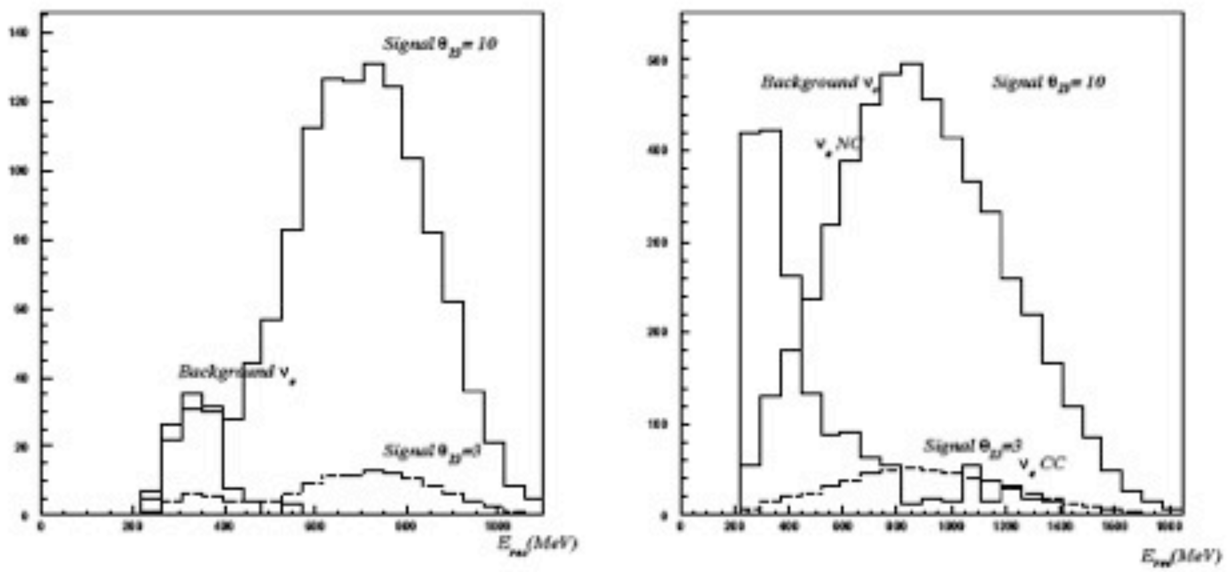


Figure 2: *Reconstructed energy for signal with* $\theta_{13} = 8^\circ$ *(solid) and* $\theta_{13} = 3^\circ$ *(dashed)) and background (dotted) at the maximum acceleration of* ^{6}He *(left) and* ^{18}Ne *(right) ions at the CERN-SPS. The absolute normalization corresponds to one year.*

