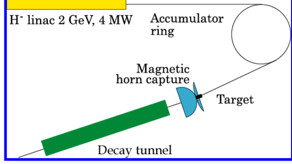
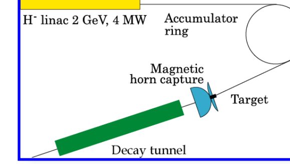


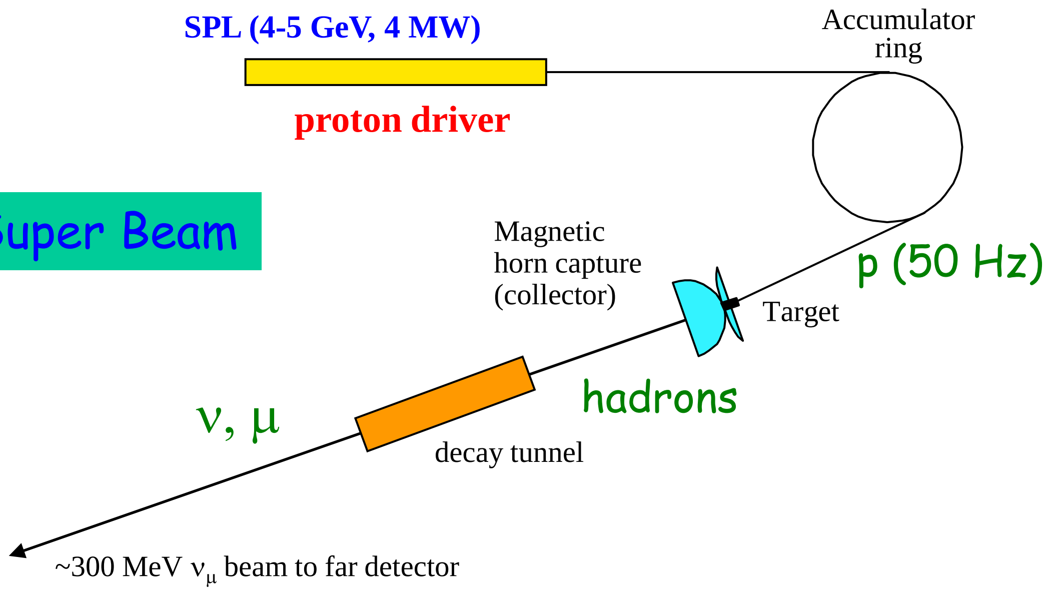
EUROν Super Beam studies (WP2)

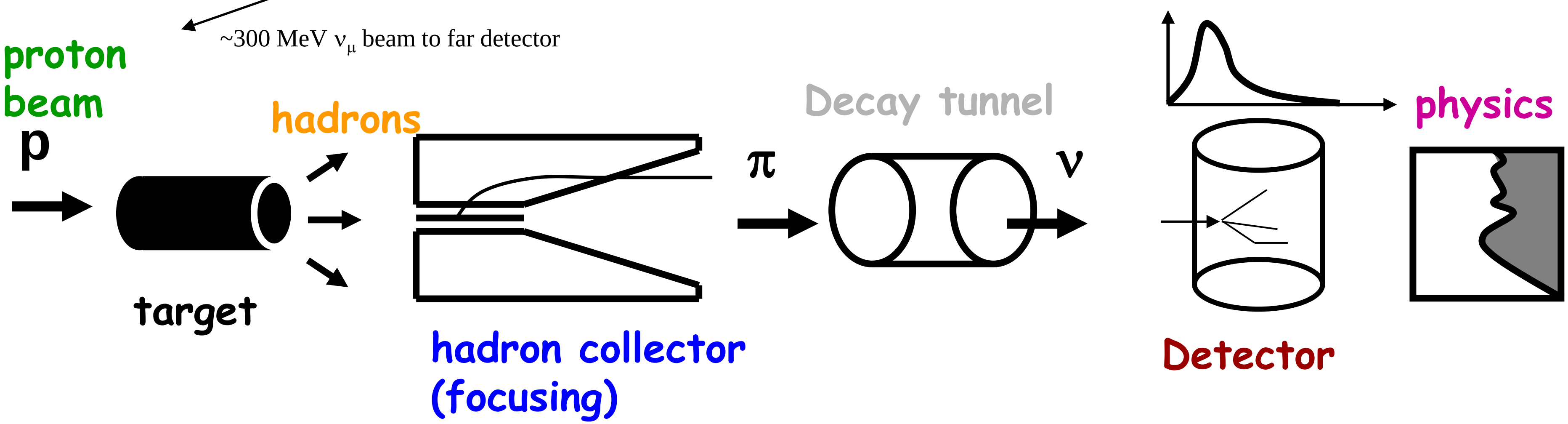
Marcos Dracos
IPHC-IN2P3/CNRS, Strasbourg
(on behalf of EUROν WP2)

Super Beam: conventional MW power neutrino beam

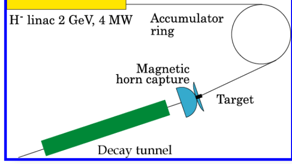


SPL Super Beam

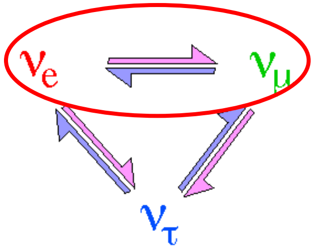




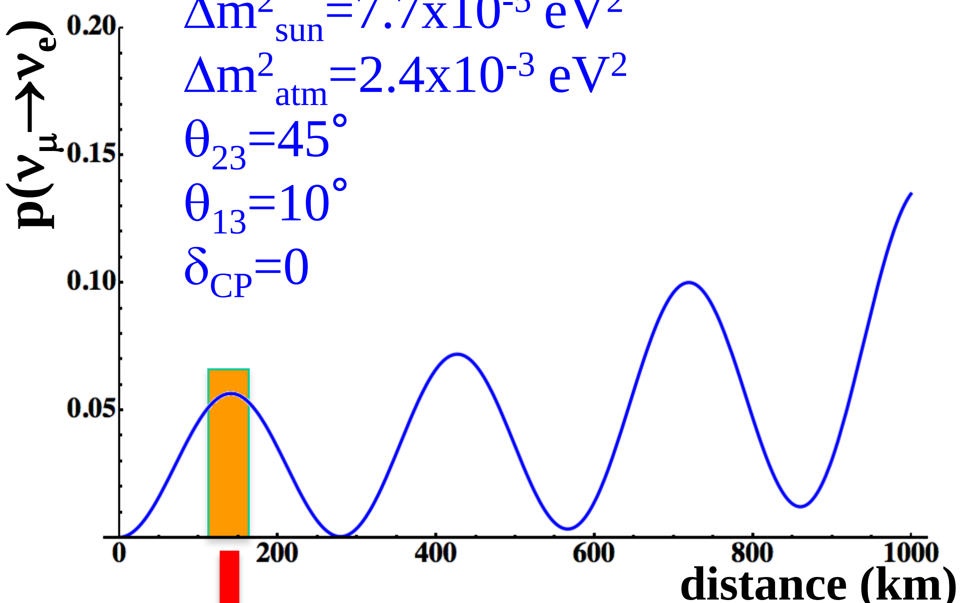
Neutrino Super Beam from HP-SPL



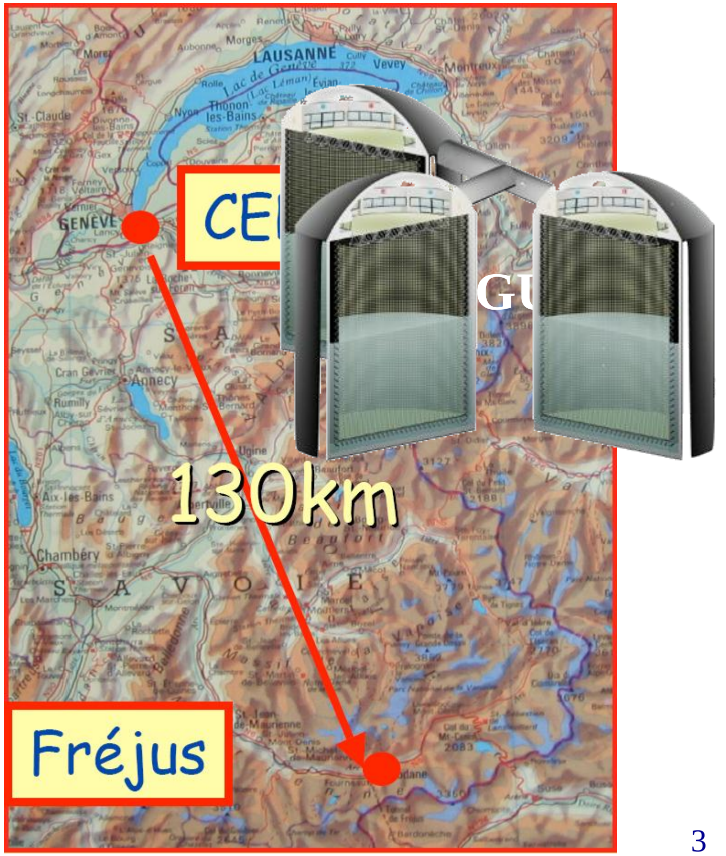
SPL proton kinetic energy: ~4 GeV



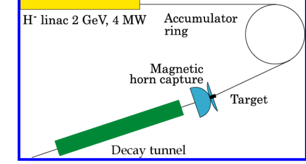
Neutrino energy: ~300 MeV



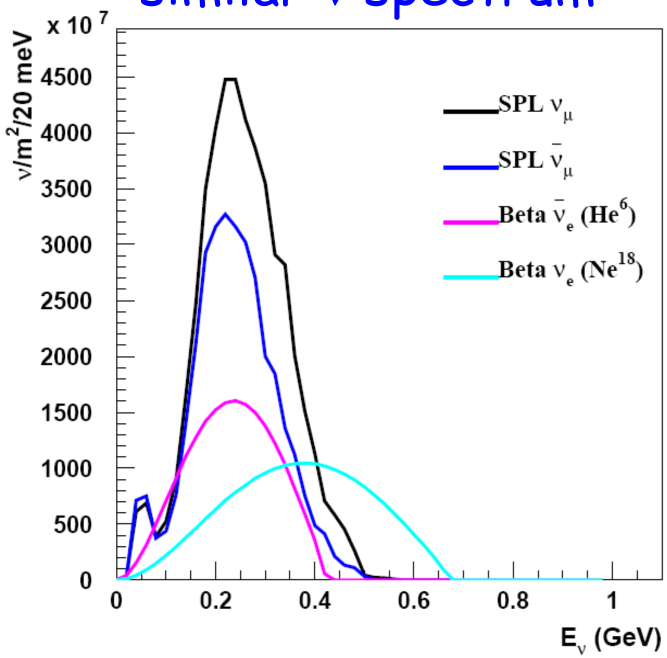
~130 km



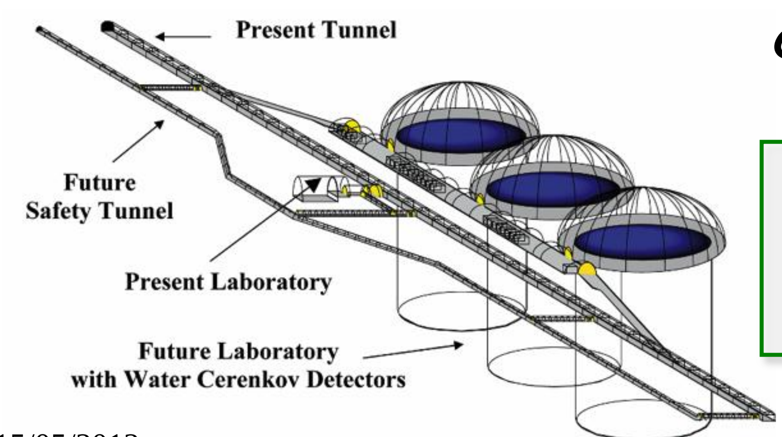
Combination of Super Beam with Beta Beam



similar ν spectrum



Beta Beam (γ~100)		Super Beam
$\nu_e \rightarrow \nu_\mu$ (β+)	(T)	$\nu_\mu \rightarrow \nu_e$ (π^+)
(CP)	(CPT)	(CP)
$\bar{\nu}_e \rightarrow \bar{\nu}_\mu$ (β-)	(T)	$\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ (π^-)



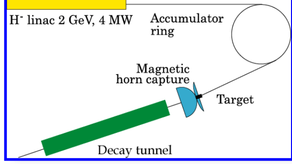
combination of CP and T violation tests

2 beams

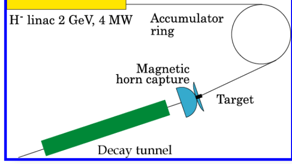
1 detector

Bonus: the unoscillated neutrinos of one facility can be used to well study the efficiencies of the other one

WP2 activities



- Beam simulation and optimization, physics sensitivities
- Beam/target interface
- Target and target station design
- Horn design
- Target/horn integration
- Cost
- Safety

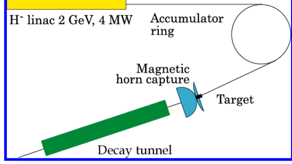


The WP2 team

- Cracow University of Technology
- STFC RAL
- IPHC Strasbourg
- Irfu-SPP, CEA Saclay
- external partners

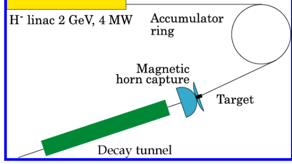
E. Baussan, O. Besida, C. Bobeth, O. Caretta, P. Cupial, T. Davenne, C. Densham, M. Dracos, M. Fitton, G. Gaudiot, M. Kozien, B. Lepers, A. Longhin, P. Loveridge, F. Osswald, P. Poussot, M. Rooney, B. Skoczen, G. Vasseur, N. Vassilopoulos, A. Wroblewski, J. Wurtz, V. Zeter, M. Zito

Technological Challenge

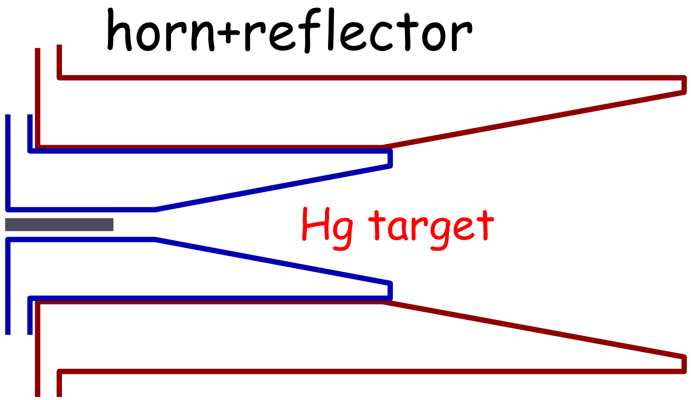


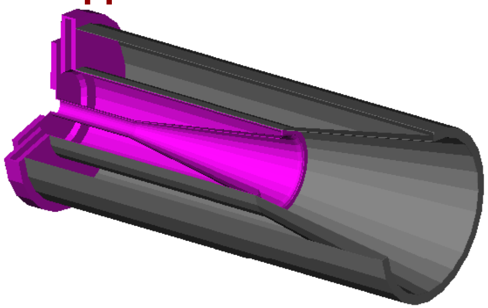
- Can we conceive a neutrino beam based on a multi-MW proton beam ?
- Can we design a target for a multi-MW proton beam ?
- Can we do it with a reliable design without compromising the physics reach ?
- **Target**
  - huge energy deposition (300-1000 J/cm^3/pulse)
  - Severe problems from: sudden heating, stress, activation
  - Solid versus liquid targets
  - cooling
- **Horn**
  - cooling
  - vibrations
  - pulser (up to 350 kA, 50 Hz)
- **Safety**
- **Lifetime** (supposed to run for 10 years)

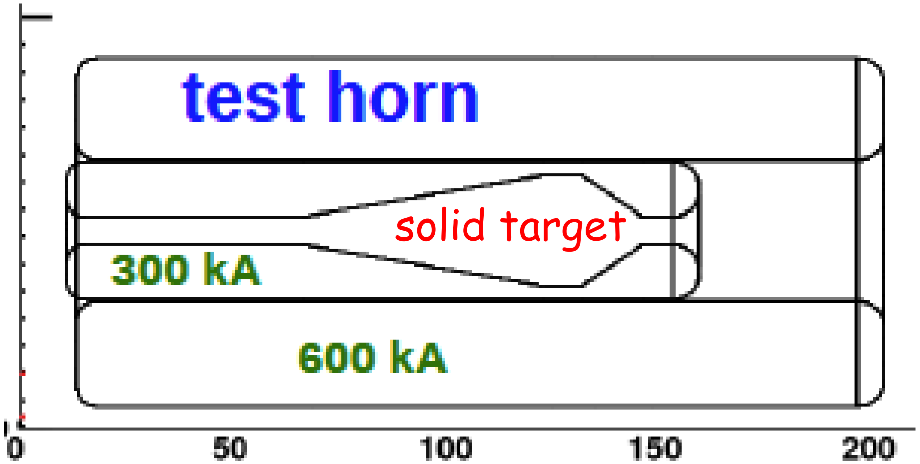
Evolution of the system

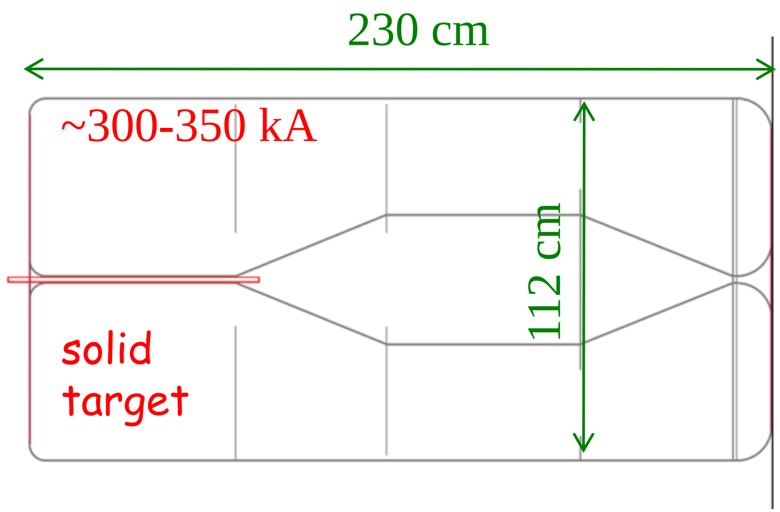


initial design





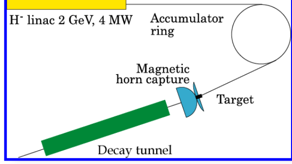




simpler optimized shape with reduced current!

