THE EUROnu PROJECT:
"A High Intensity Neutrino Oscillation Facility In Europe"

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Rob Edgecock, STFC/RAL

EUROnu

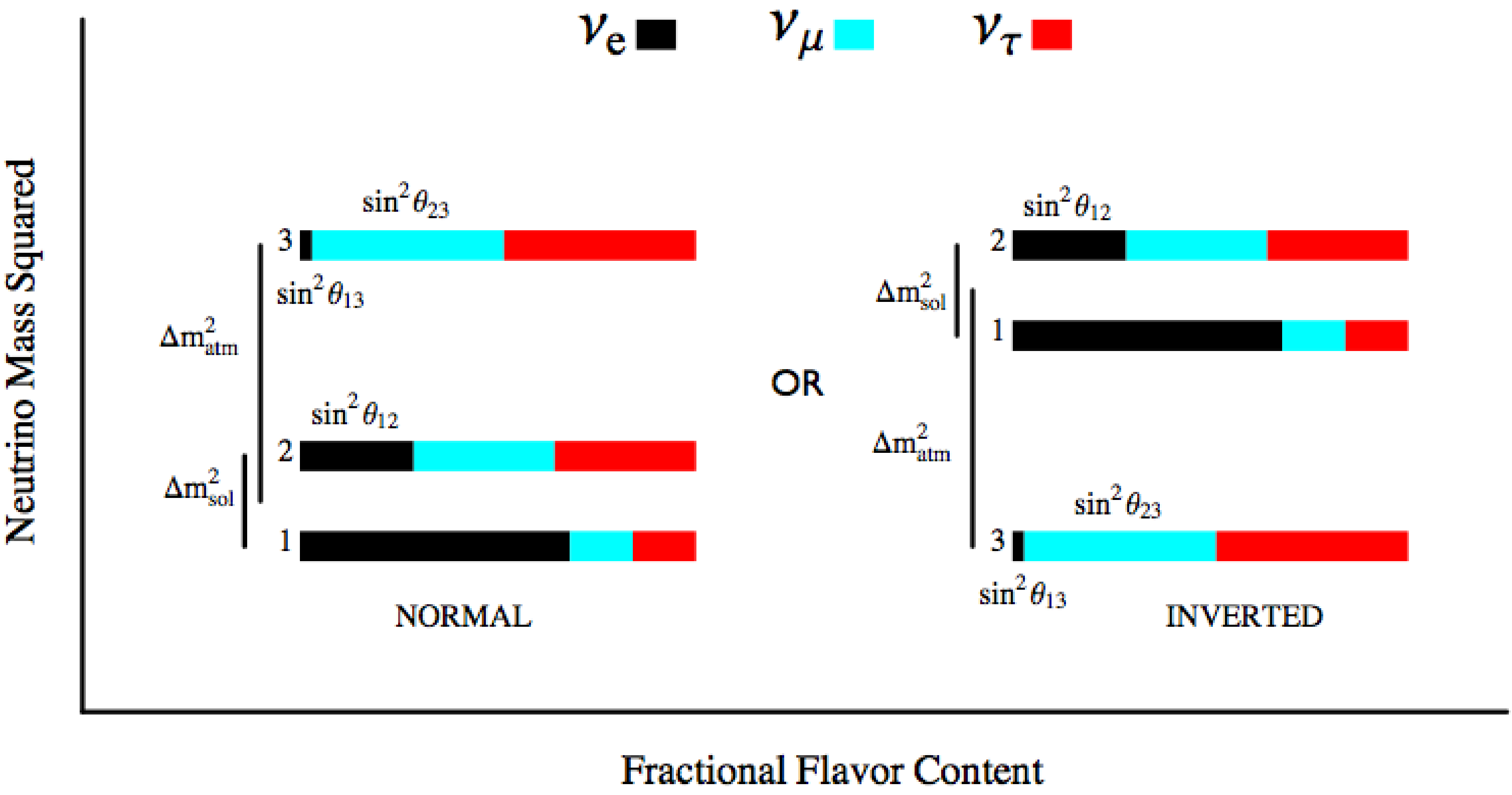
- FP7 Design Study
- Focus on possible “next” generation neutrino oscillation facilities in Europe
  - CERN to Frejus Superbeam (SB)
  - Neutrino Factory (NF), in collaboration with IDS-NF
  - Beta Beams (BB)
  - Performance of baseline detectors and physics reach
- Aim: comparison of physics, “cost” & risk
- Reported to CERN Council via SG/ECFA
- Project started: 1st September 2008
- Duration: 4 years – completion in August 2012

Partners

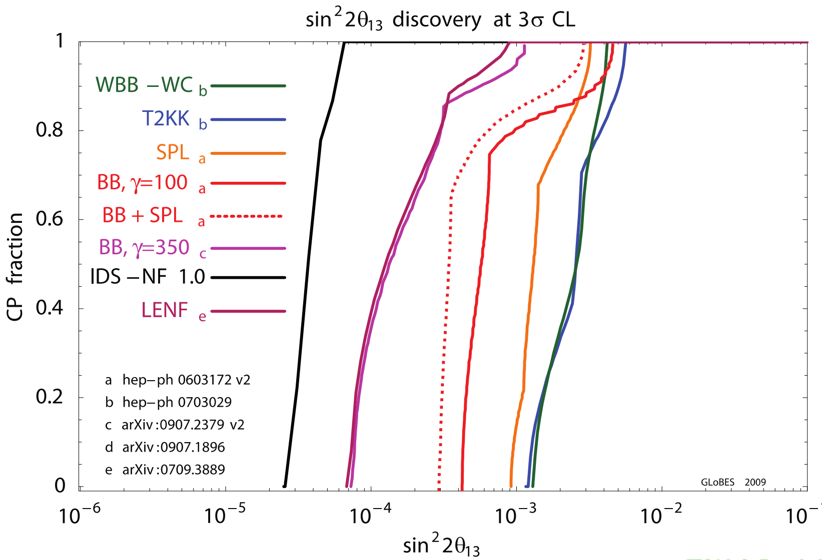
Country	Partner
Belgium	Louvain
Bulgaria	Sofia
France	CEA
	CNRS (4)
Germany	MPG (3)
Italy	INFN (3)
Poland	Cracow
Spain	CSIC (2)
Switzerland	CERN
UK	Durham
	Glasgow
	Imperial
	Oxford
	STFC
	Warwick

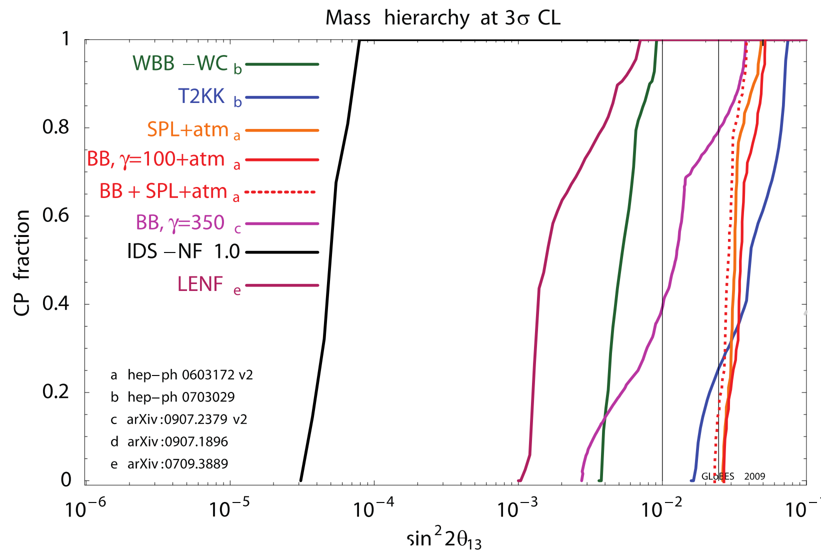
Country	Associate
Canada	TRIUMF
France	GANIL
Germany	Aachen
India	INO
Israel	Weizmann
Portugal	Lisbon
Russia	IAP, Novgorad
	JINR, Dubna
Switzerland	Geneva
UK	Brunel
USA	Argonne
	Brookhaven
	FNAL
	Virginia Tech
	Muon Collaboration