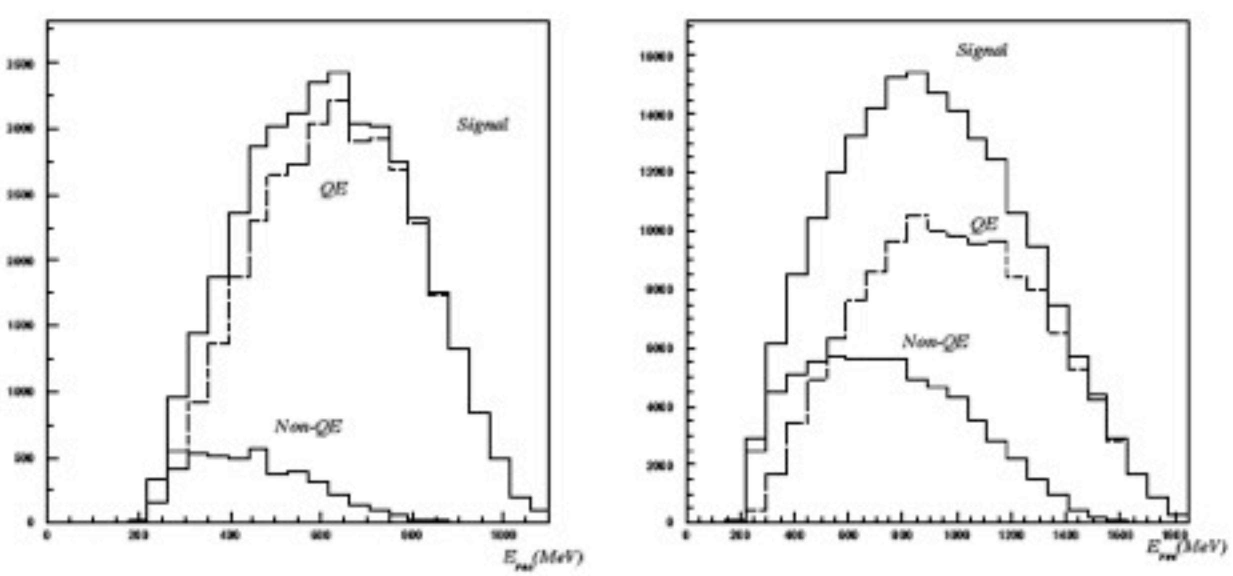
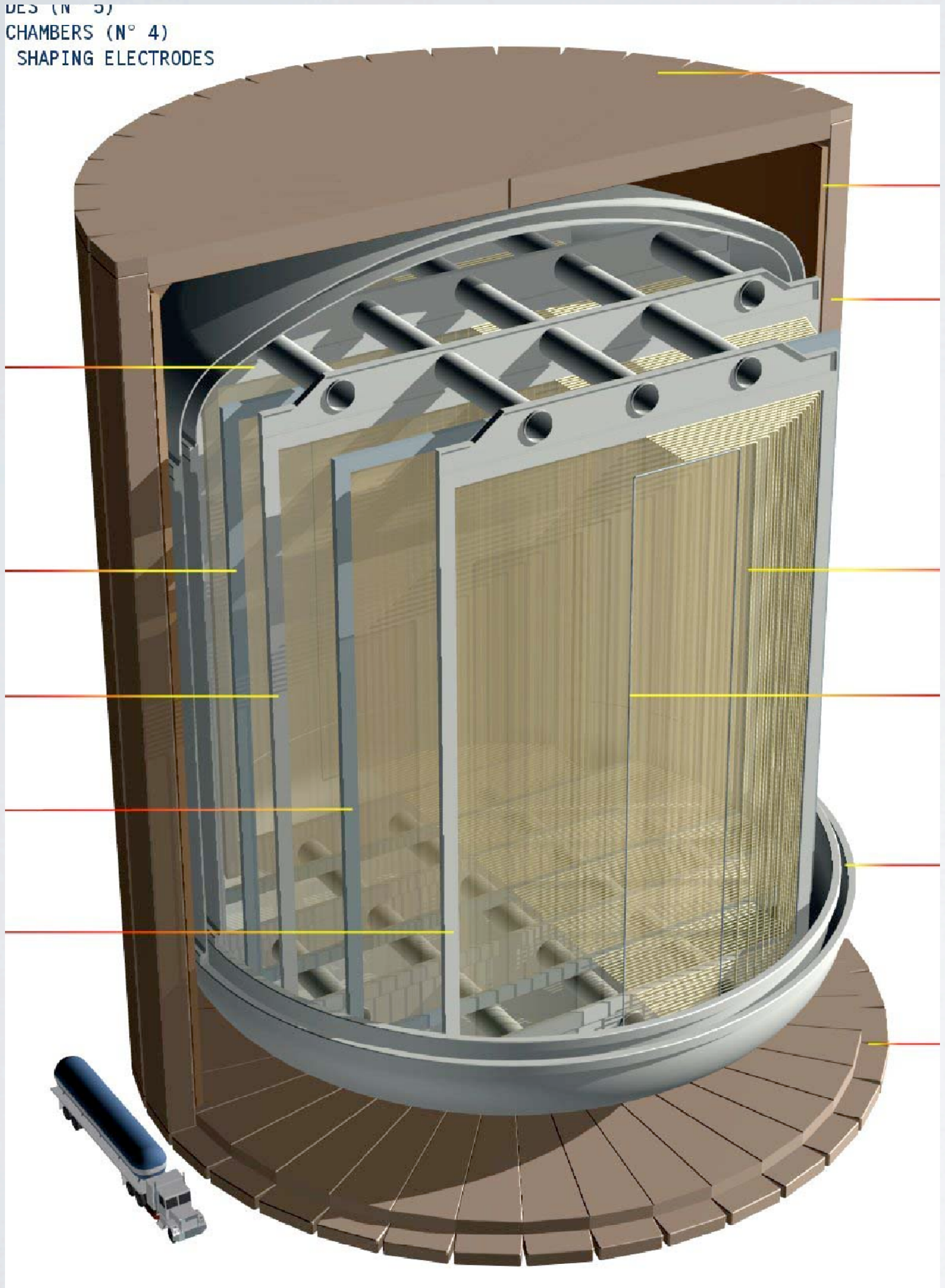