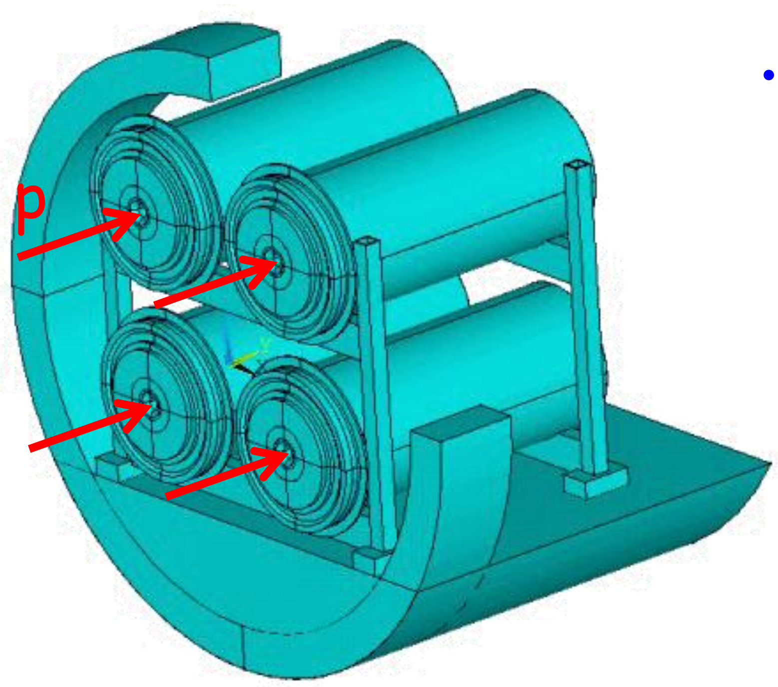
final design

How to mitigate the power effect



4 target/horn system (4x4 m^2) with single decay tunnel (~25 m)

→ solid targets able to afford up to ~1.5 MW proton beam

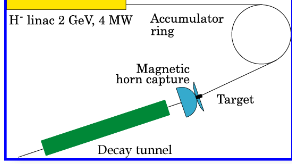


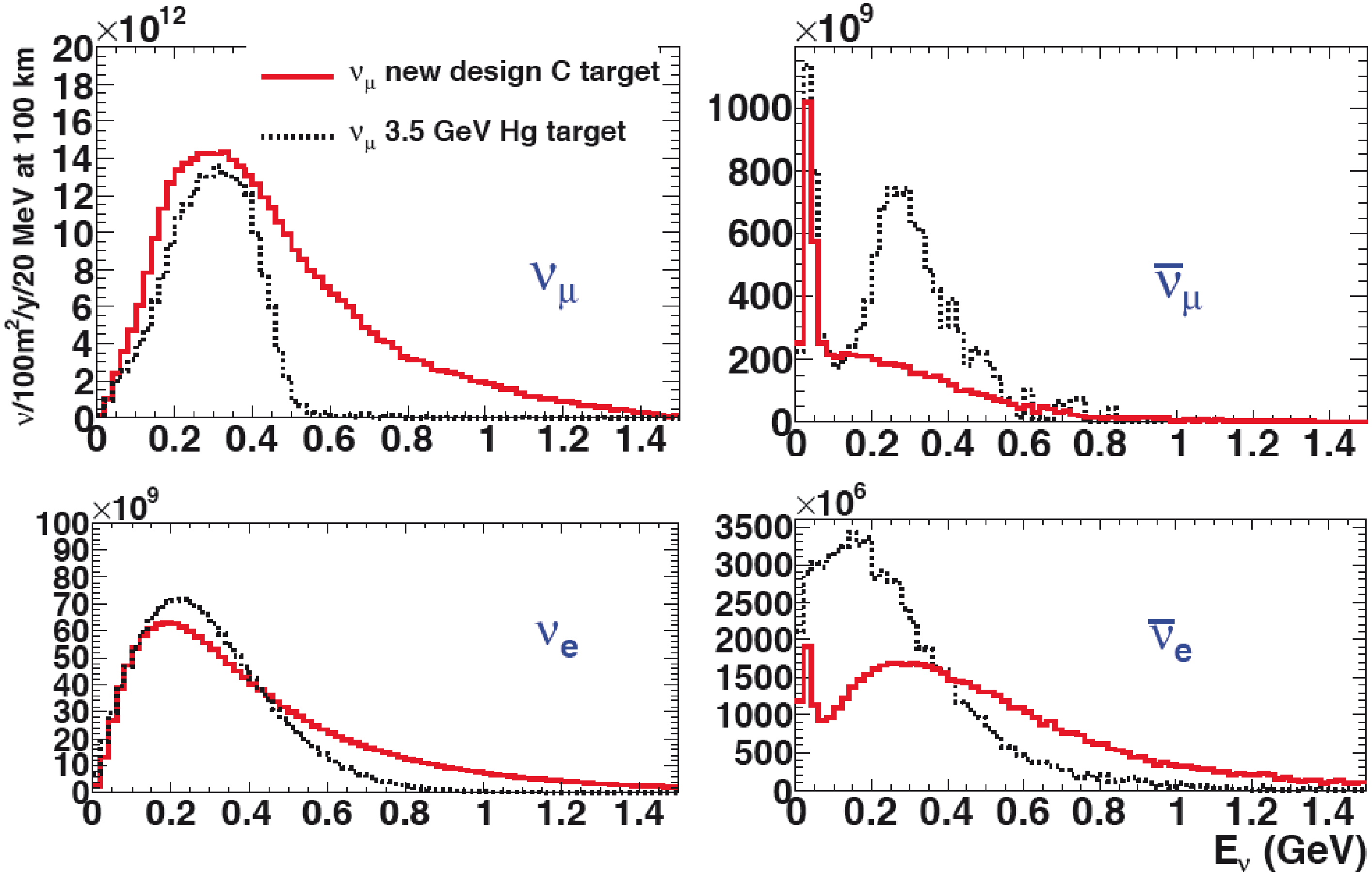
- send 4 MW/system every 50/4 Hz
  - in case of failure of one horn/target, continue with the 3 remaining ones sharing the 4 MW power

→ we get rid of Hg, but what about particle production?

more expensive but more reliable system

Comparison Mercury/Carbon



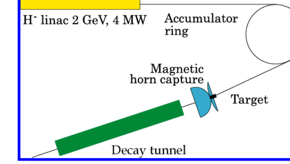


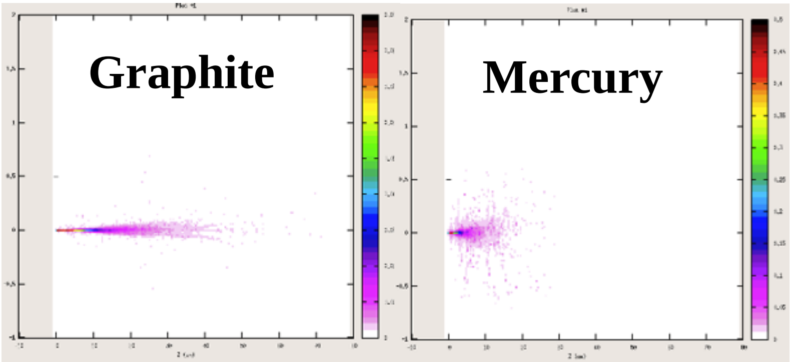
neutrino production

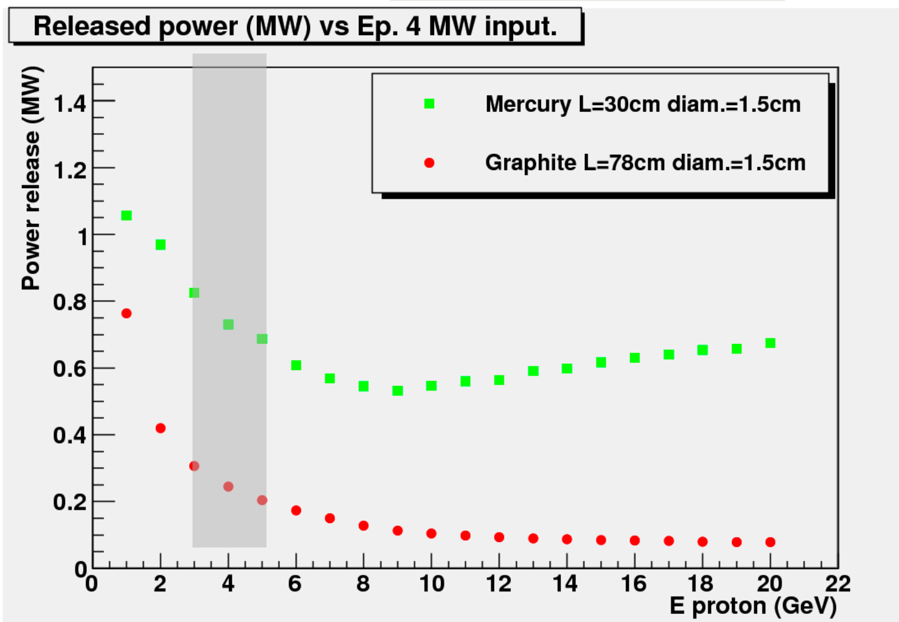
graphite target must be longer (76 cm,2 interaction lengths)

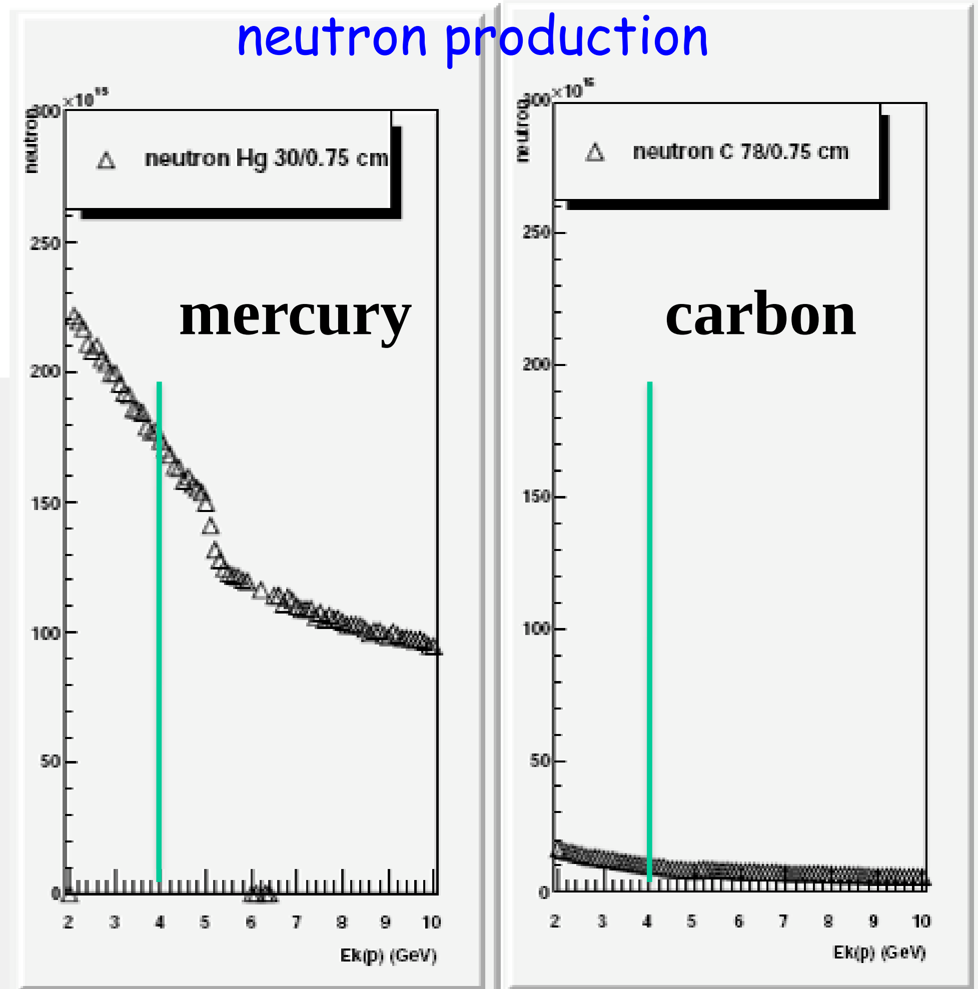
- neutrino intensity is higher with graphite
- neutrino contamination is lower
- high energy tail for graphite is more important

The Bonus…







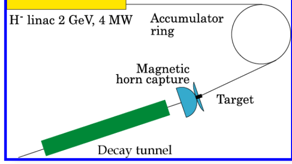


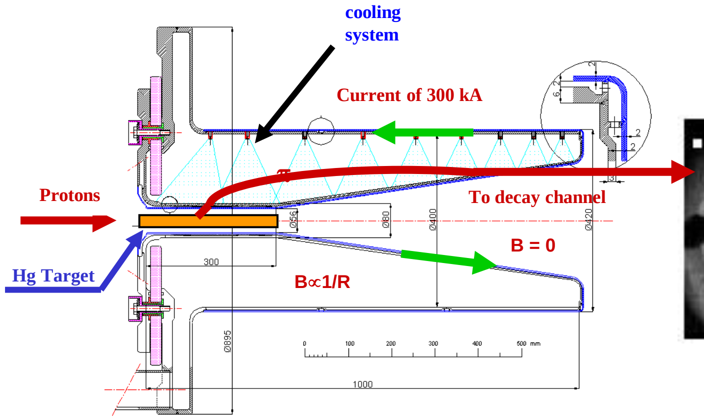
Released power:

- Hg: ~ 1 - 0.6 MW
- C : ~ 0.8 - 0.1 MW
- lower for graphite !