EUROnu physics I



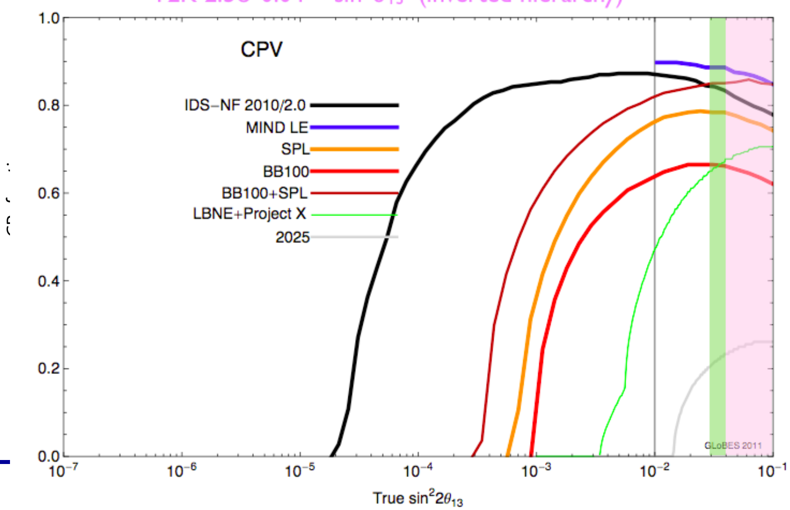
EUROnu physics II



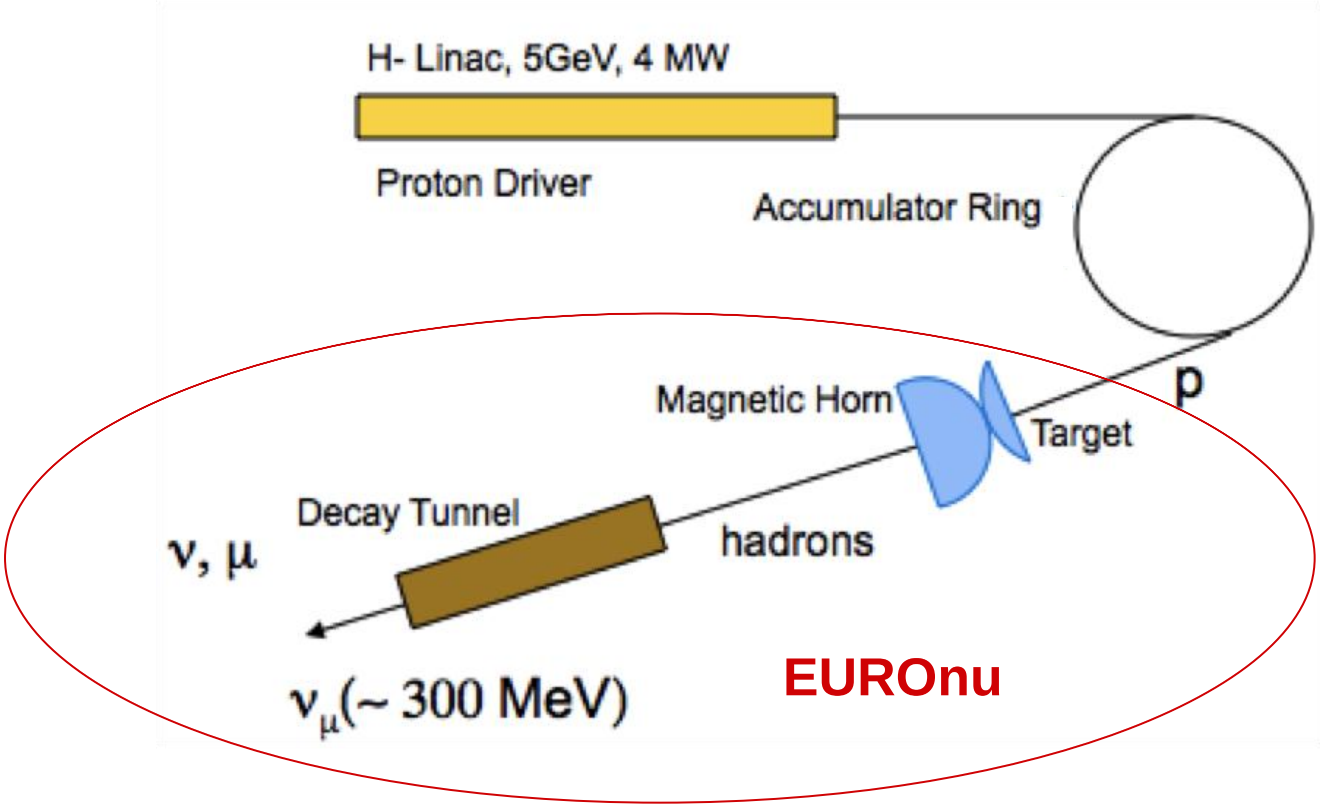


T2K 2.5σ 0.03 < $\sin^2\theta_{13}$ (normal hierarchy)

T2K 2.5σ 0.04 < $\sin^2\theta_{13}$ (inverted hierarchy)



The Superbeam



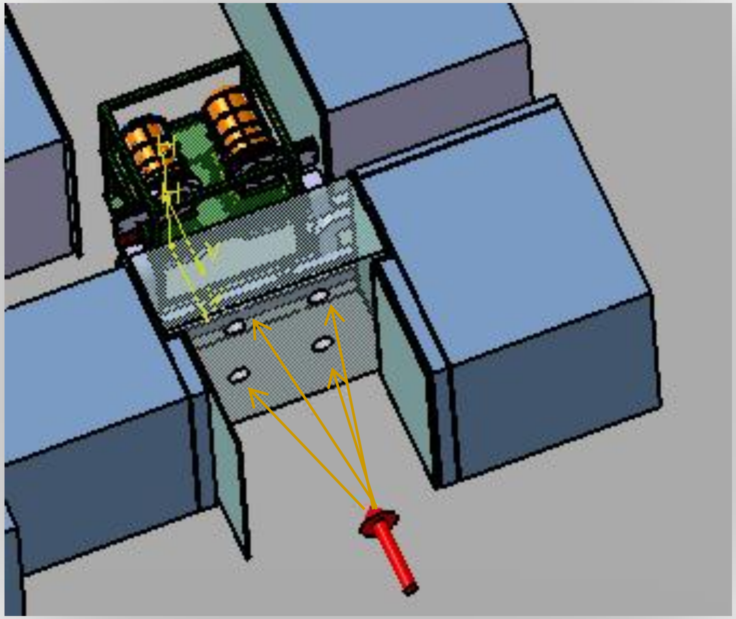
Parameter	Value
Beam Power	4 MW
Beam energy	4.5 GeV
Target length	78 cm
Target radius	1.2 cm
Decay tunnel radius	2m
Decay tunnel length	25m

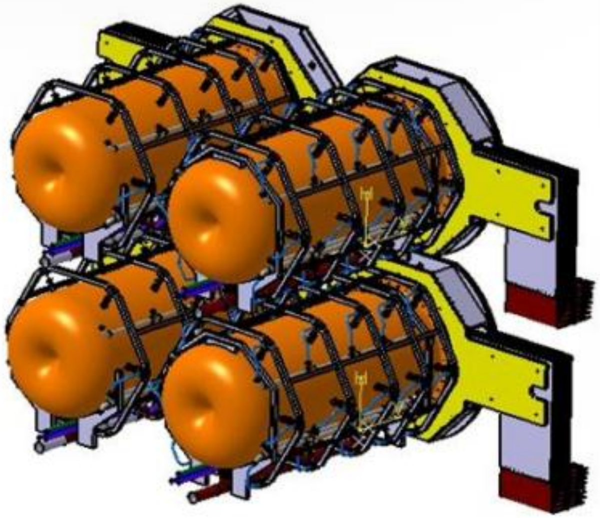
Detector in the Fréjus tunnel

Superbeam favored by T2K hints

4MW accommodation

- E_b = 4.5 GeV
- Beam Power = 4MW -> 4x1-1.3MW
- Repetition Rate = 50Hz -> 12.5Hz
- Protons per pulse = 1.1 x 10^{14}
- Beam pulse length = 0.6ms





- 4-horn/target system in order to accommodate the 4MW
- power @ 1-1.3MW, repetition rate @ 12.5Hz for each target

The Target Choice

Summary of target options

Mercury jet
- high-Z (too many neutrons & heat load on horn)
- not chemically compatible with horn

Graphite rod
- thermal conductivity degrades with radiation damage
- mechanical stress depends on dT
- hence short life time

Beryllium rod
- thermal stress is significant
- alternative geometries could overcome the problem (still under investigation)

Integrated Be target and horn
- extra heat load makes it even more challenging
- combined failure modes could reduce the life time