Figure 3: *Quasi-elastic and non-quasielastic components in the* μ *appearance signal for unit oscillation probability (the absolute normalization is arbitrary) at maximum CERN-SPS acceleration of* ^{6}He *(left) and* ^{18}Ne *(right).*

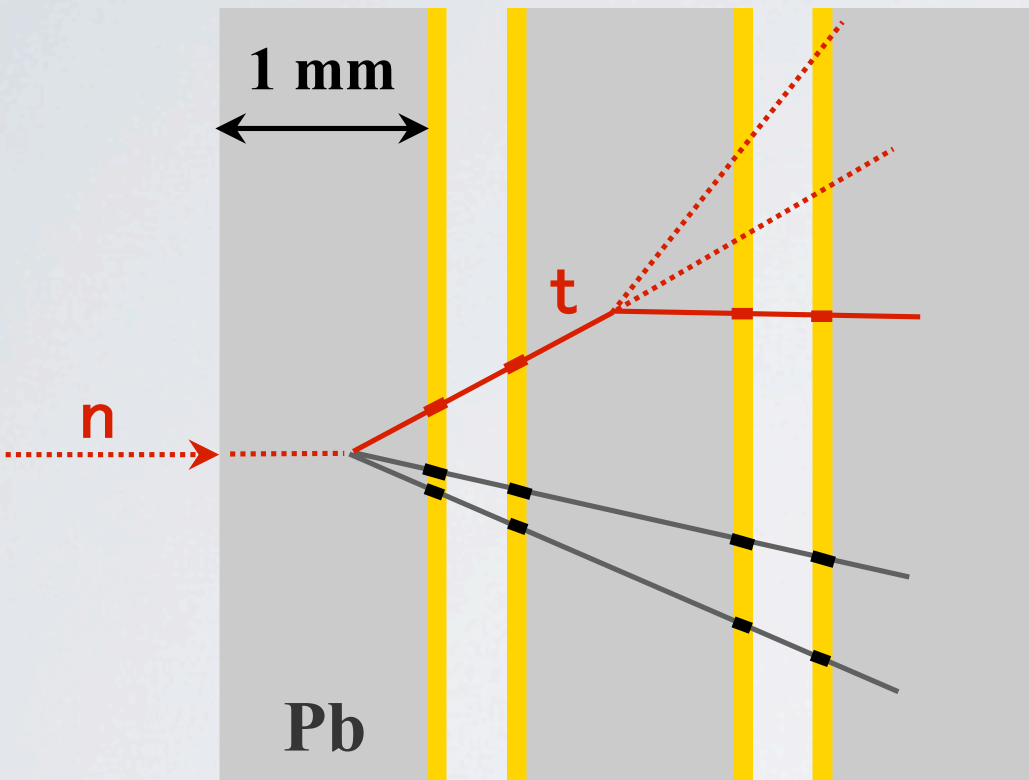
- QE muons are not so easy to separate from pions as the signal becomes weak the background becomes nasty
- Energy is reconstructed assuming that the event is QE but often the event is not QE. One needs to correct for that.

GGI: MONSTER LAR



- Fully active detector. It should do better than iron to separate low energy muons from pions.
- Kinematical capability to identify, at least statistically taus and electrons. Opens up all other channels.
- What about the skeptical physicist? Look at the truck side in the picture!

GGI: THE ULTIMATE OPERA



- Can do tausl
- How massive can you do it?

THE HOPEFUL PHYSICIST

- The role of future neutrino facilities is to measure three fundamental physics parameters unknown yet to us: θ_{13}, δ and the matter hierarchy.
- If θ_{13} is not too small, this goal may be "easy". T2K and NOVA have a good chance of measuring a non-null value and maybe give a hint of the matter sign.
- Measuring δ and getting some precision in θ_{13} in particular for smaller values is a difficult task. No machine and no detector technology seem perfect for a full job. Even more, no machine and no detector technology are fully demonstrated.
- Large water detectors and large iron detectors seem plausible and a bit of a BAU. Exploiting the silver and platinum channels require more advanced concepts such as the TAS or the monster LAR.
- Hopefully you will have got a flavor of the daunting challenges. Now, go ahead and pretend is easy. Neutrinos are the toys not of skeptical but of hopeful physicists.