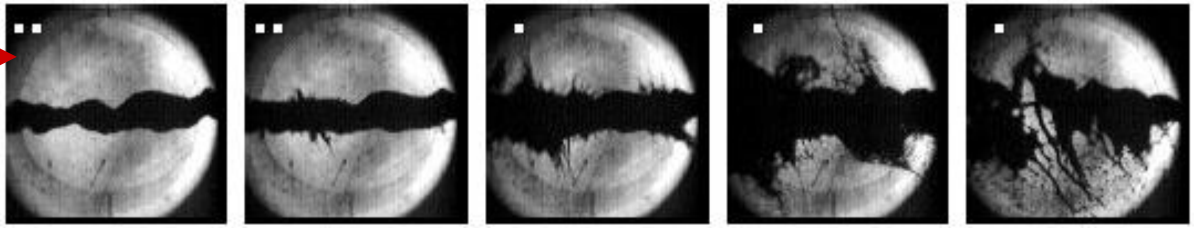
neutron flux dramatically reduced wrt Hg!
(~ x15)

From Liquid to Solid Targets



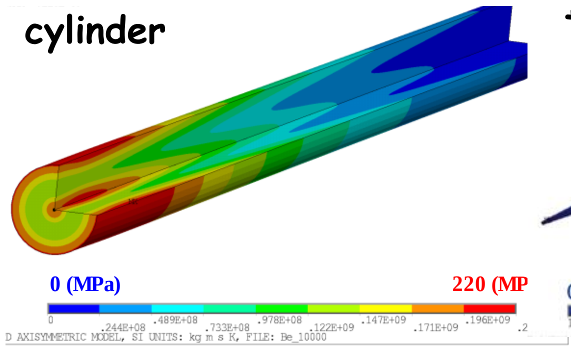


Free mercury jet

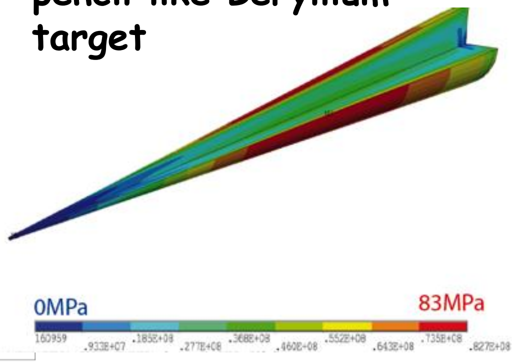


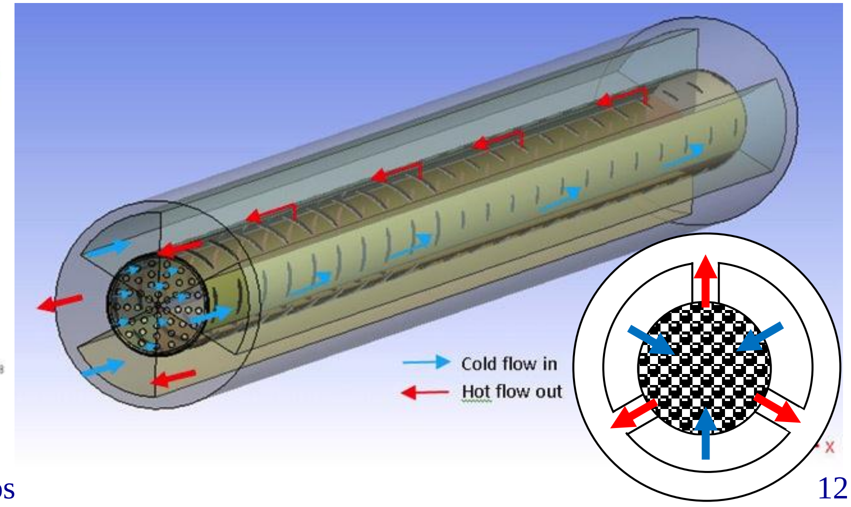
Packed bed canister in symmetrical transverse flow configuration, titanium alloy spheres

Beryllium or Graphite cylinder

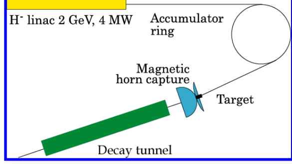


pencil like Beryllium target

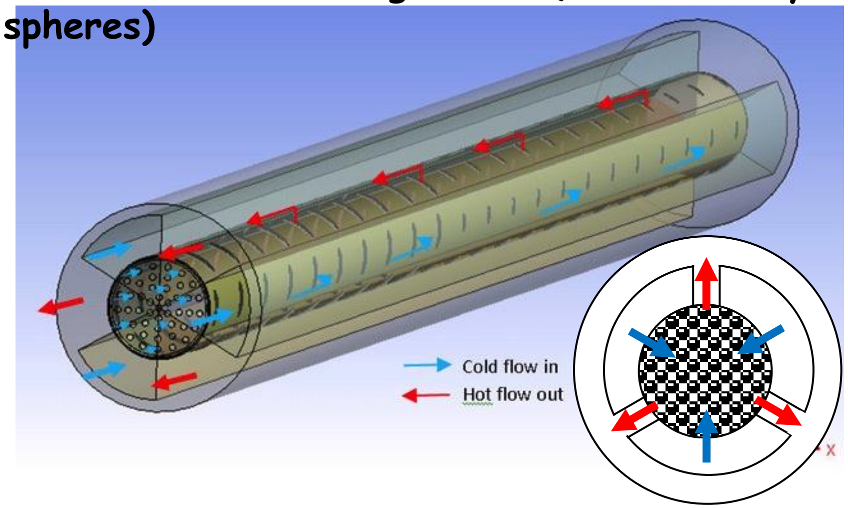


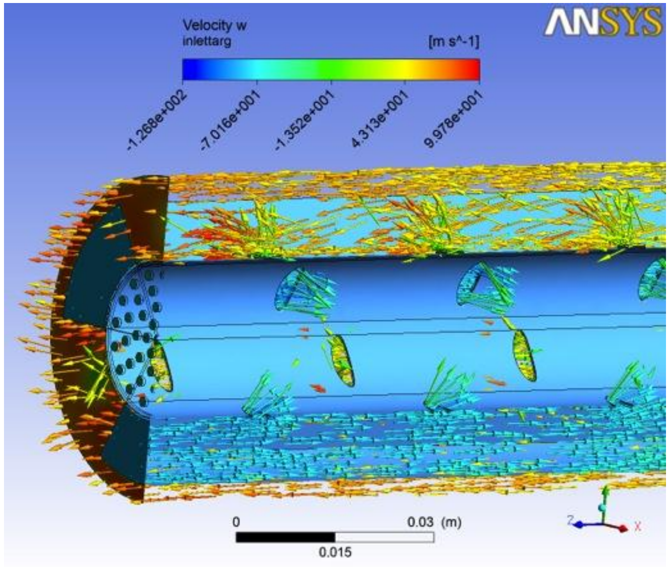


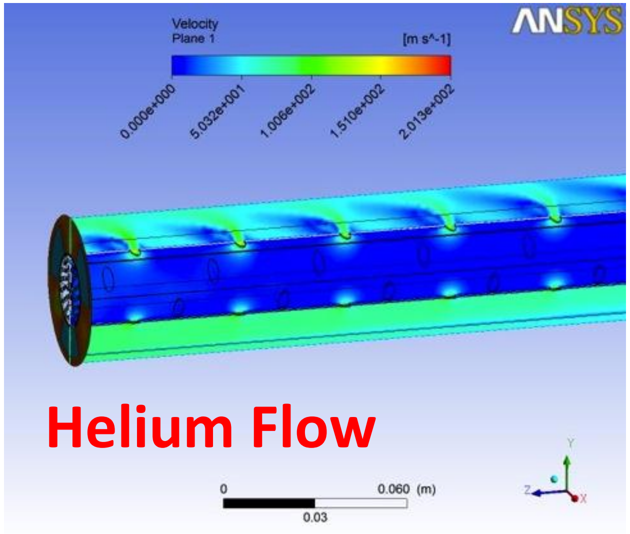
Solid Target

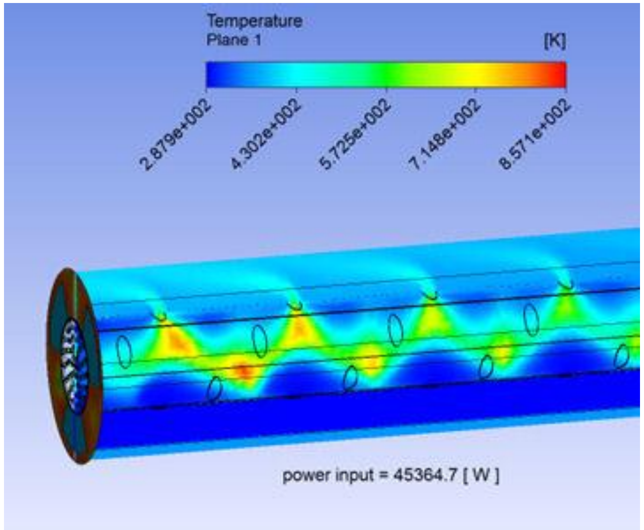


Packed bed canister in symmetrical transverse flow configuration (titanium alloy spheres)









Helium Velocity

Maximum flow velocity = 202m/s

Maximum Mach Number < 0.2

Helium Gas Temperature

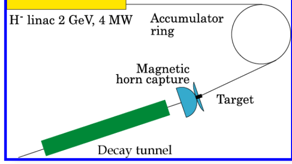
Total helium mass flow = 93 gr/s

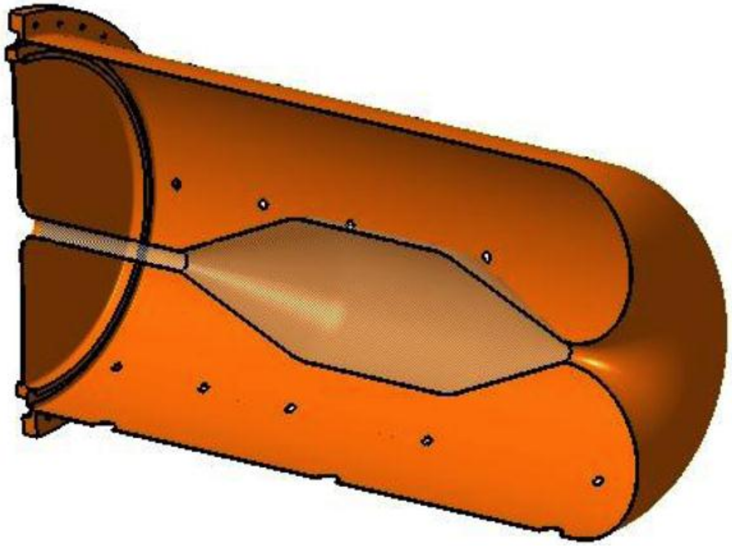
Maximum Helium temperature = 584° C

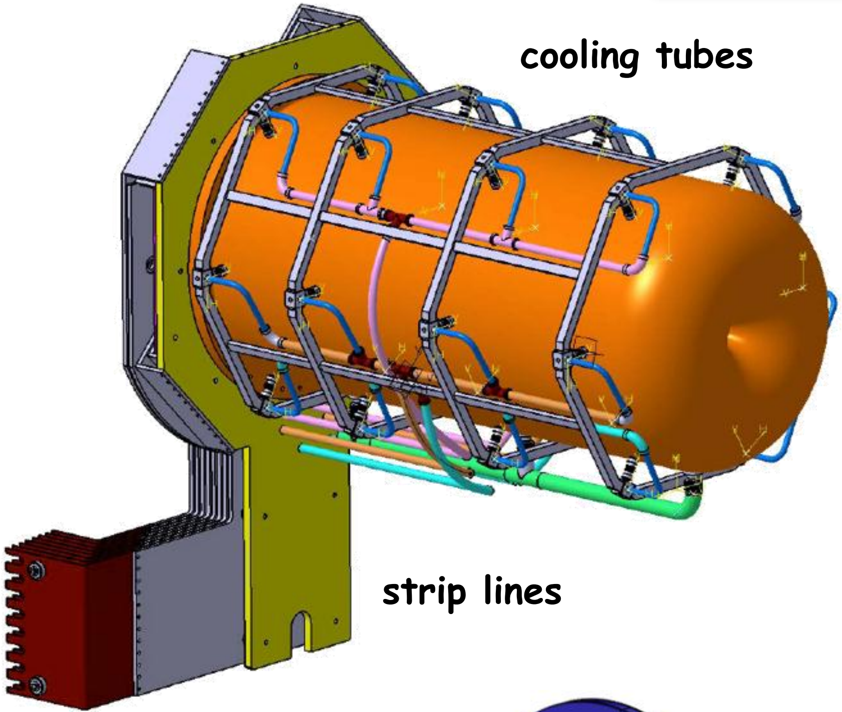
Helium average outlet Temperature = 109° C

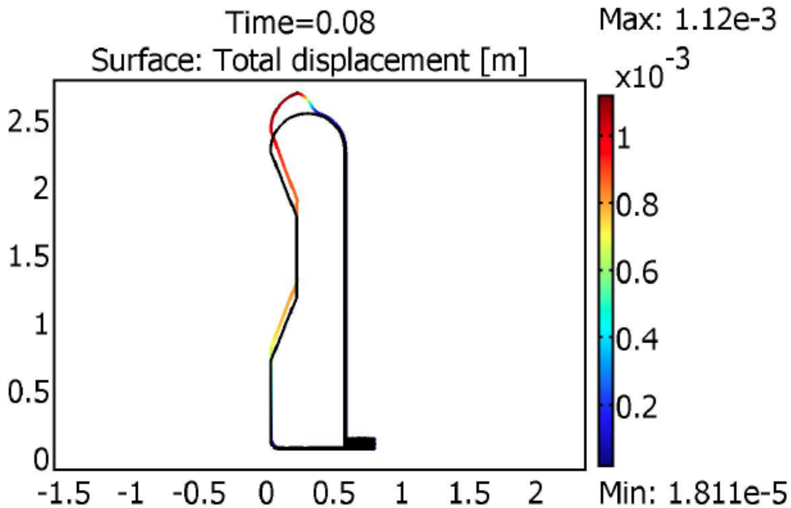
First tests with beam in the new HiRadMat@SPS facility at CERN in 2014

Studies on horn

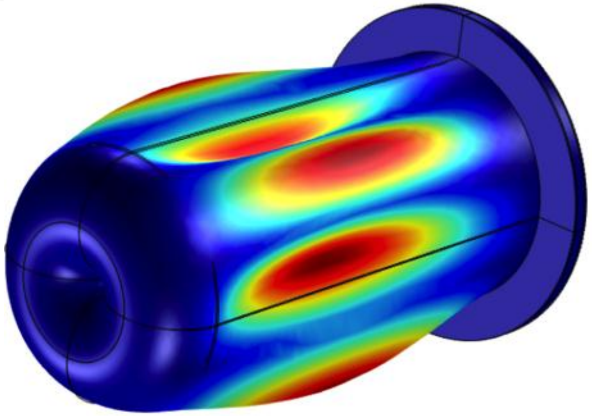








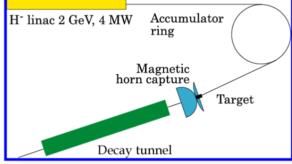
Horn displacement (max. 1.2 mm)