Fluidised powder target
- potential solution for higher heat load

Static pebble bed
- reduced stresses. Favourable transversal cooling. Good yield

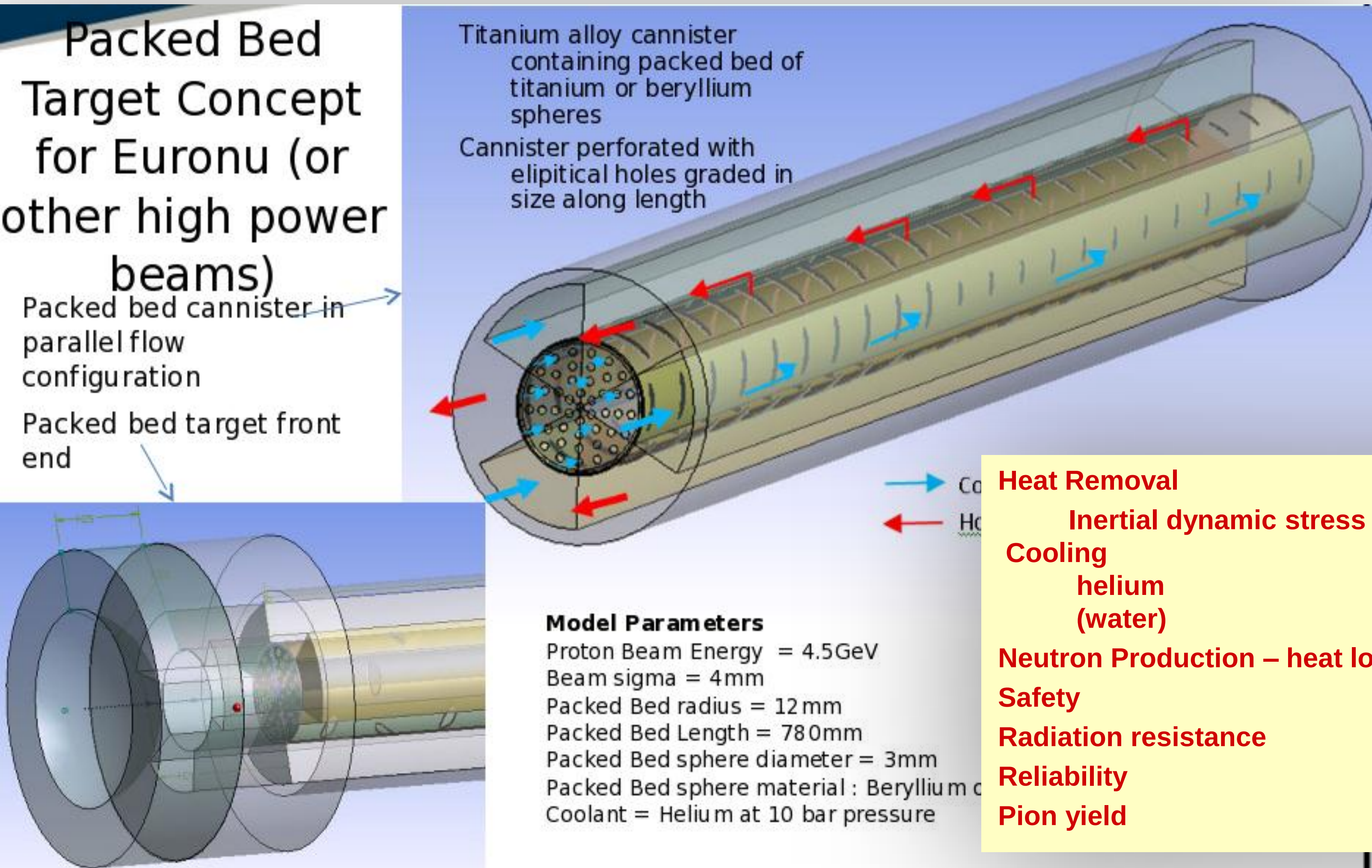
favourable baseline for Superbeam to Fréjus

Science & Technology Facilities Council
Rutherford Appleton Laboratory

Ottone Caretta, RAL, January 2011

High Power Targets

Favored Target for Superbeam



Heat Removal
- **Inertial dynamic stress waves**

Cooling
- **helium**
- **(water)**

Neutron Production – heat load/damage of horn

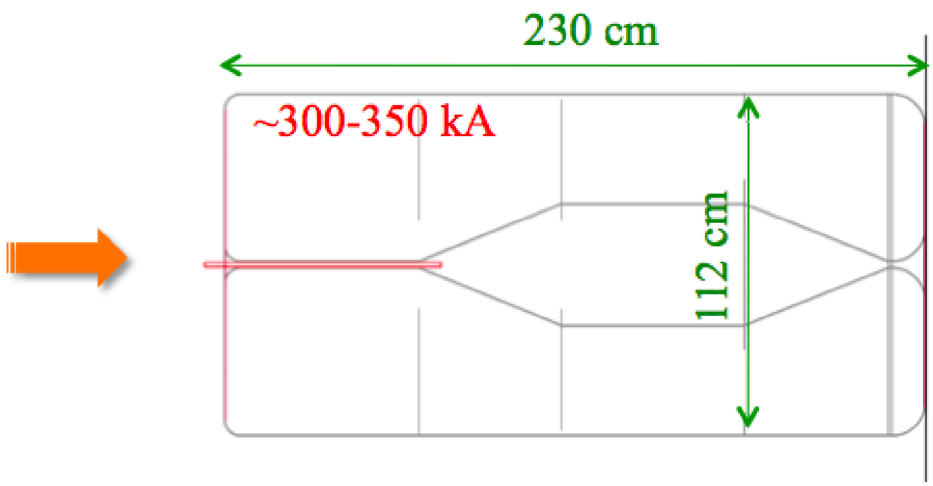
Safety

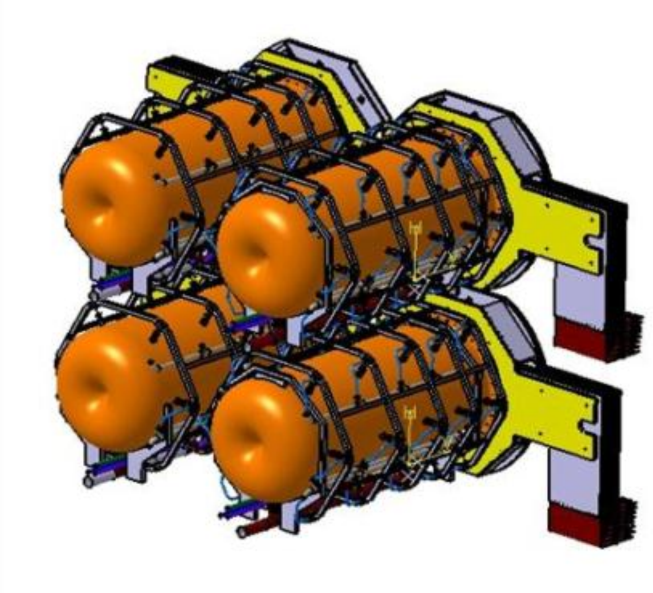
Radiation resistance

Reliability

Pion yield

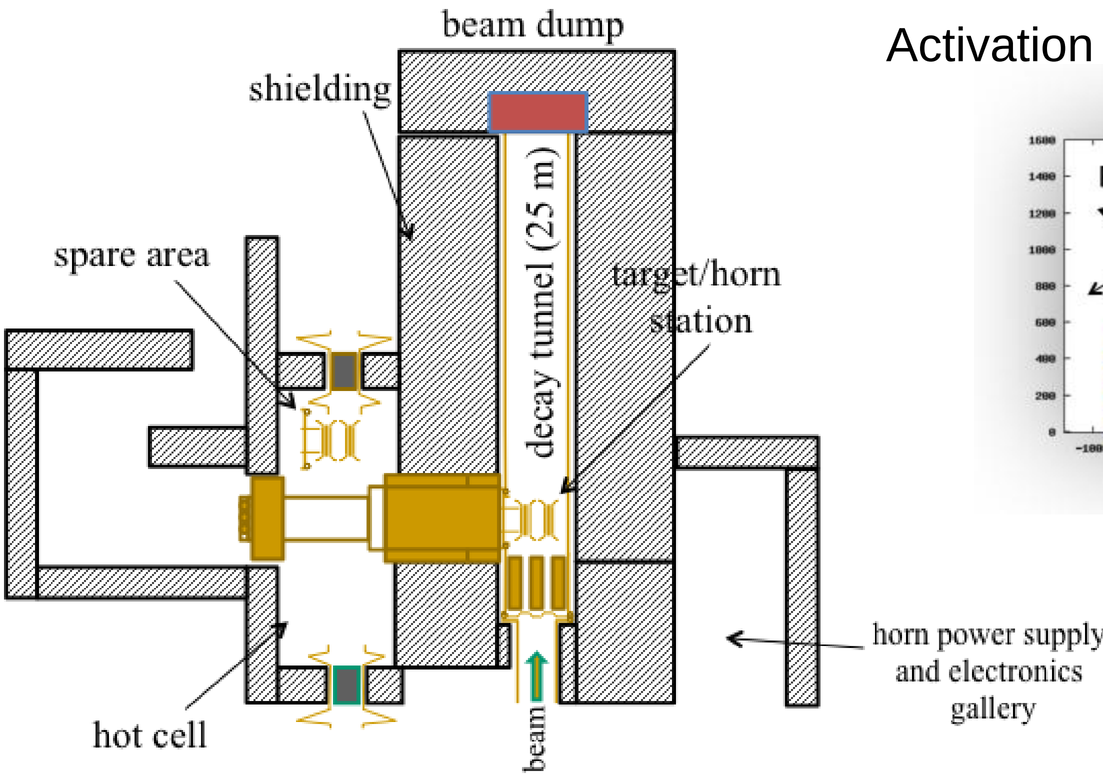
The Horn Design



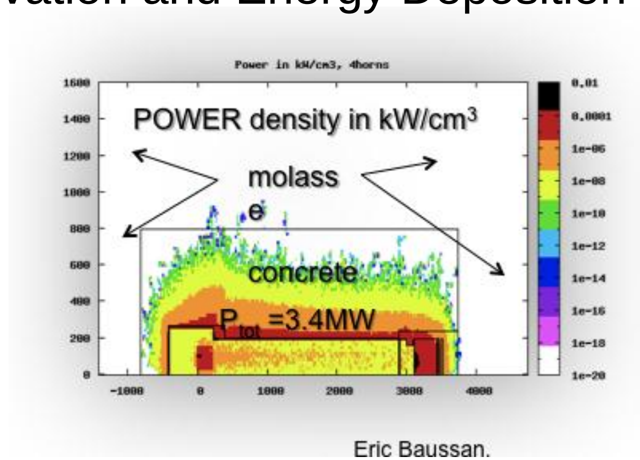


Forward-closed shape with no-integrated target: best compromise between physics and reliability