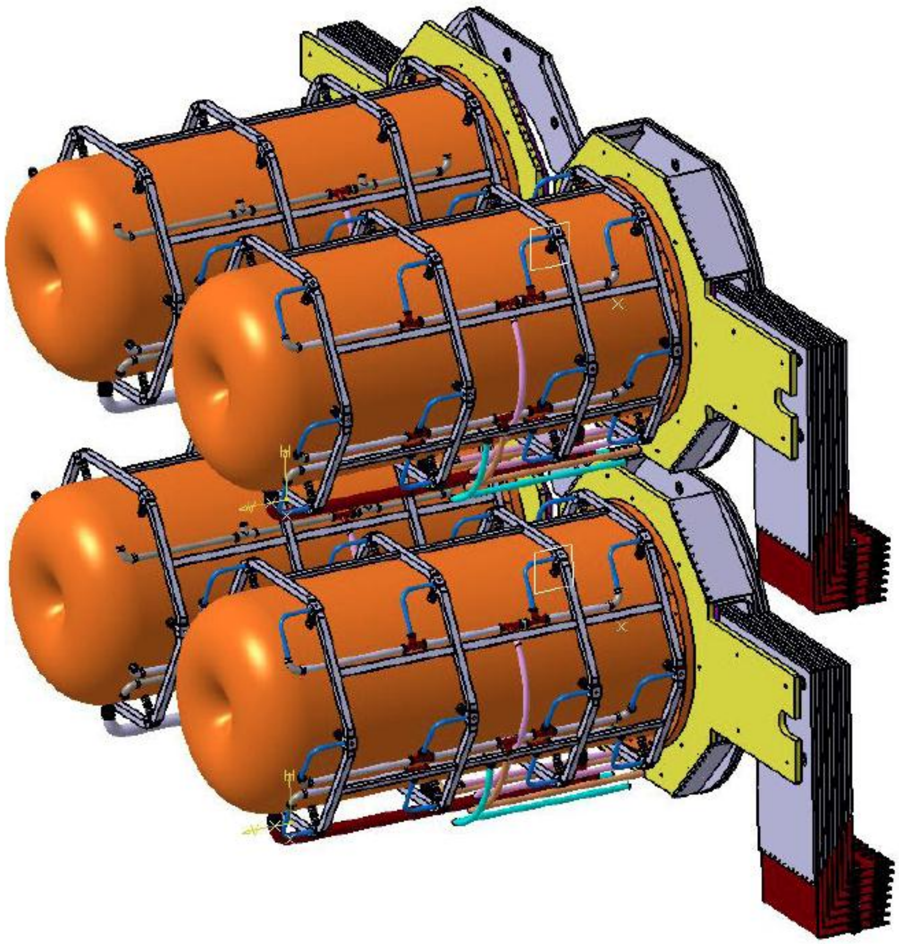


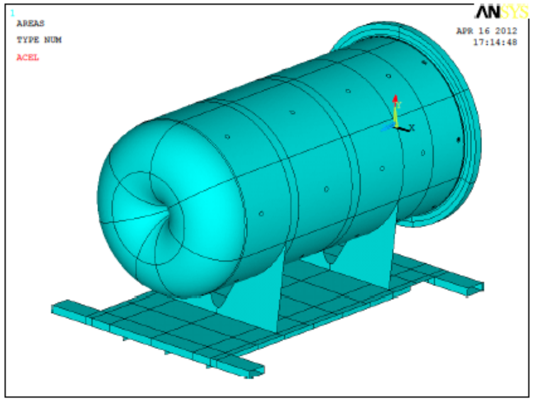
f) $f = 144.2$ Hz

Eigen frequency studies

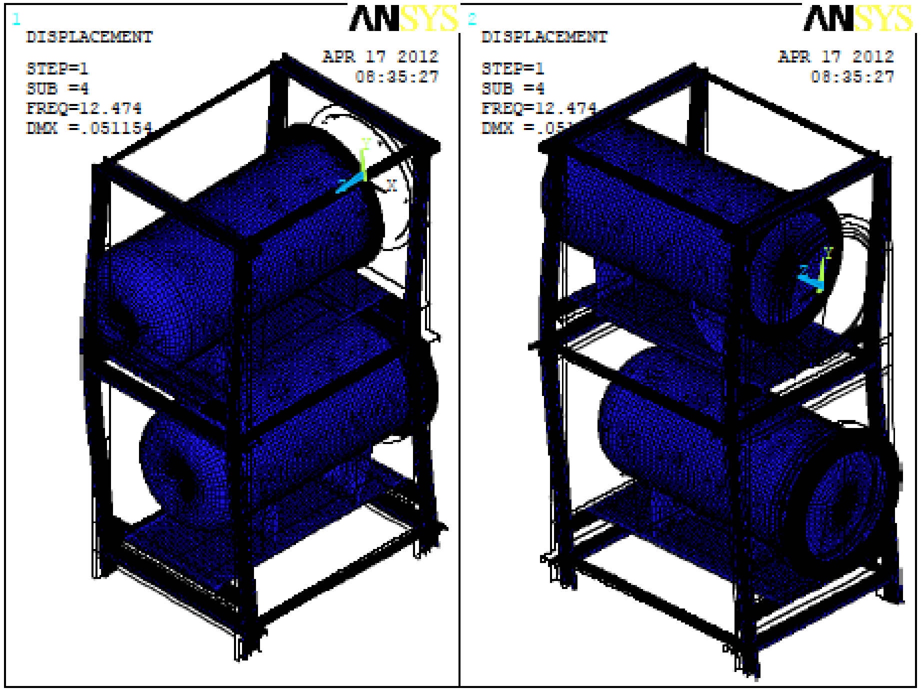
4-Horn system





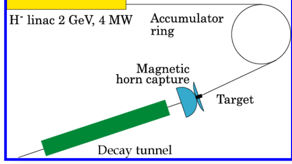


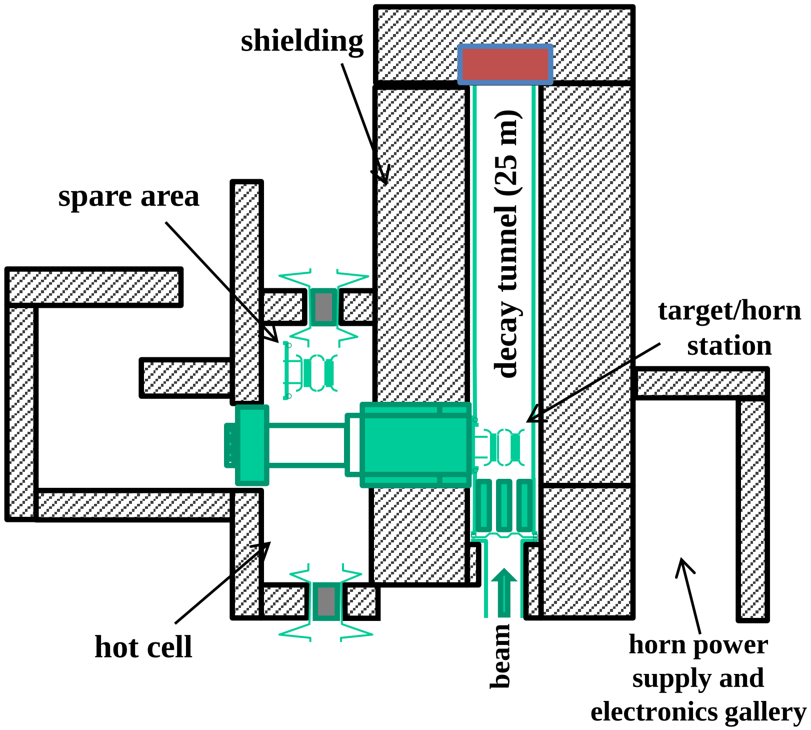
supporting structure



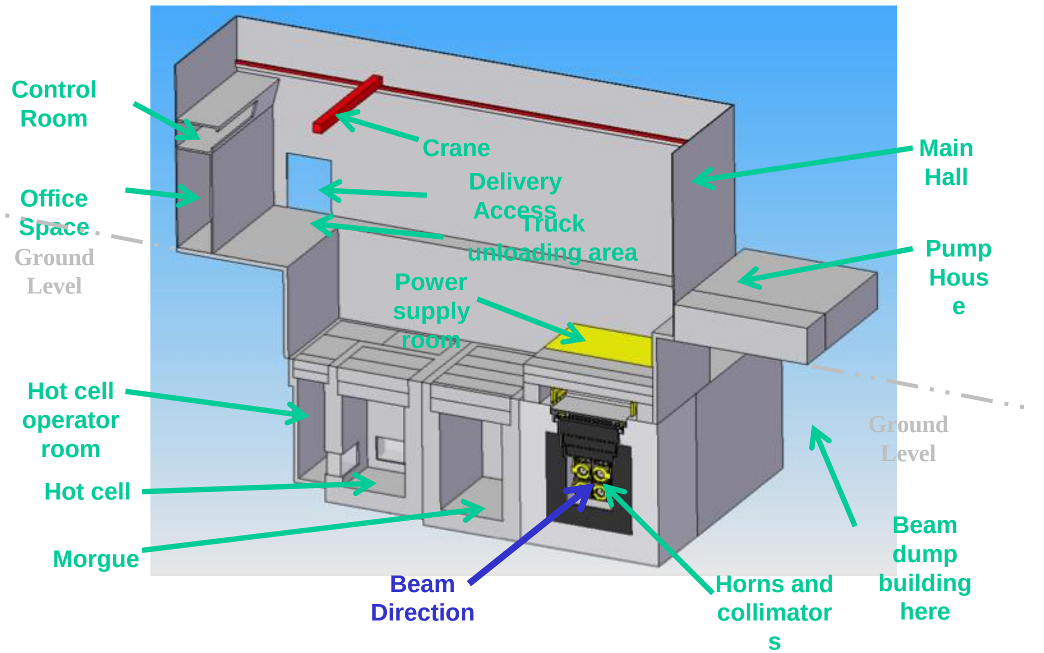
Displacement studies

Layout

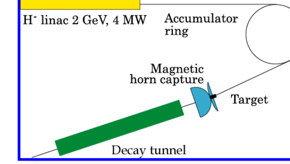


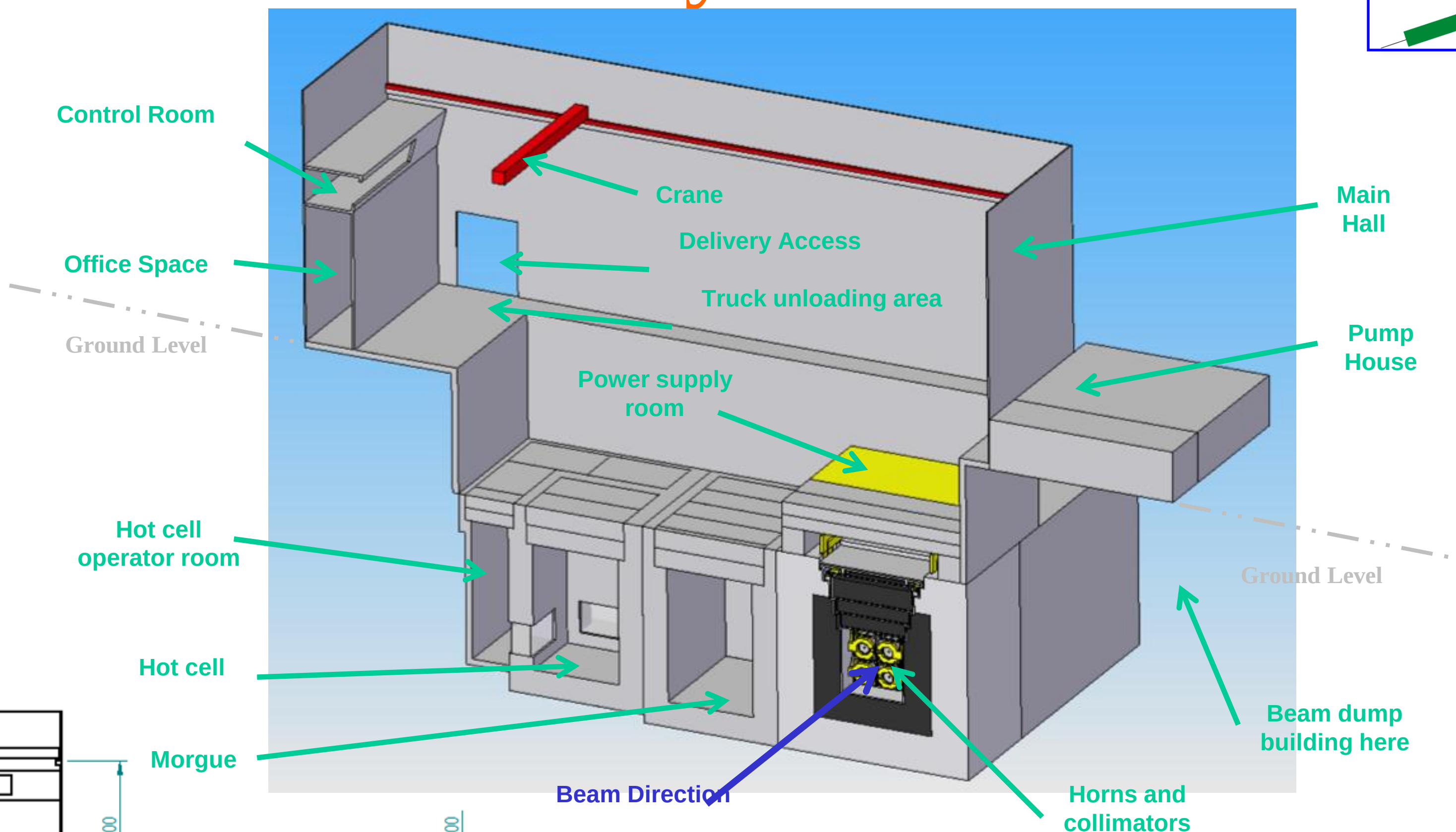


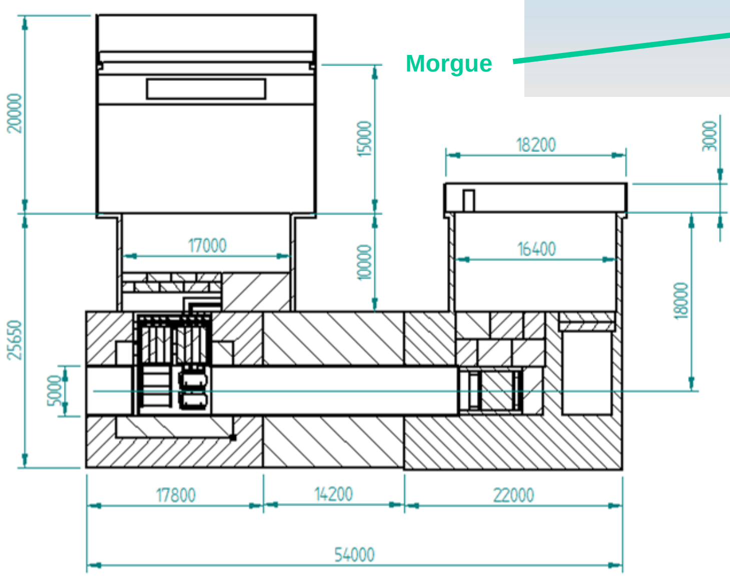
T2K like installation

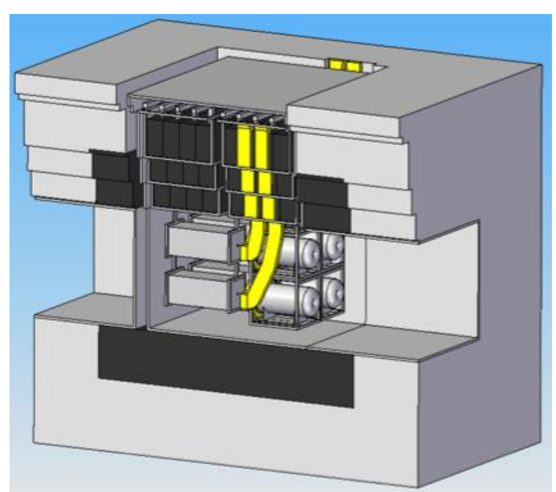


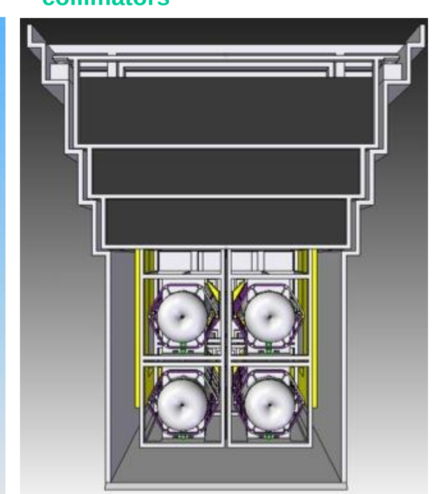
Layout


H⁻ linac 2 GeV, 4 MW
Accumulator ring
Magnetic horn capture
Target
Decay tunnel

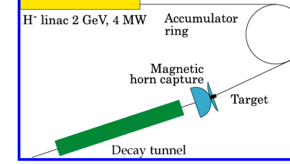

Control Room
Crane
Office Space
Delivery Access
Truck unloading area
Main Hall
Ground Level
Pump House
Power supply room
Hot cell operator room
Ground Level
Hot cell
Beam dump building here
Morgue
Beam Direction
Horns and collimators

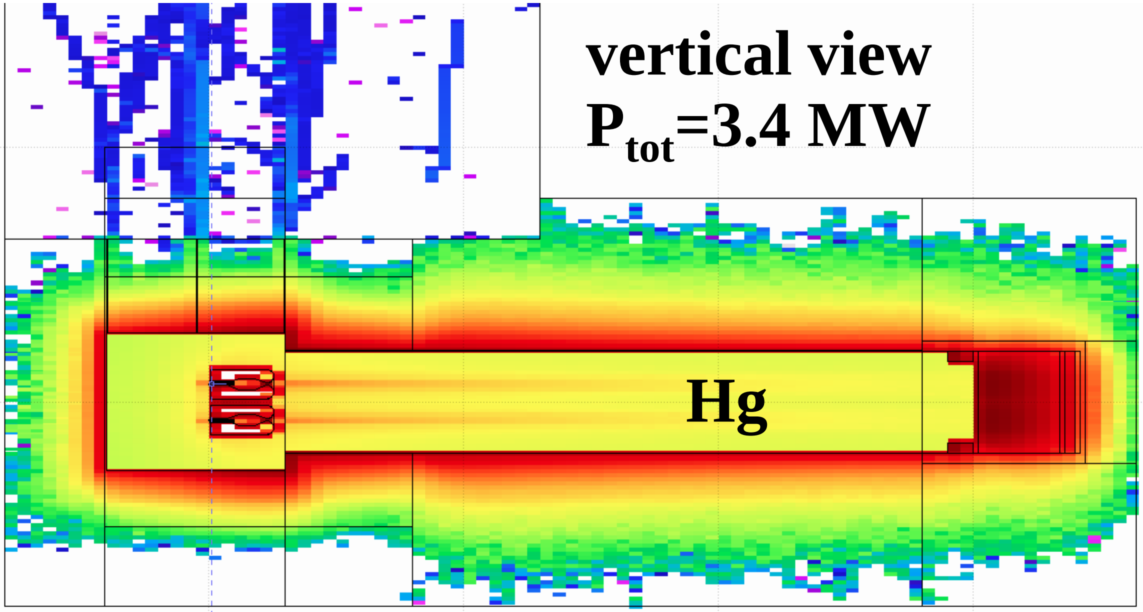

20000
15000
3000
18200
17000
10000
16400
18000
25650
5000
17800
14200
22000
54000