Integration, Safety and Maintenance



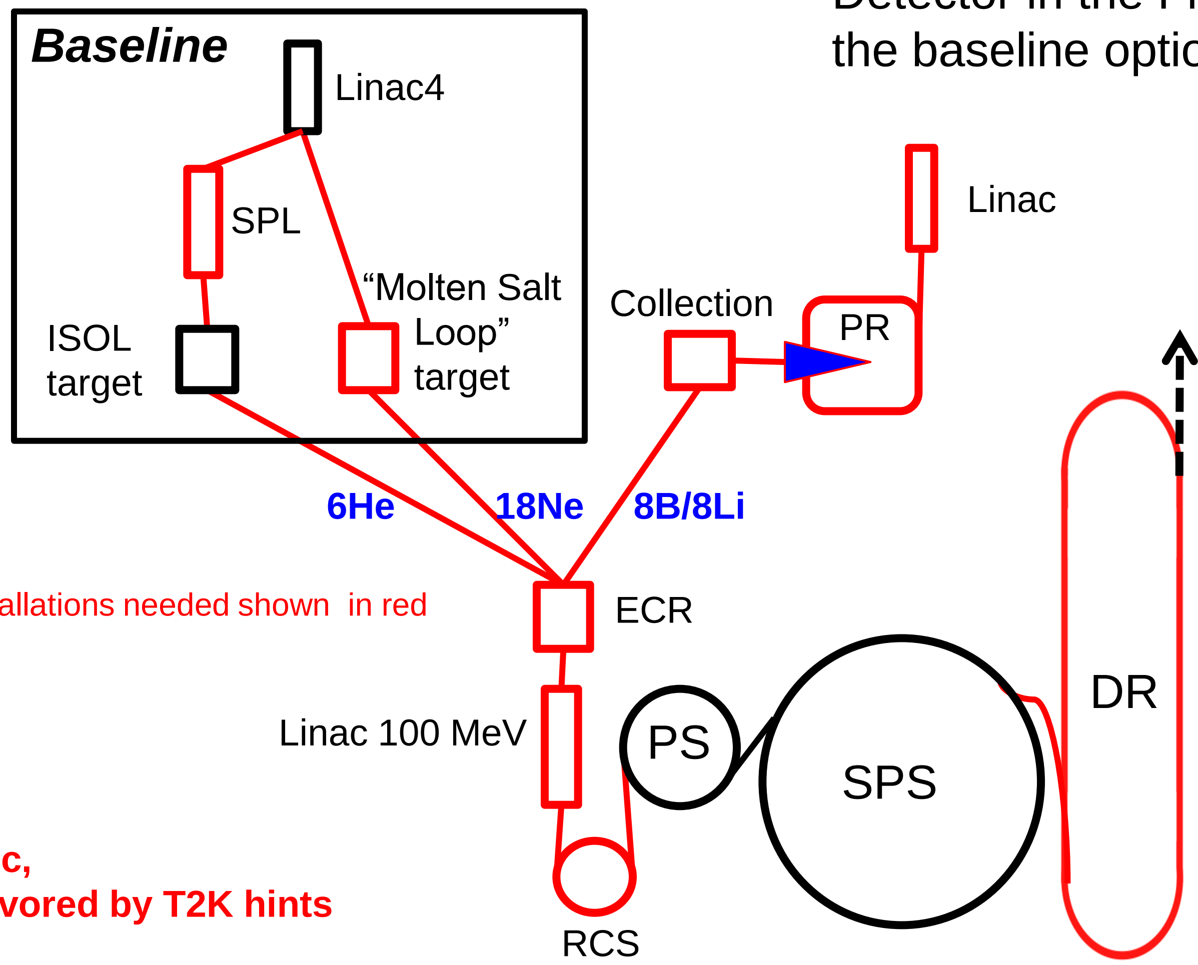
Activation and Energy Deposition



The Superbeam is a well proven technological option for the next round of experiment towards CP violation!

The CERN Beta Beam

Detector in the Fréjus tunnel for the baseline option



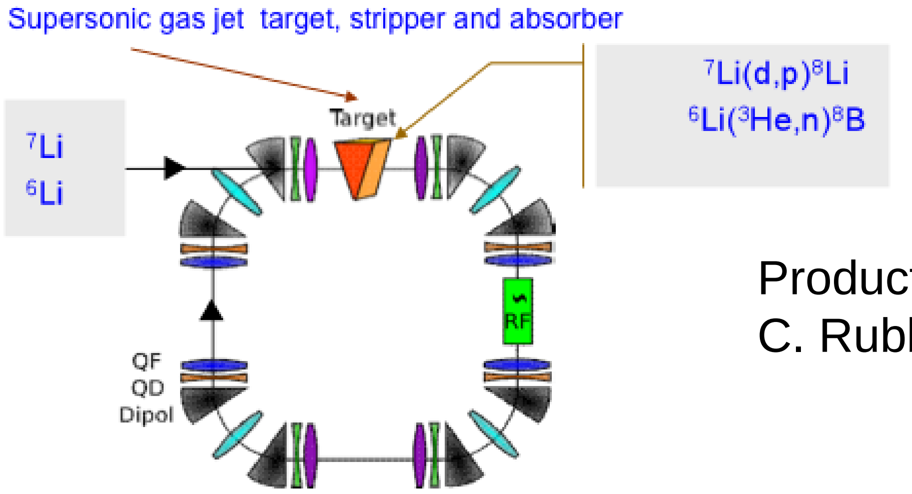
ν-Beam from beta decay of circulating radioactive ions

New installations needed shown in red

CERN Specific,
Beta Beam favored by T2K hints

Decay Ring: Bρ ~ 500 Tm, B = ~6 T, C = ~6900 m, L_{ss}= ~2500 m, γ = 100, all ions

The Production Ring (^{8}B and ^{8}Li)