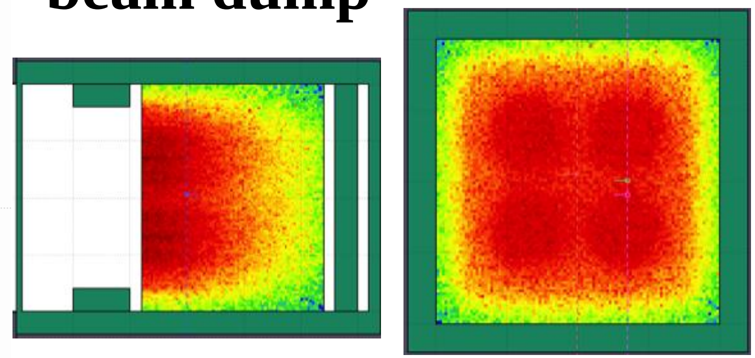


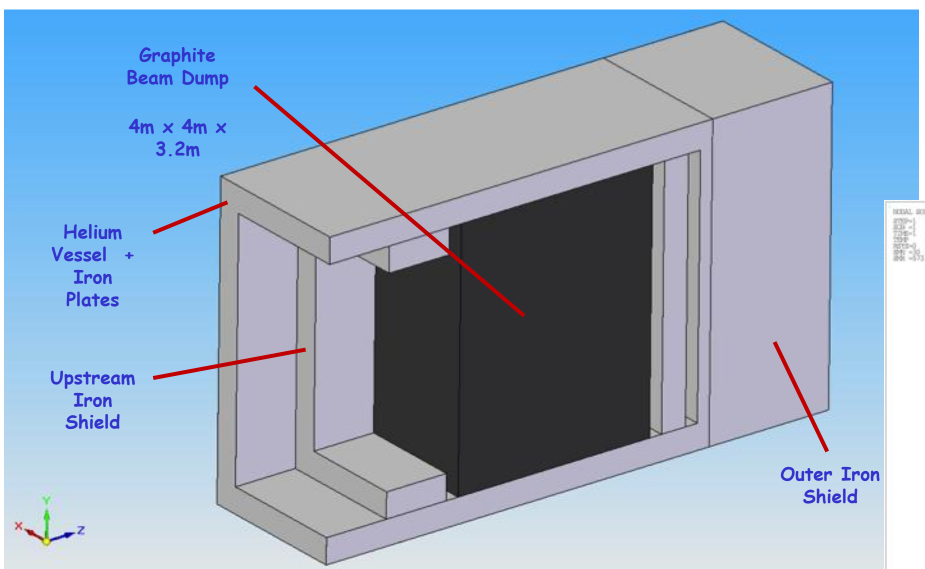
Radiation Studies



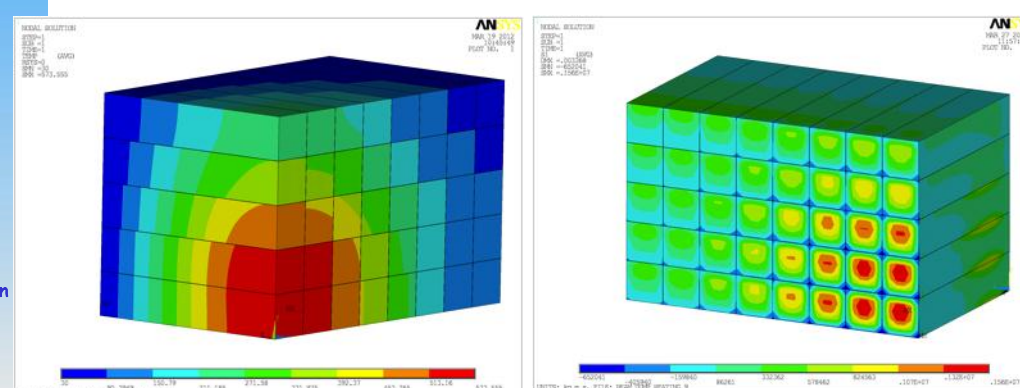


beam dump **780 kW**

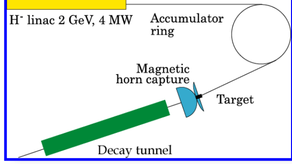




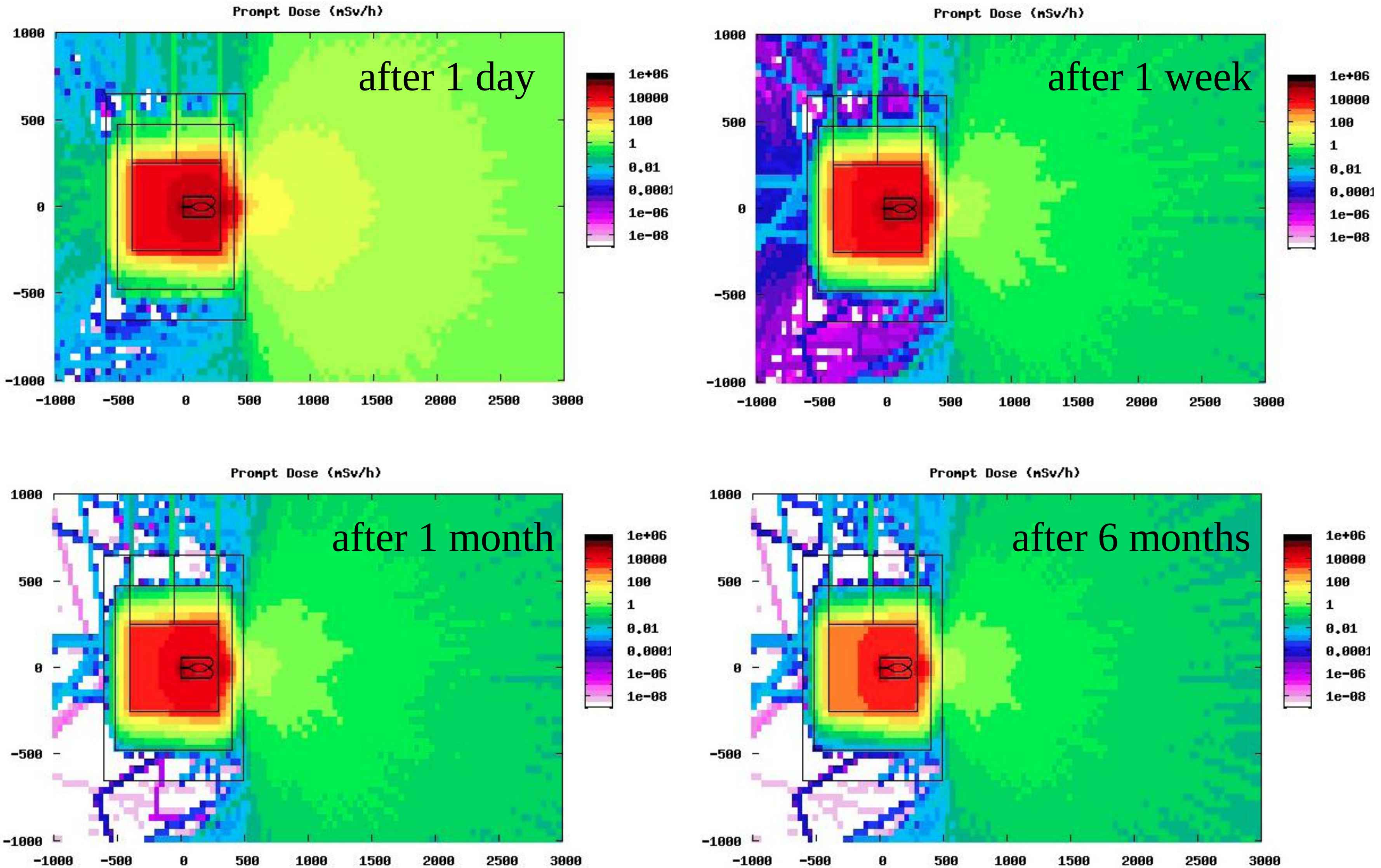
Graphite blocks, helium conduction across 2 mm gaps, T_{max} = 575 ° C, tensile stress < 1.56 MPa



Safety and Activation studies

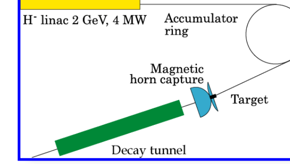


around the target station after 200 running days (1 year)

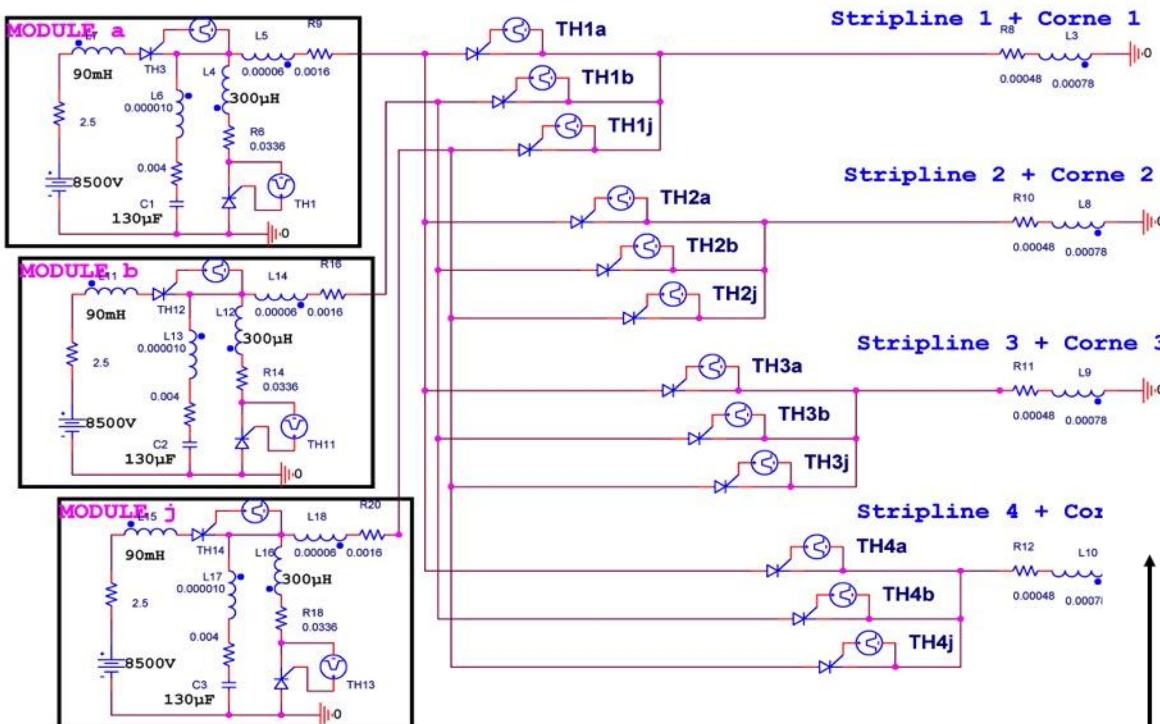


Power Supply for horn pulsing

(another challenge)

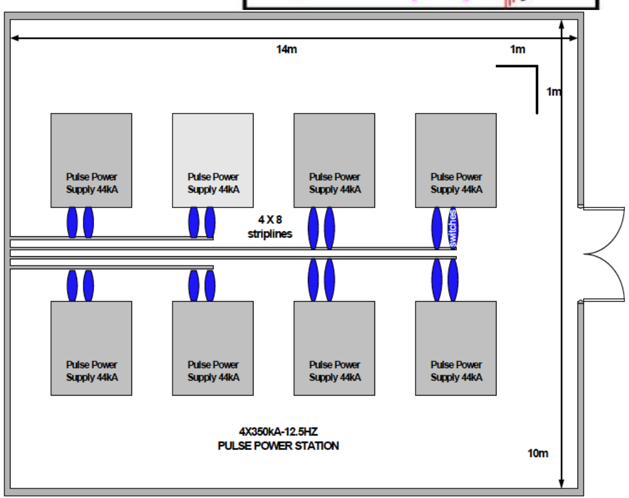


8 MODULES

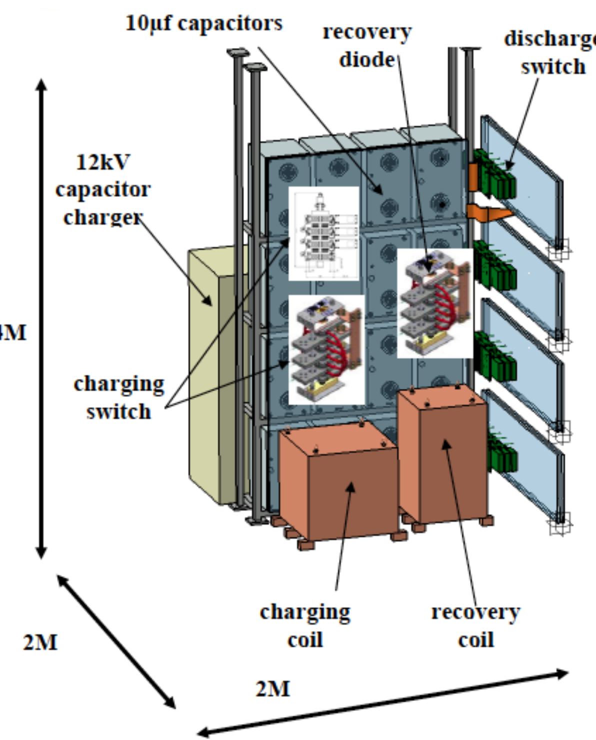


- each MODULE delivers a current of 44kA max at F=50HZ

- For each HORN : current of 350kA max at 12.5HZ

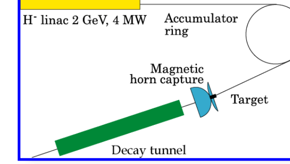


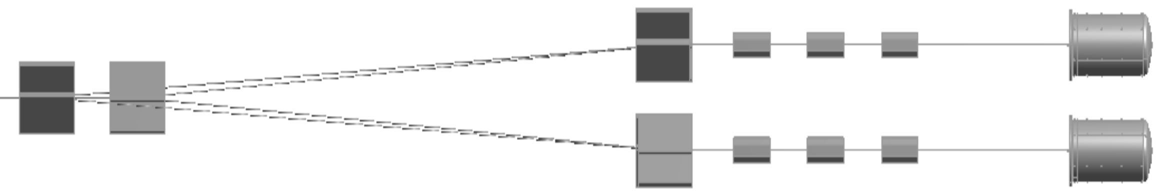
- energy recuperation (>90%) and reinjection
- lifetime > 13 Bcycles (10 years, 200 days/year)



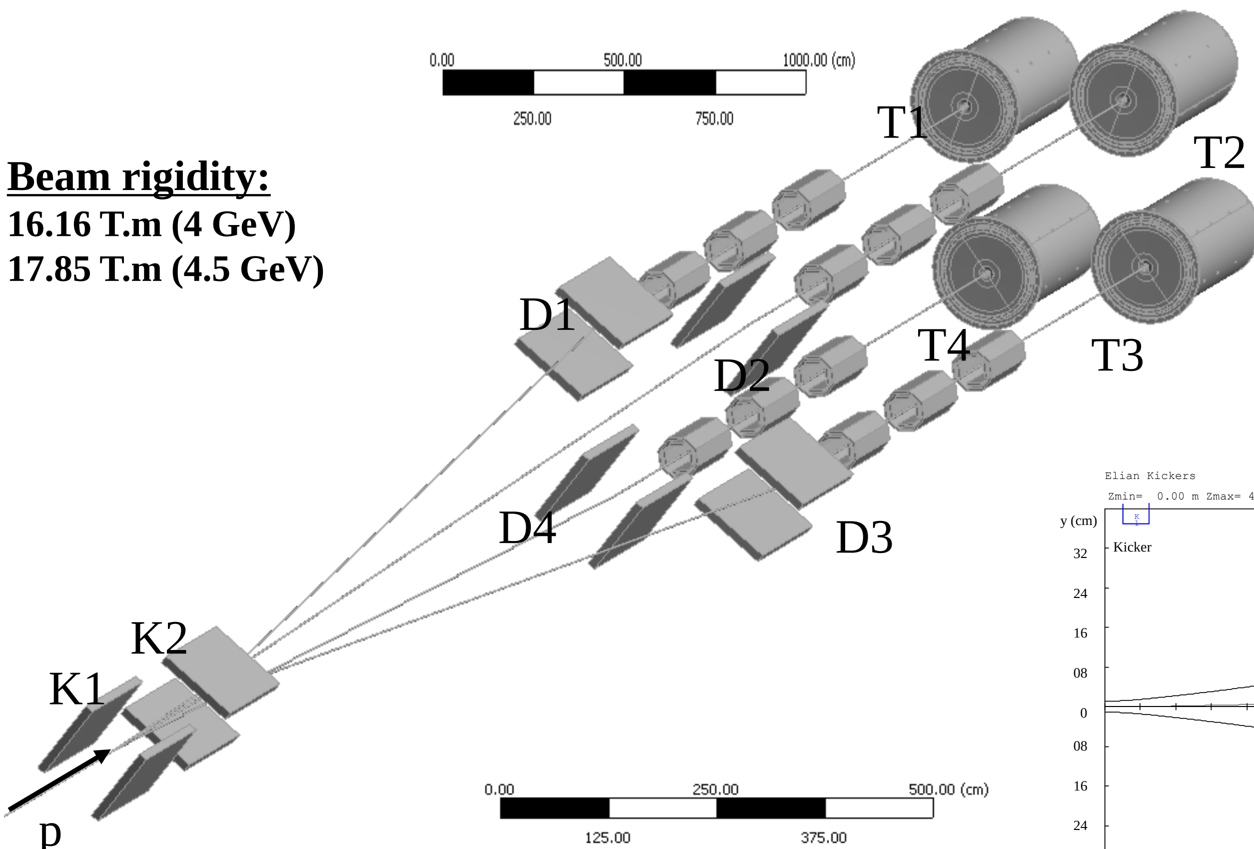
M. Dracos

4-proton lines





Energy	4-5 GeV
Beam Power	4 MW
Proton per pulse	1.1 x 10^{+14}
Rep. rate	50 Hz
Pulse duration	3.2 μs
Beam shape	Gaussian
Emittances rms	3π mm mrad**

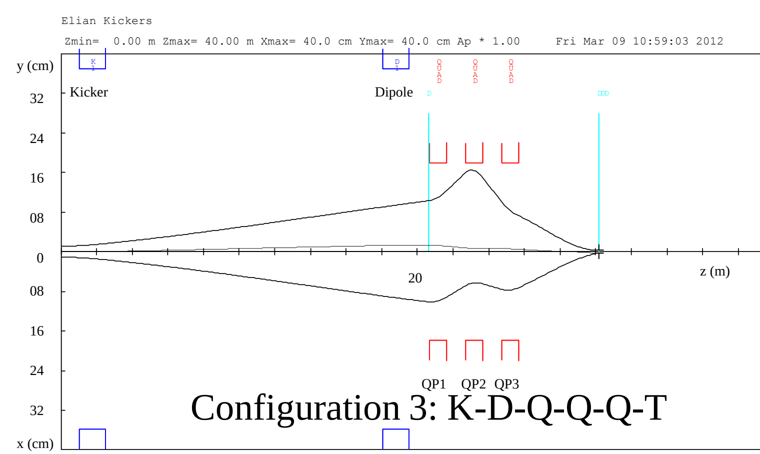


Beam rigidity:

16.16 T.m (4 GeV)

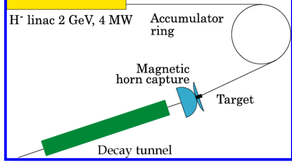
17.85 T.m (4.5 GeV)

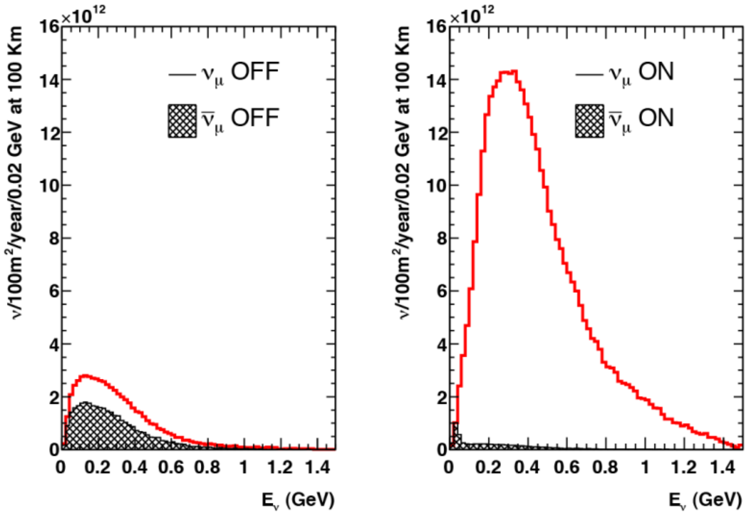
Target length	78 cm
Target radius	1.5 cm
Beam shape	Gaussian
Rep. rate	12.5 Hz
Pulse duration	3.2 μs
Sigma	4 mm