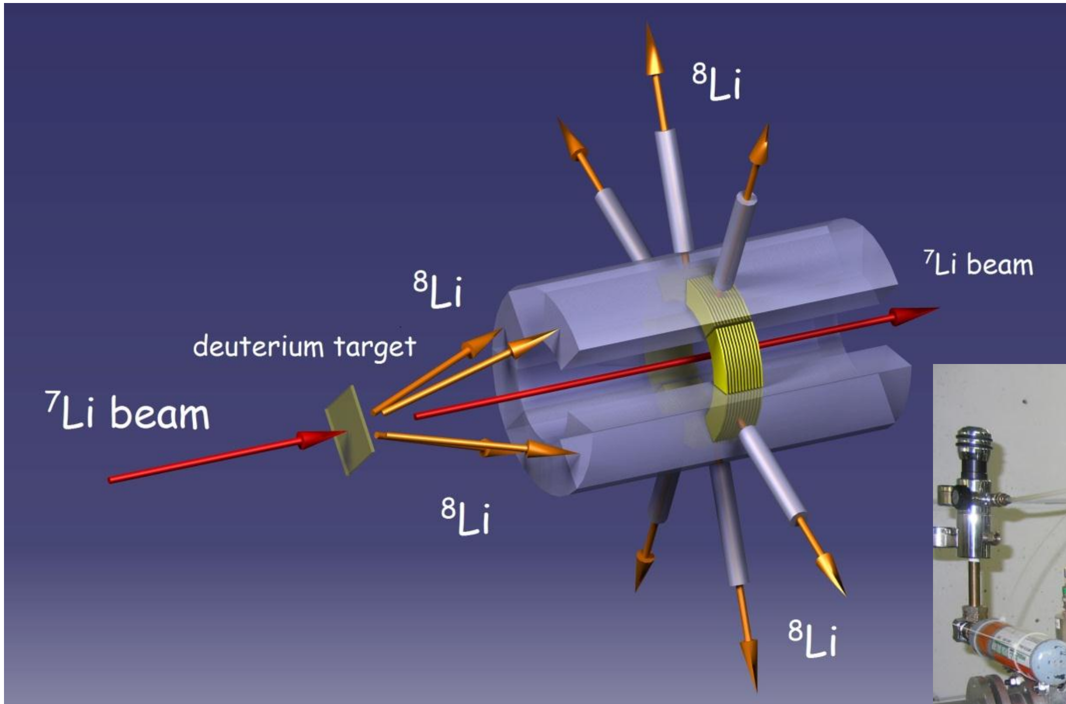


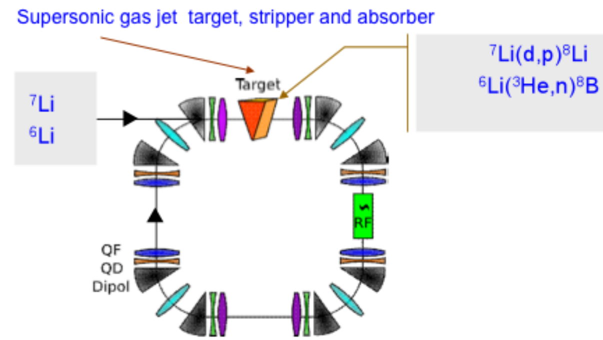
Aachen Univ., GSI, CERN

Production of 8B and 8Li
C. Rubbia, EUROnu proposal

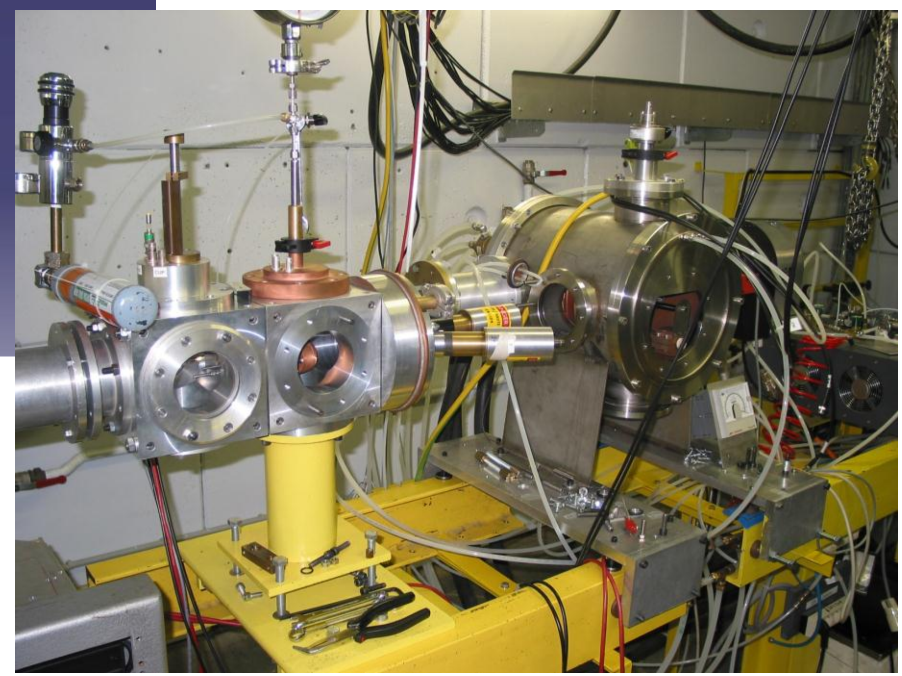
- Gas Jet target proposed in EUROnu:
  - too high density would be needed
  - vacuum problems
- Direct Production with liquid film targets
  - Collaboration ANL

The collection device

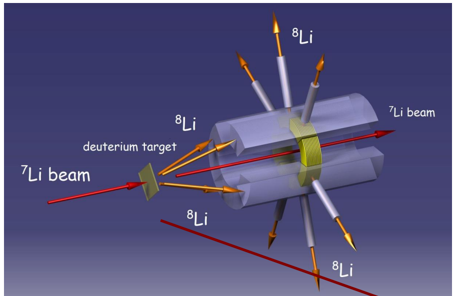




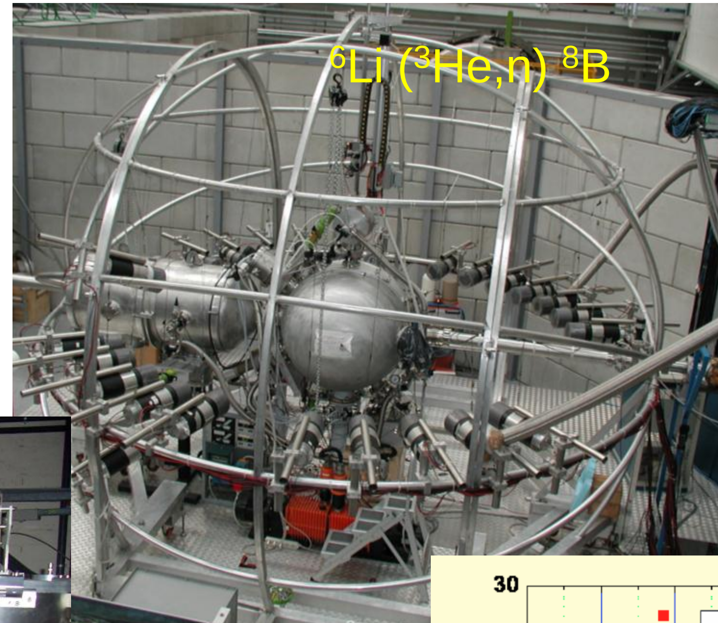
UCL, Louvain la Neuve

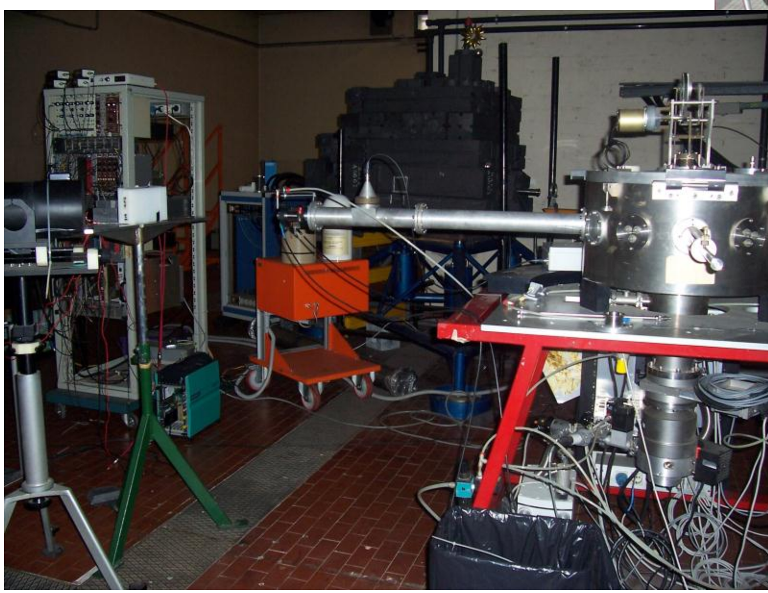


^{8}B & ^{8}Li production: X-sections

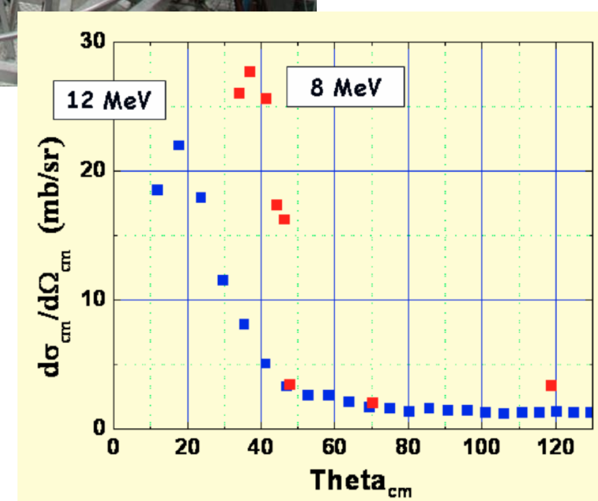


^{7}Li (d,p) ^{8}Li ^{6}Li (^{3}He,n) ^{8}B

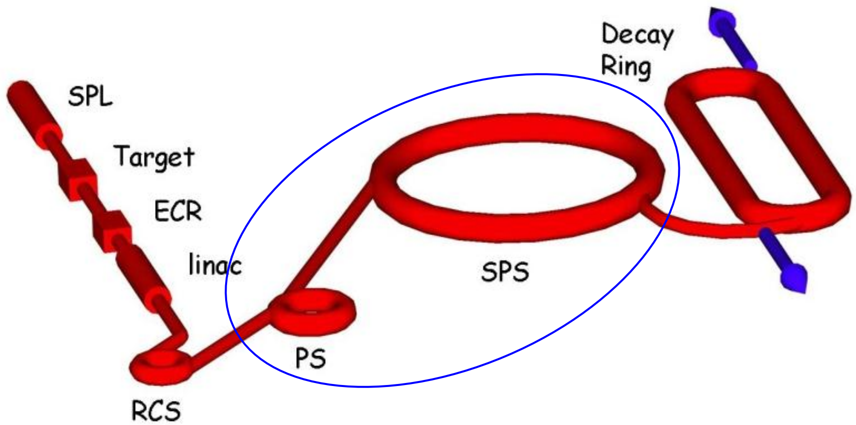


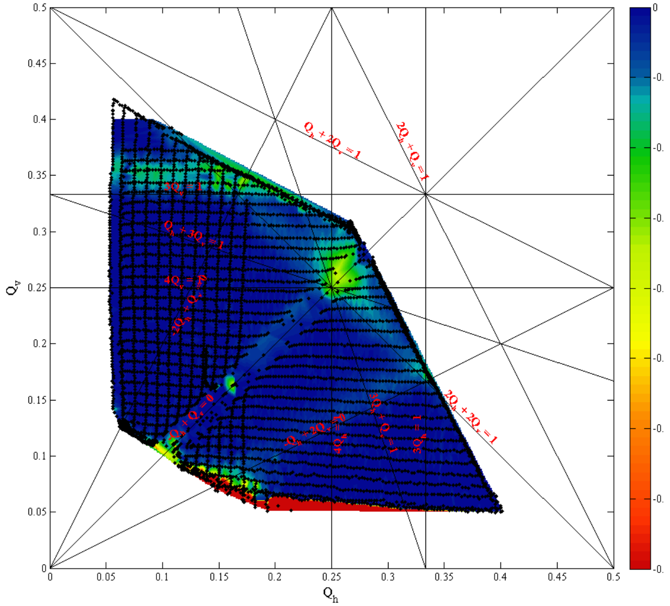


INFN, Legnaro



Integration: PS & SPS





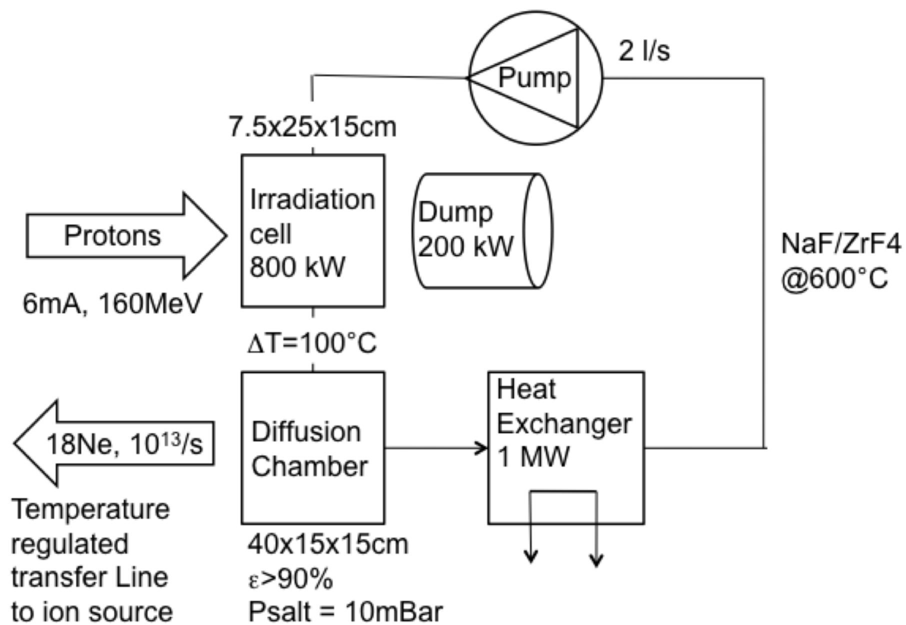
- End-to-End simulations and optimisations needed:
- Handling space charge & collective effects in PS and SPS

^{18}Ne Experiments for Beta Beams

- Molten salt loop experiment to produce 18Ne
  - experiments at CERN & LPSC (Grenoble)

NaF salt loop → 2 reactions

$$^{19}F(p,2n)^{18}Ne$$
$$+$$
$$^{23}Na(p,X)^{18}Ne$$



^{18}Ne production rate estimated to 1 x10^{13} ions/s (dc) for 960 kW on target.

Production of Beta Beam isotopes

Aim: 2.0 10^{13} for low-Q **Targets below MWatt is a considerable advantage!**

Type	Accelerator	Beam	I_{beam} mA	E_{beam} MeV	P_{beam} kW	Target	Isotope	Flux s^{-1}	
ISOL & n-converter	SPL	p	0.07	2 10^{3}	135	W/BeO	6He	5 10^{13}	
ISOL & n-converter	Saraf/GANIL	d	17	40	680	C/BeO	6He	5 10^{13}	
ISOL	Linac 4	p	6	160	960	23Na 19F Molten NaF loop	18Ne	1 10^{13}	
ISOL	Cyclo/Linac	p	15	60	900	23Na 19F Molten NaF loop	18Ne	1 10^{13}	
ISOL	LinacX1	3He	85	21	1800	MgO 80 cm disk	18Ne	1 10^{13}	
P-Ring	LinacX2	d	0.160	25	4	7Li	8Li	3 10^{13}	
P-Ring	LinacX2	3He	0.160	25	4	6Li	8B	8 10^{11}	