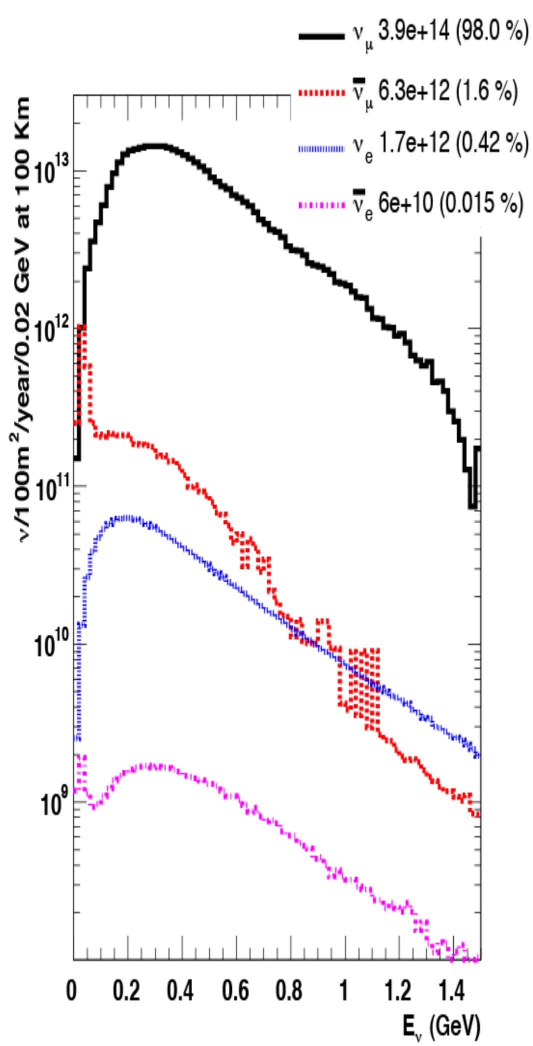
Configuration 3: K-D-Q-Q-Q-T

Neutrino Spectra

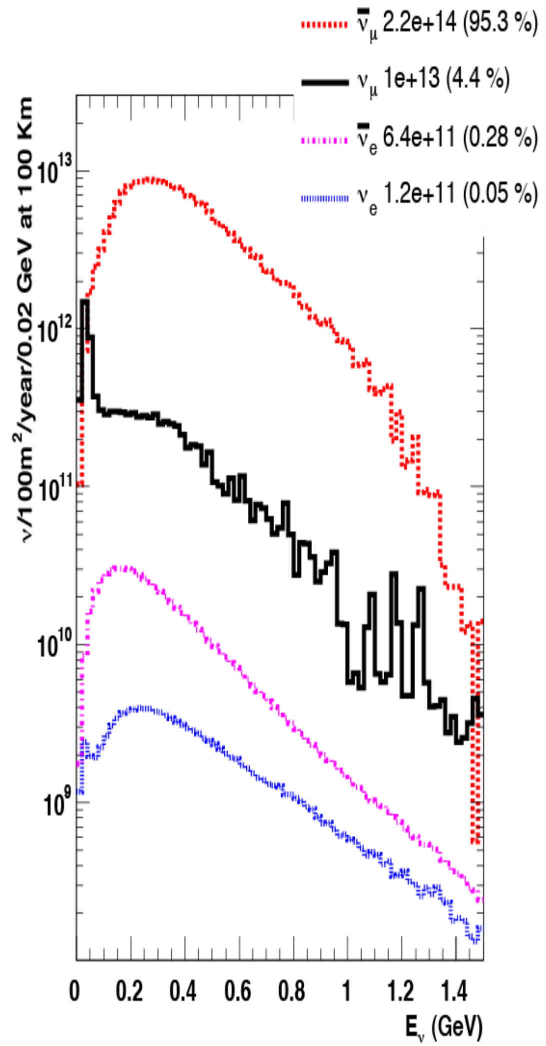




horn on/off

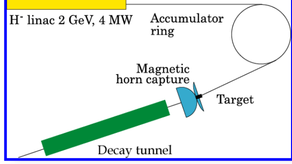


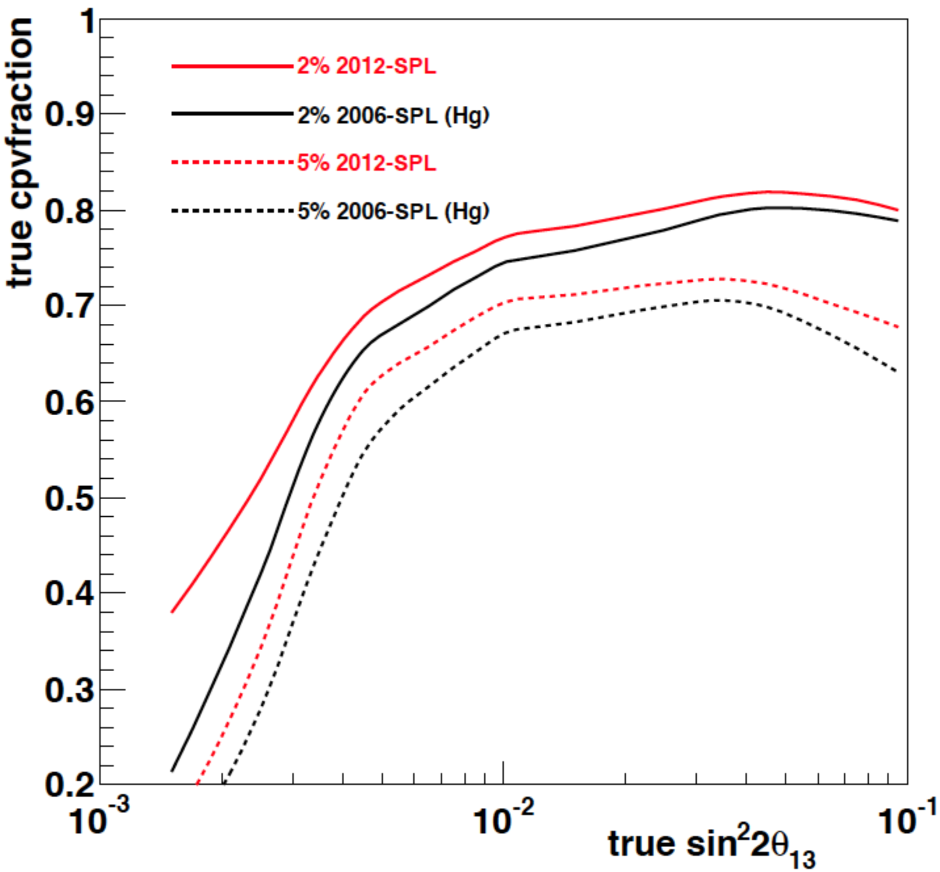
neutrinos

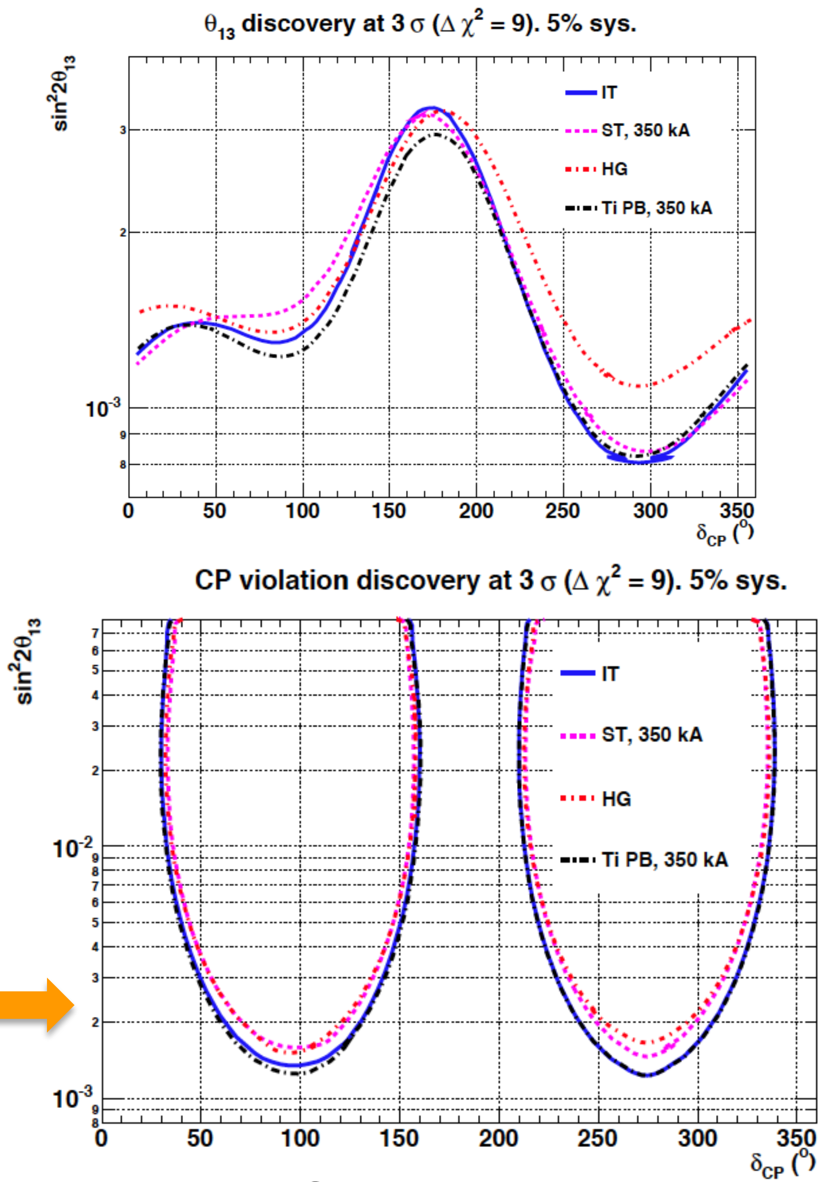


anti-neutrinos

Physics Performance





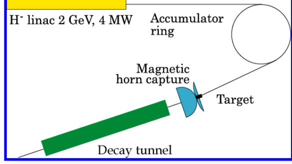


better results with the new horn geometry and target

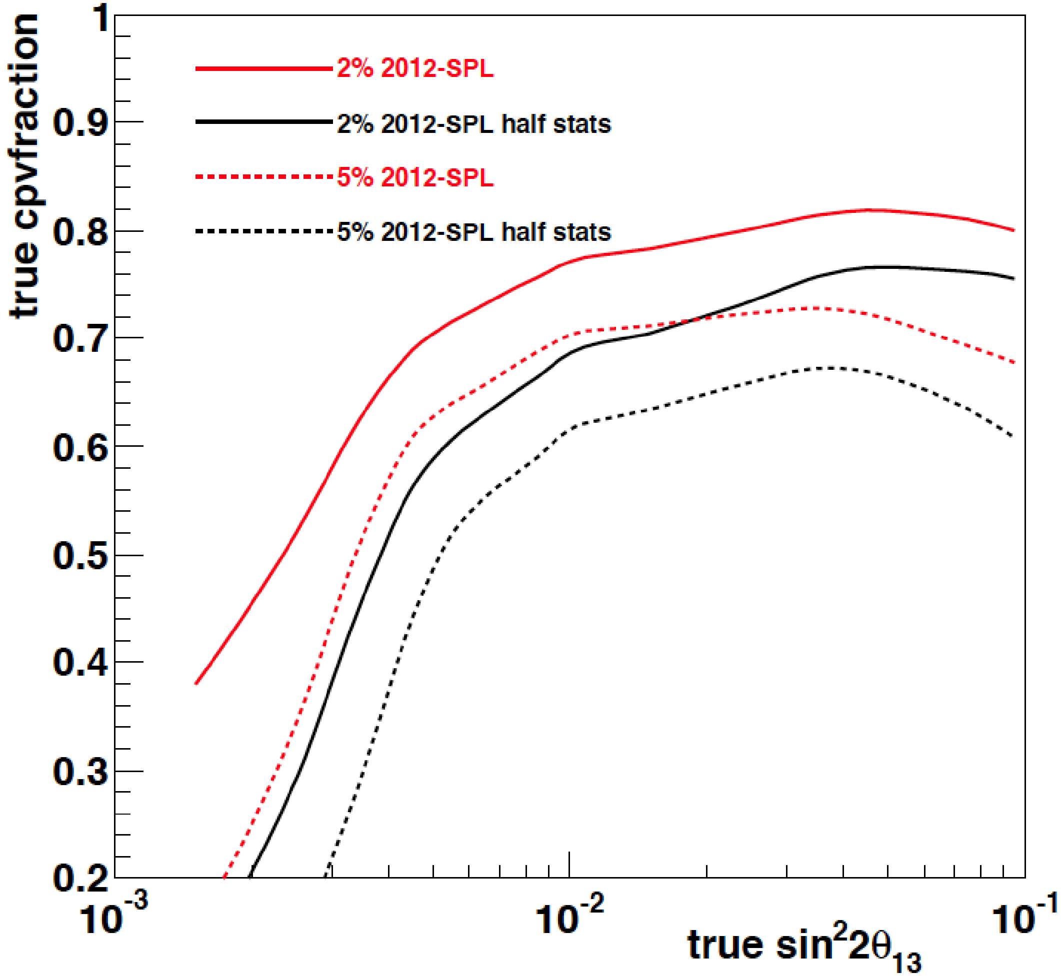
➡

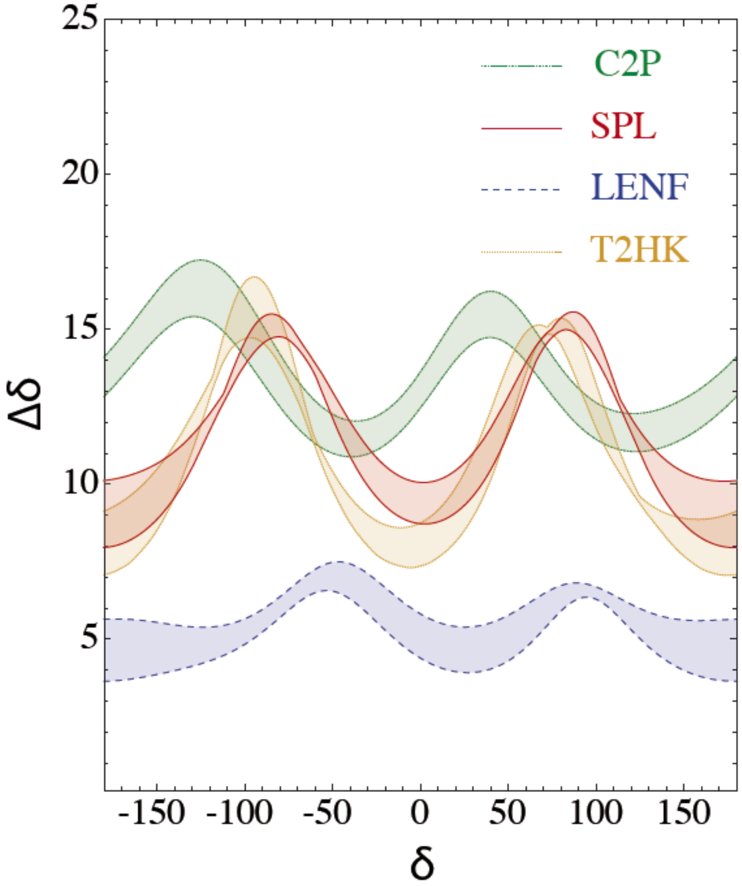
very promising (baseline)

final design



Physics Performance

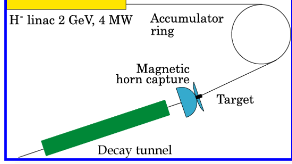


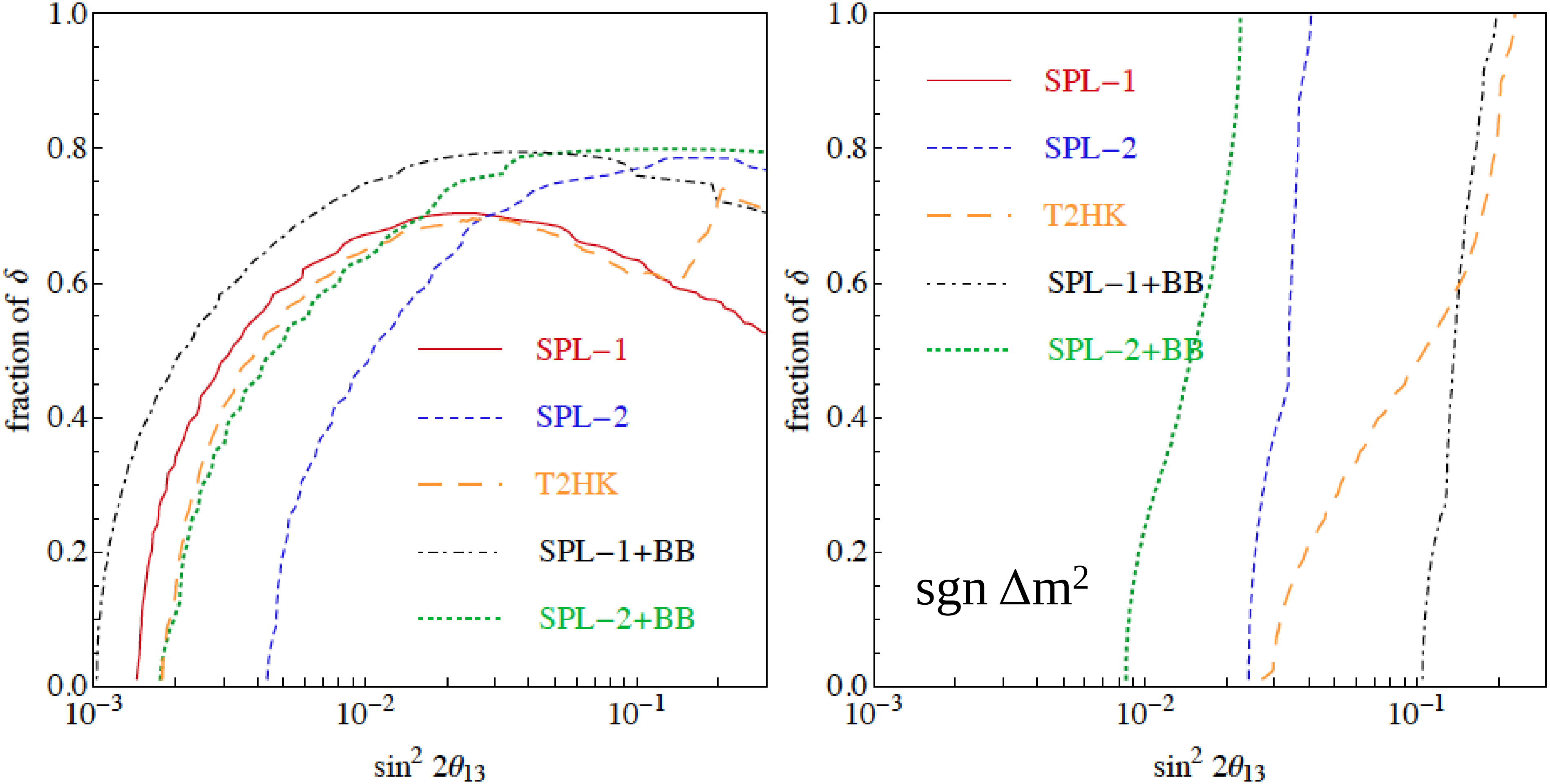


$sin^2 2\theta_{13} = 0.1$

arXiv:1203.5651v1

Physics Performance



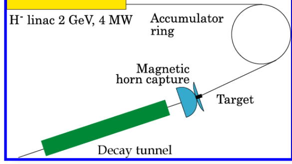


- SPL-1: CERN to Fréjus (130 km)
- SPL-2: CERN to Canfranc (650 km)

1 Mton WC detector (440 kton fiducial), 5% syst.

arXiv:1110.4583

Mass Hierarchy

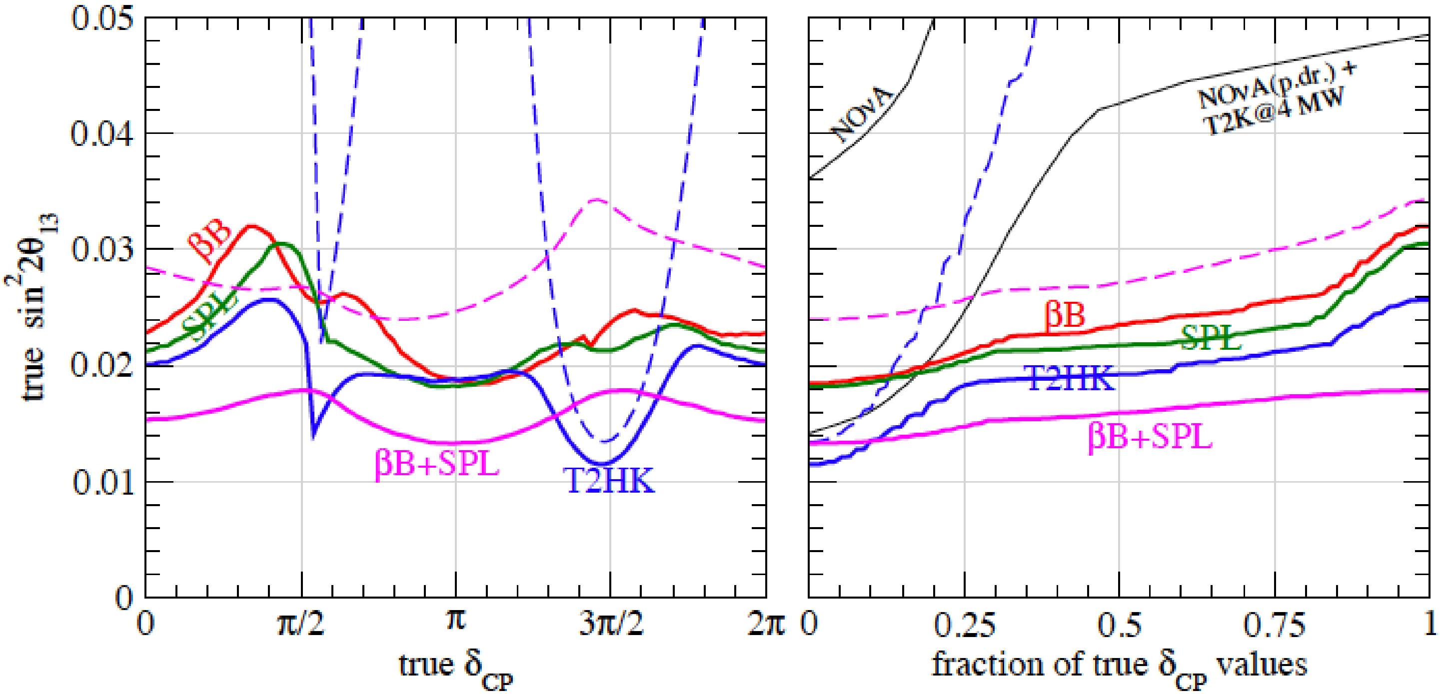


arXiv:hep-ph/0603172v3

For $\sin^2 2\theta_{13}$ = 0.1, it is quite likely that with ~Mt yr atm neutrino data from a WC detector we will determine the hierarchy (T. Schwetz)

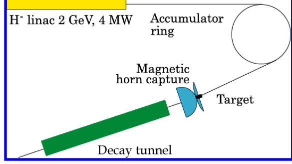
	βB	SPL	T2HK
Detector mass	440 kt	440 kt	440 kt
Baseline	130 km	130 km	295 km
Running time ($\nu + \bar{\nu}$)	5 + 5 yr	2 + 8 yr	2 + 8 yr
Beam intensity	$5.8\,(2.2) \cdot 10^{18}$ He (Ne) dcys/yr	4 MW	4 MW
Systematics on signal	2%	2%	2%
Systematics on backgr.	2%	2%	2%

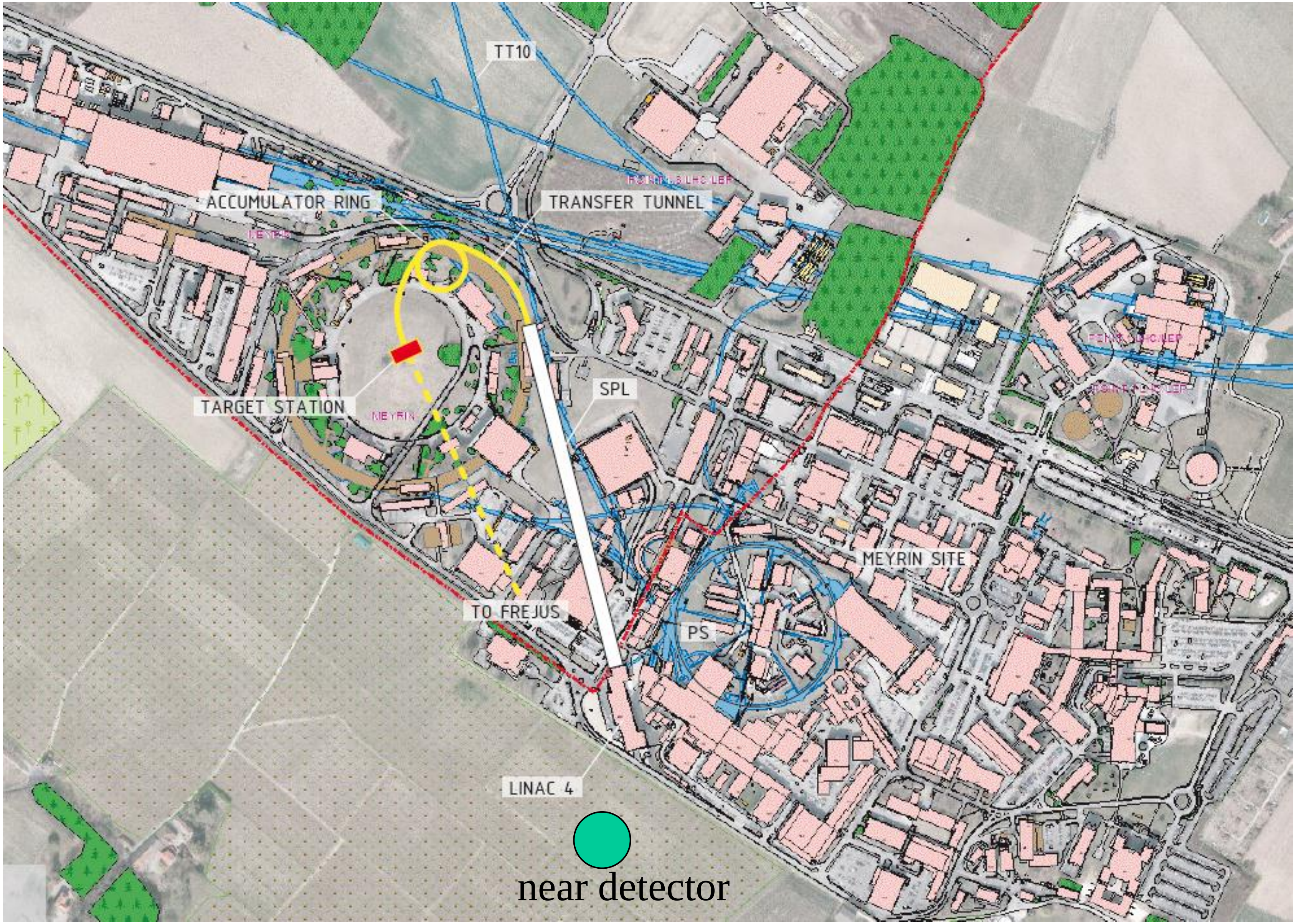
2σ sensitivity to normal hierarchy from LBL + ATM data

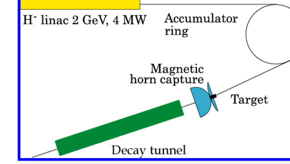


- solid line: LBL+atm.
- dashed line: LBL

HP-SPL Super Beam at CERN

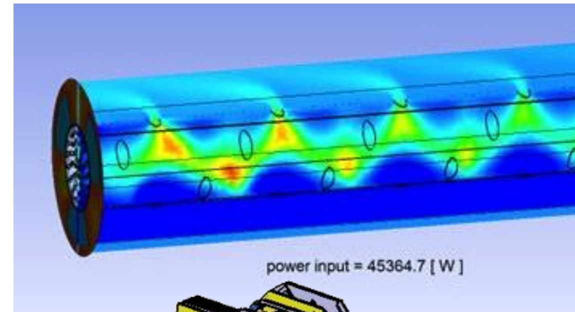


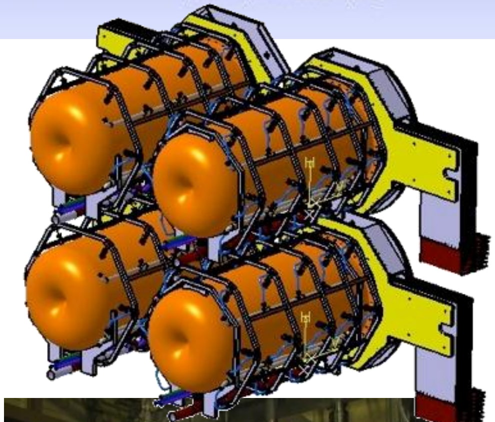




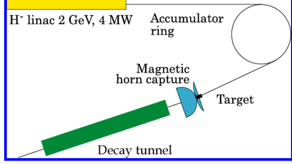
After EUROν

- R&D is needed for:
  - target
  - horn
  - horn pulsing system
- When?
  - next relevant EU call (Horizon2020)?

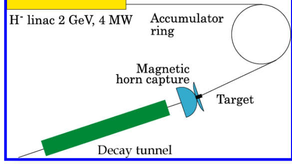




Conclusions

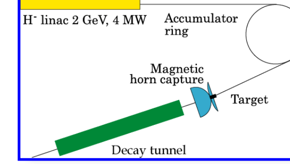


- The SPL to Fréjus Super Beam project is under study in FP7 EUROnu WP2:
  - Conventional technology
  - Many synergies with other projects
  - Very competitive CP sensitivity
- Work in EUROν:
  - physics performance has been improved.
  - the proposed system is now feasible and reliable
- We have started freezing all elements of this facility.
- Cost estimation very soon.
- The physics potential of this project is very high (also for astrophysics) especially in case of SB/BB combination.
- R&D is needed.

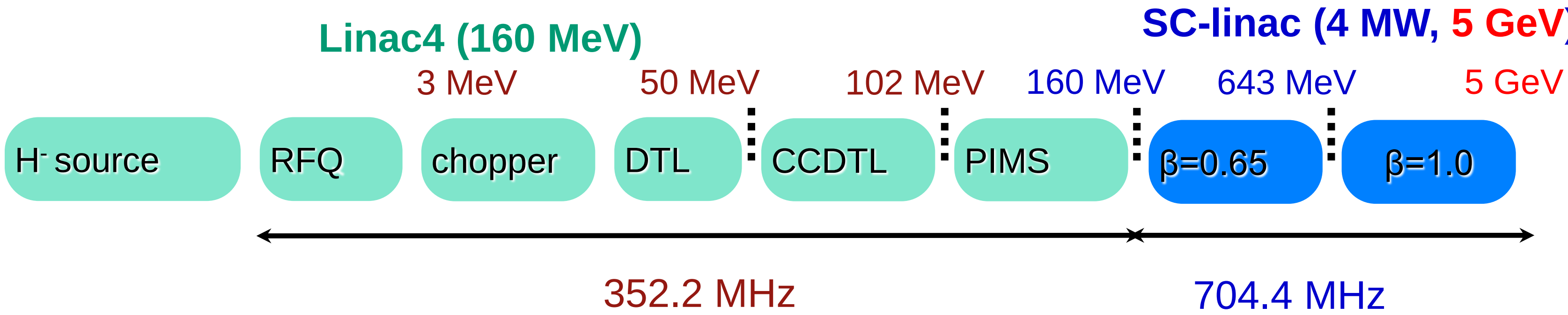

H- linac 2 GeV, 4 MW
Accumulator ring
Magnetic horn capture
Target
Decay tunnel

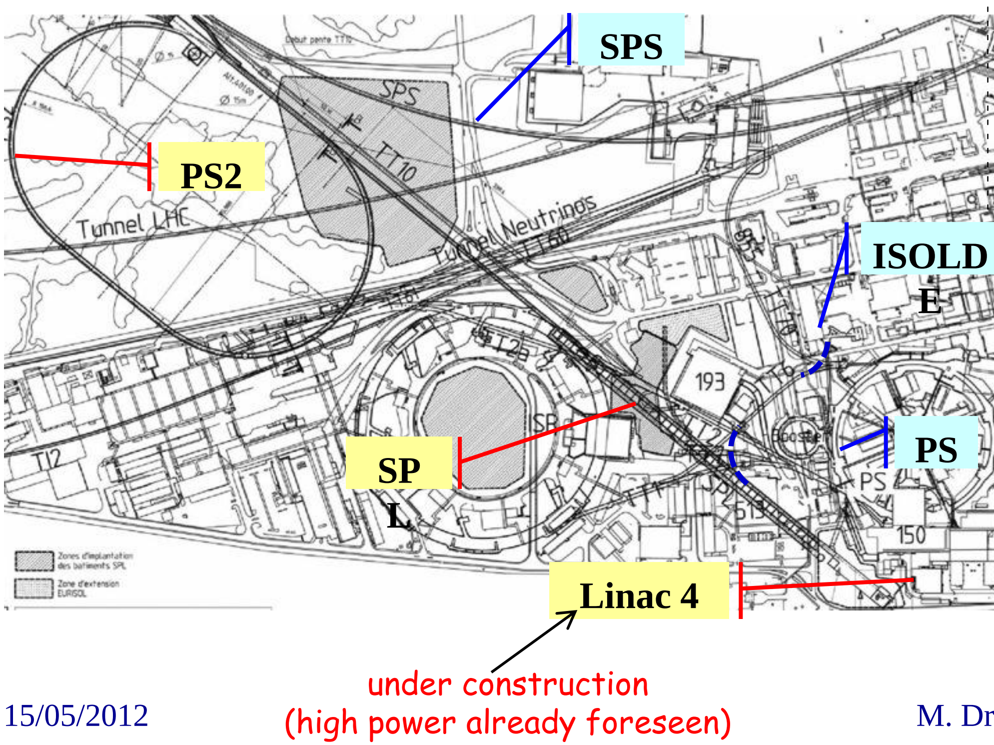
End

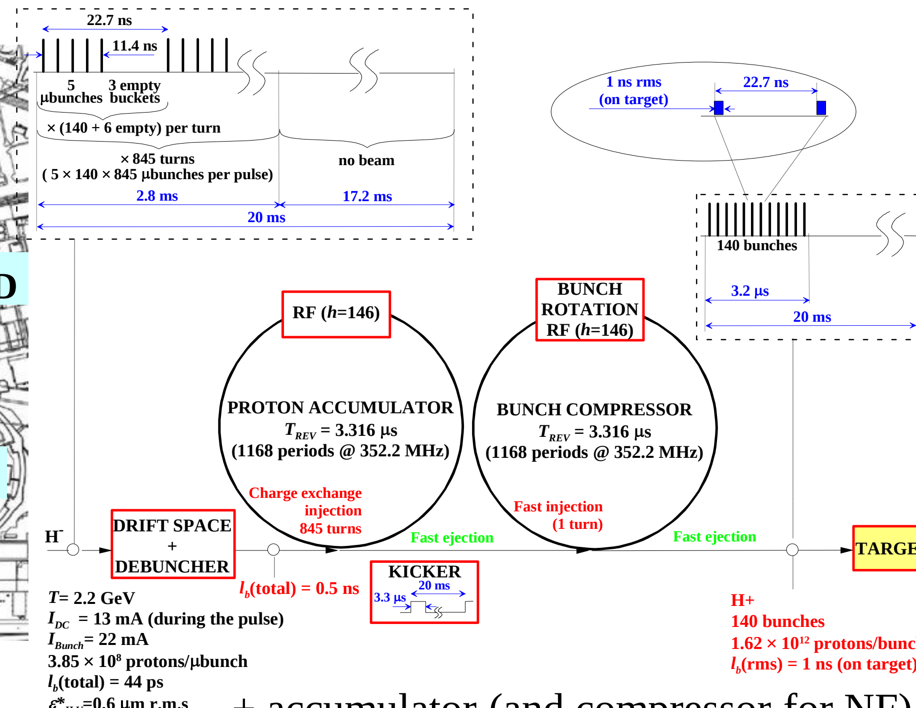
HP-SPL for Neutrino Beams



- CDR for 2.2 and 3.5 GeV HP-SPL already published (CERN 2000-012, CERN 2006-006)

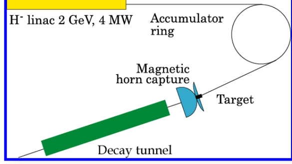






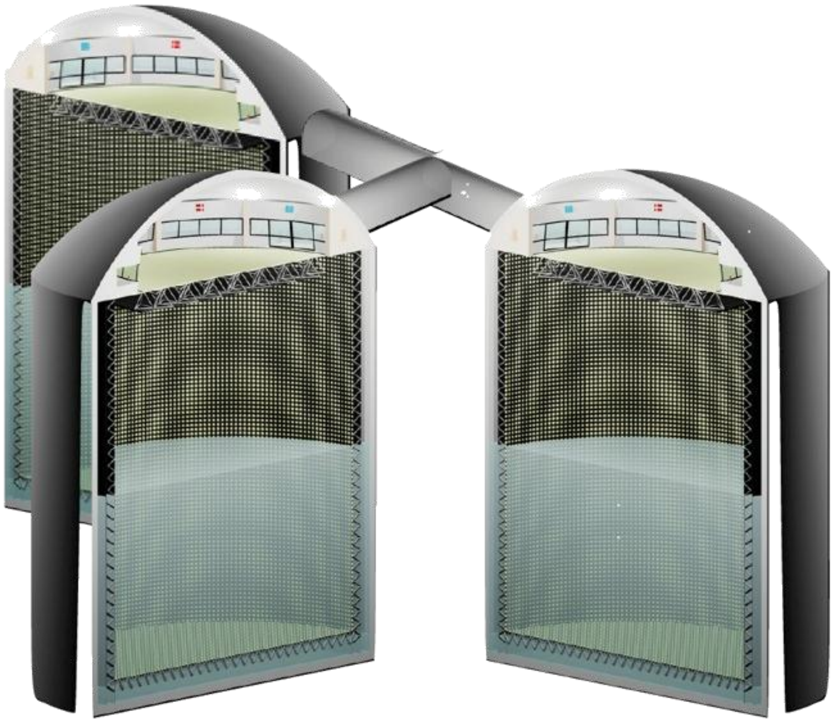
+ accumulator (and compressor for NF)

The MEMPHYS Project
(within FP7 LAGUNA DS)



Mainly to study:

- **Proton Decay (GUT)**
  - **up to ~10^{35} years lifetime**
- **Neutrino properties and Astrophysics**
  - **Supernovae (burst + "relics")**
  - **Solar neutrinos**
  - **Atmospheric neutrinos**
  - **Geoneutrinos**
  - **neutrinos from accelerators (Super Beam, Beta Beam)**

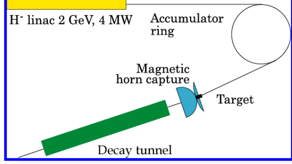


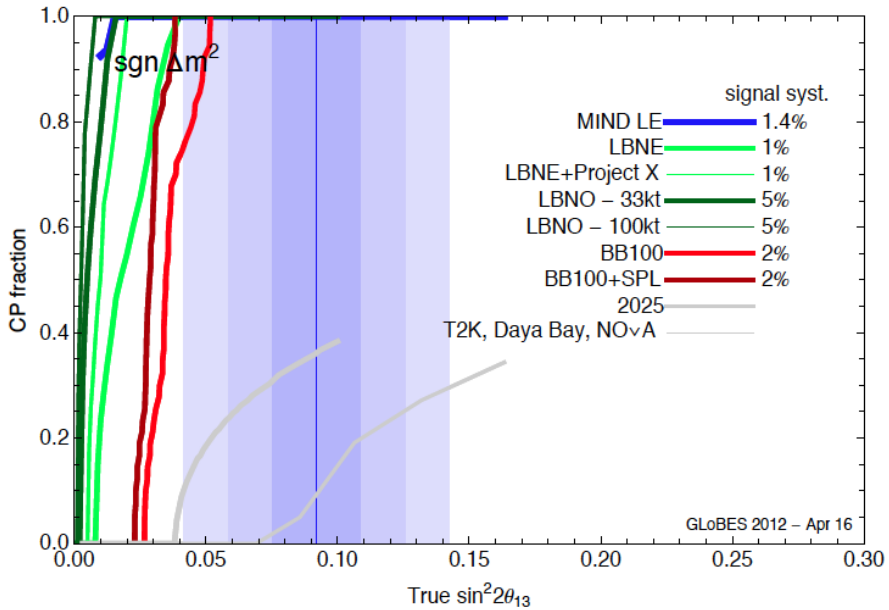
Water Cerenkov Detector with total fiducial mass: 440 kt:
- **3 Cylindrical modules 65x65 m**
- **Readout: 3x81k 12” PMTs, 30% geom. cover.**

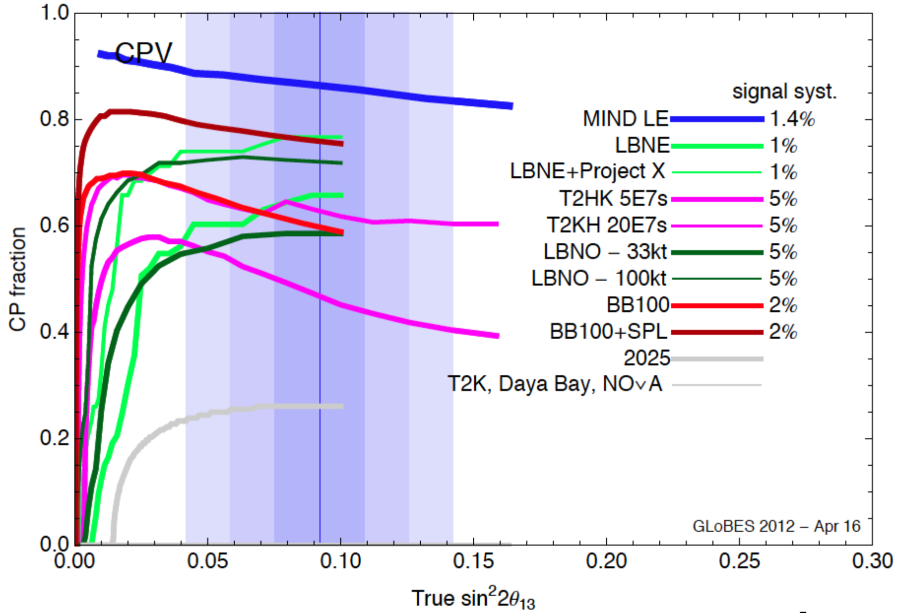
(#PEs =40% cov. with 20” PMTs).

(arXiv: hep-ex/0607026)

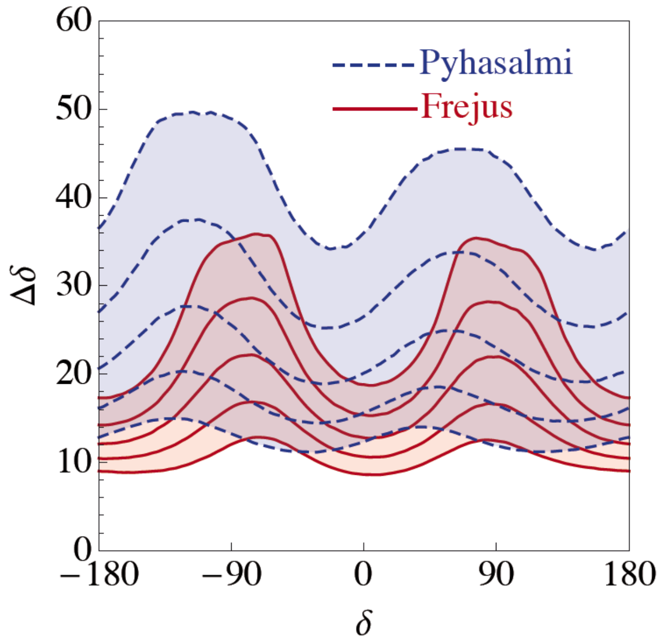
Physics Performance







P. Huber



$\sin^2 2\theta_{13} = 0.1$

Enrique Fernandez-Martinez