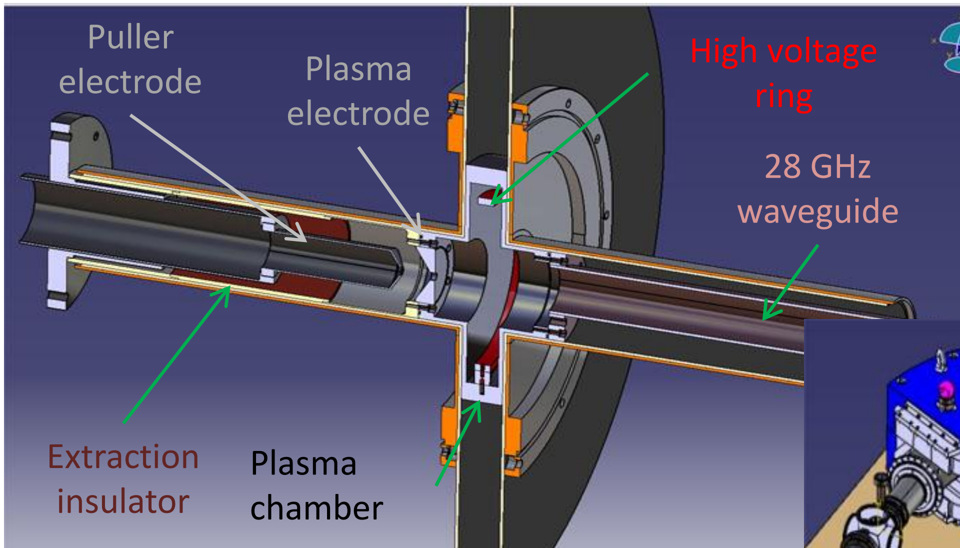
Planned experiments
ISOLDE CERN

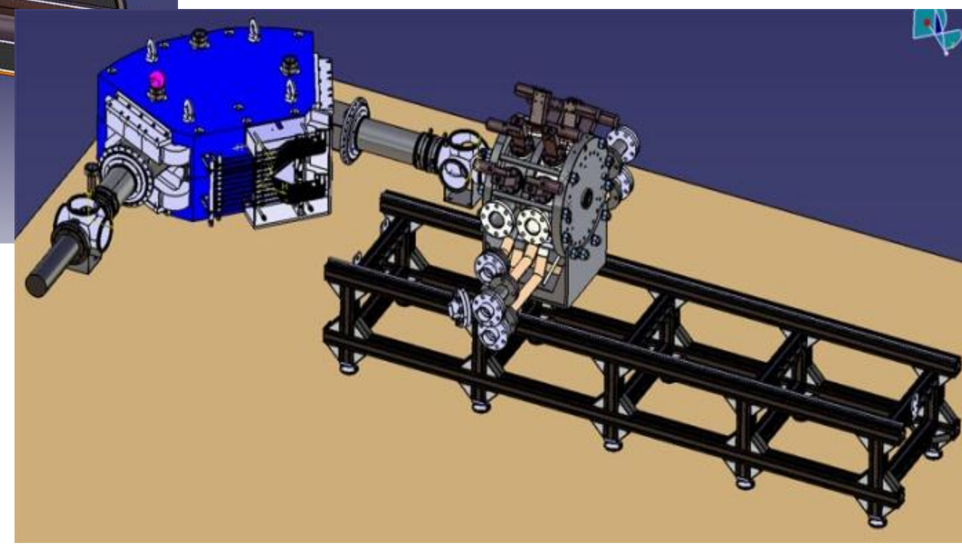
Experimentally OK

On paper OK, exp. 2011

Not OK yet

60 GHz ECR Source

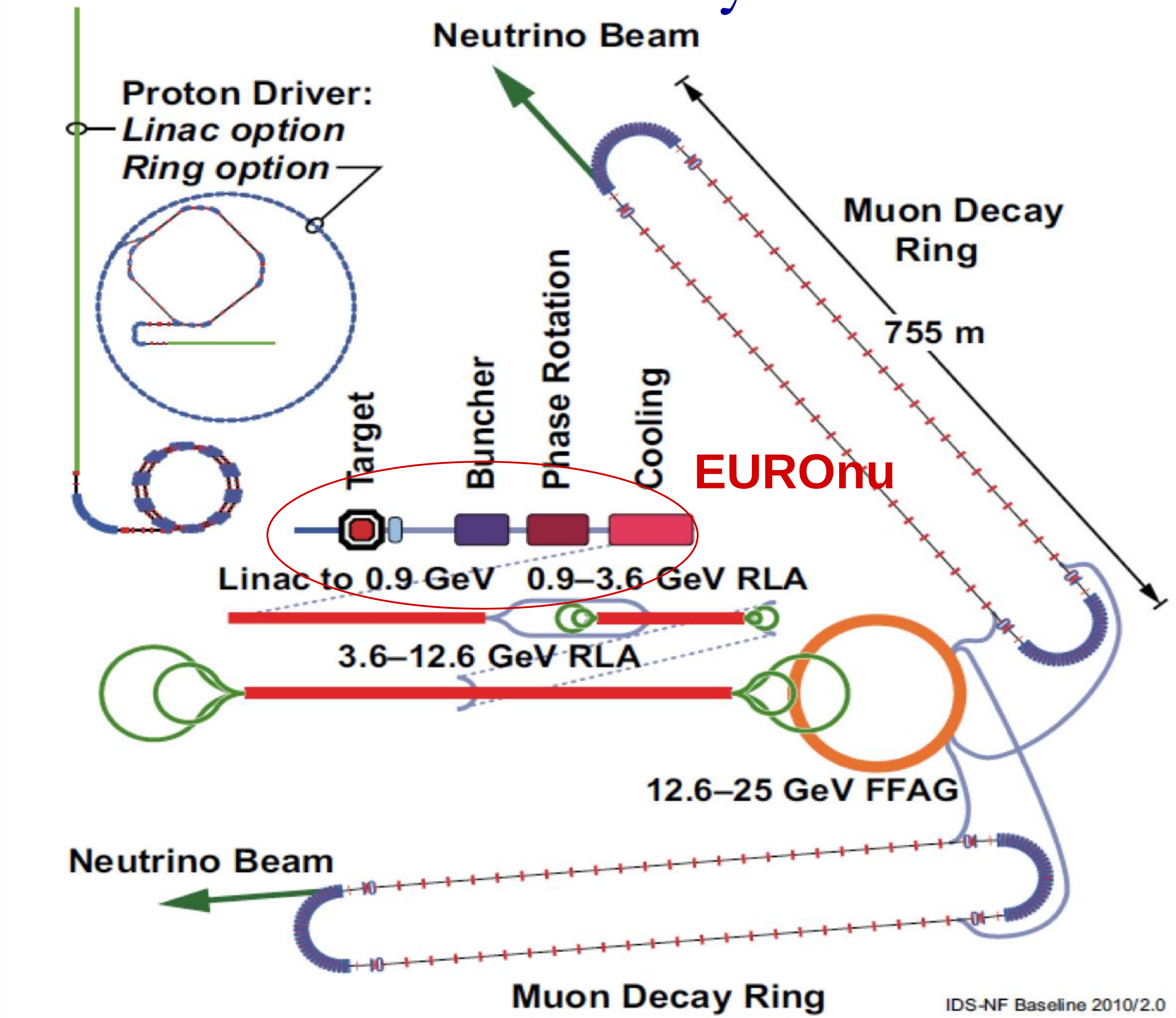




The SEISM Collaboration

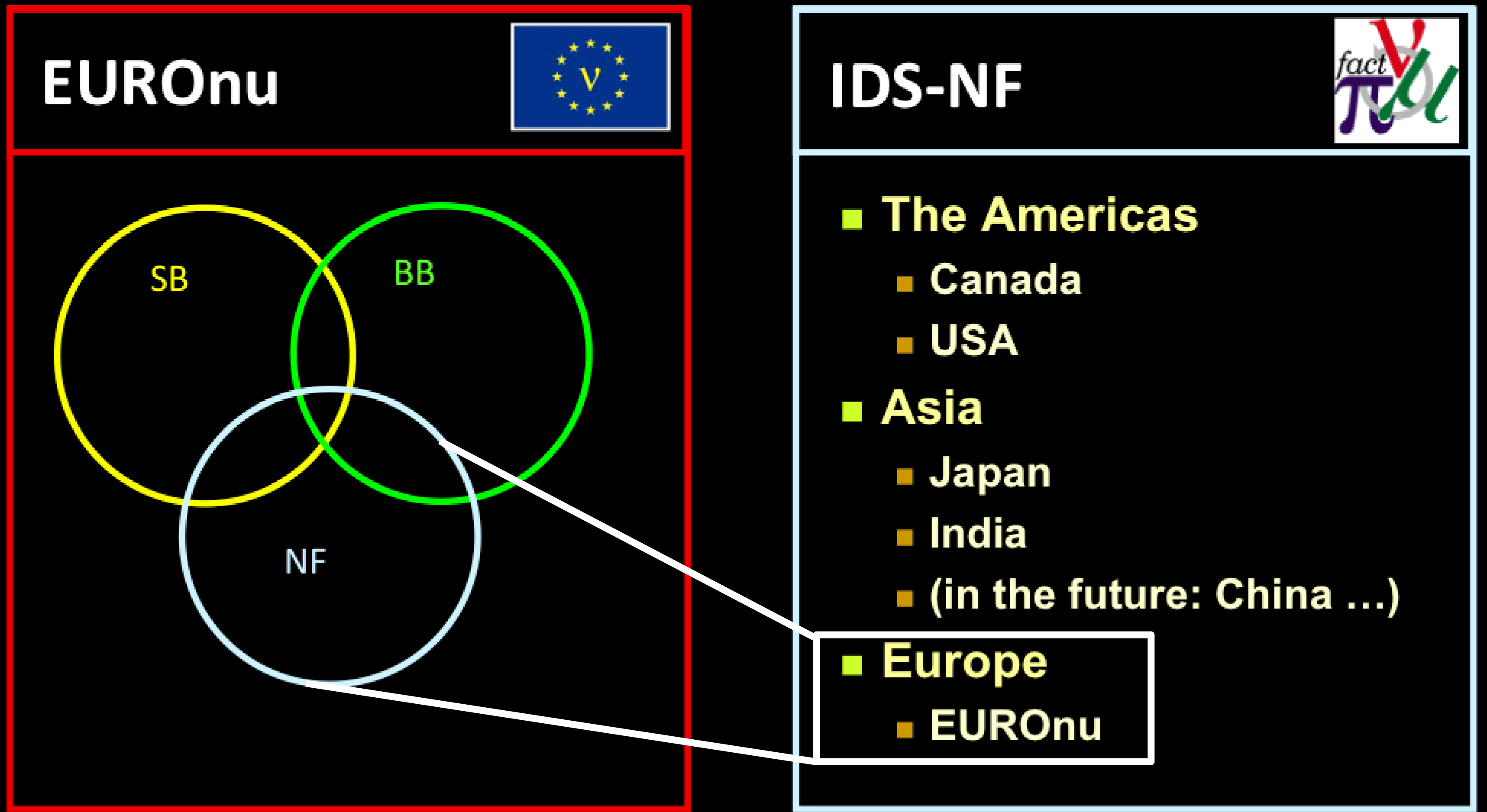
T. Lamy

The Neutrino Factory

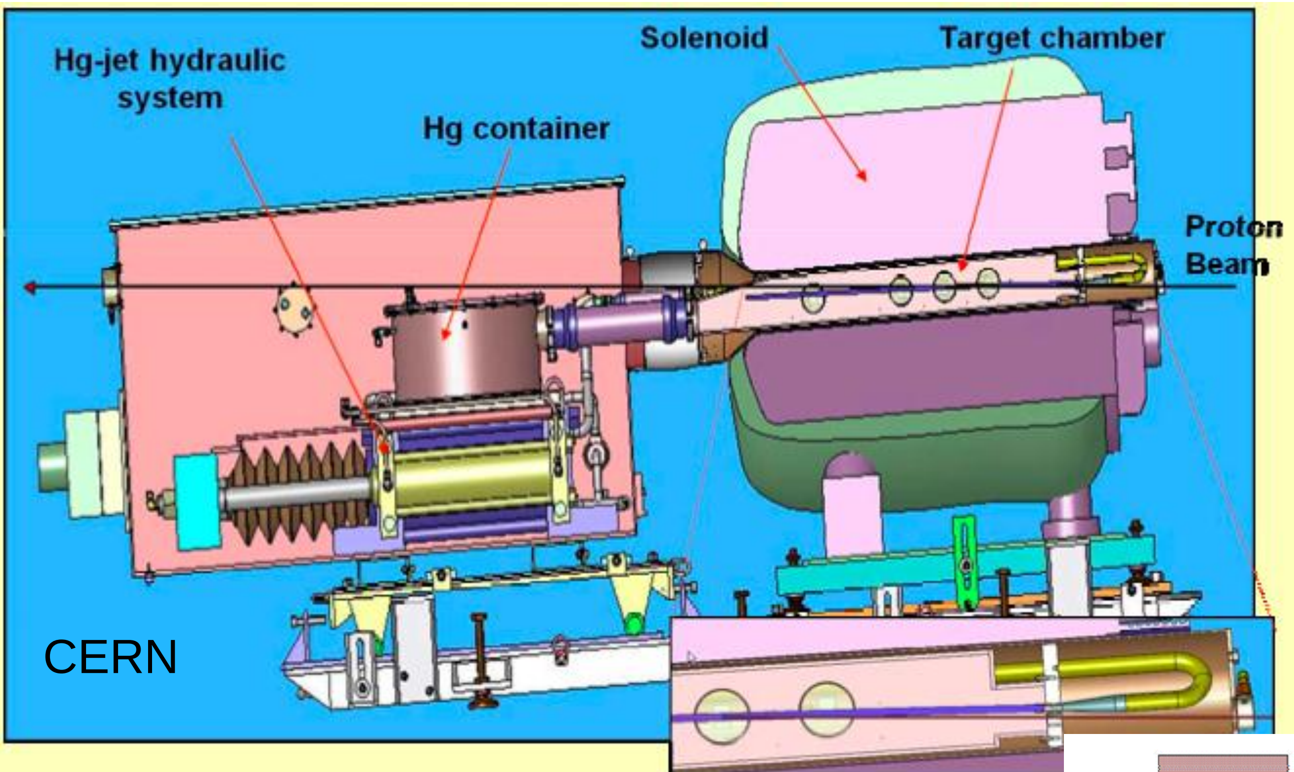


EUROnu and IDS-NF

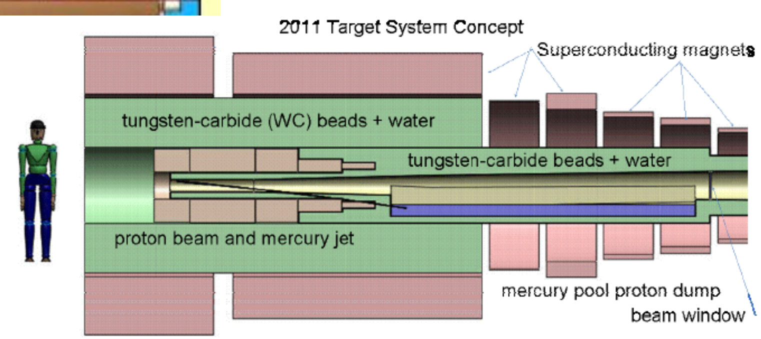
- EUROnu is the European contribution to the IDS-NF



MERIT: Hg targets

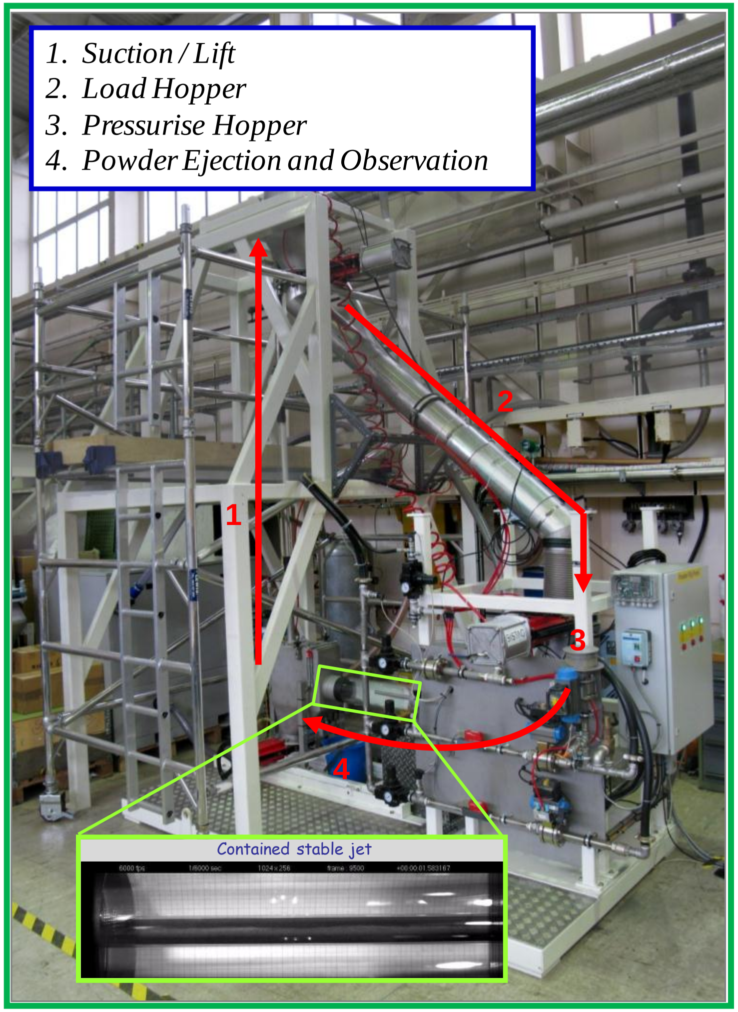


- Free mercury jet target
- Intercepting a 4-MW proton beam
- Surrounding solenoid of 15 T

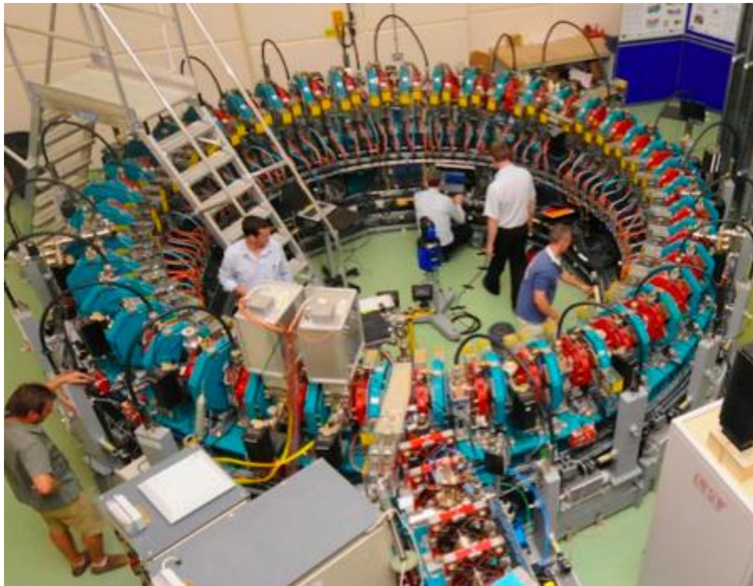


Powder Targets

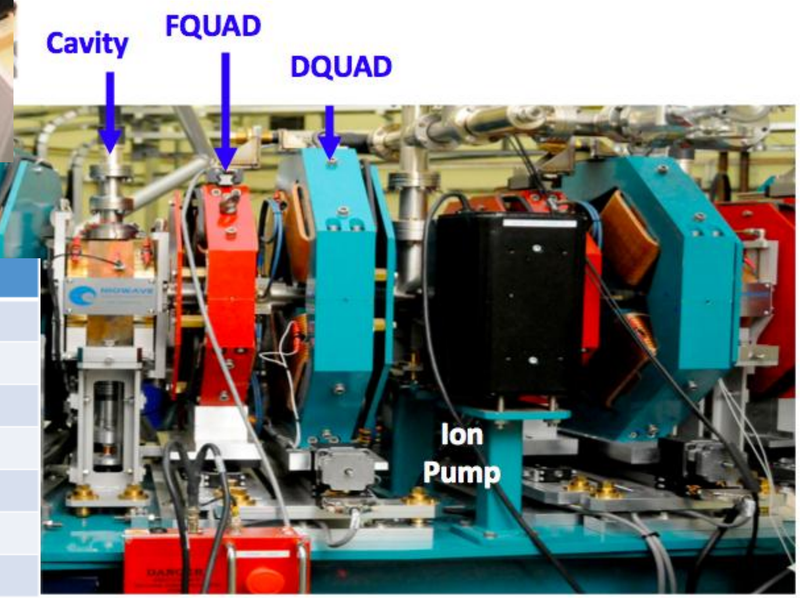
- Solid target:
  - Lifetime limitation from beam-induced shock:
- Tungsten-powder jet:
  - (Jet) advantage:
    - Avoids issue of shock
  - (Solid) advantage:
    - Avoids issue of Hg handling
  - ‘Bench-test’ system under evaluation
  - Proof of principle:
    system under consideration



EMMA: Linear nonscaling FFAG



- EMMA electron model of muon accelerator
- Commissioning without surprises
- Proof of principle!



	Muon FFAG	EMMA	Ratio
Momentum	12.6 – 25 GeV/c	10 – 20 MeV/c	1 : 0.001
rf voltage	1214 MV	2.28 MV	1 : 0.002
Number of cell	64	42	1 : 0.66
Circumference	667 m	16.6 m	1 : 0.025
QD/QF length	2.251/1.087 m	0.0777/0.0588 m	1 : 0.035/0.054
Straight section	5 m	0.2 m	1 : 0.04
Aperture	~ 300 mm	~ 30 mm	1 : 0.1

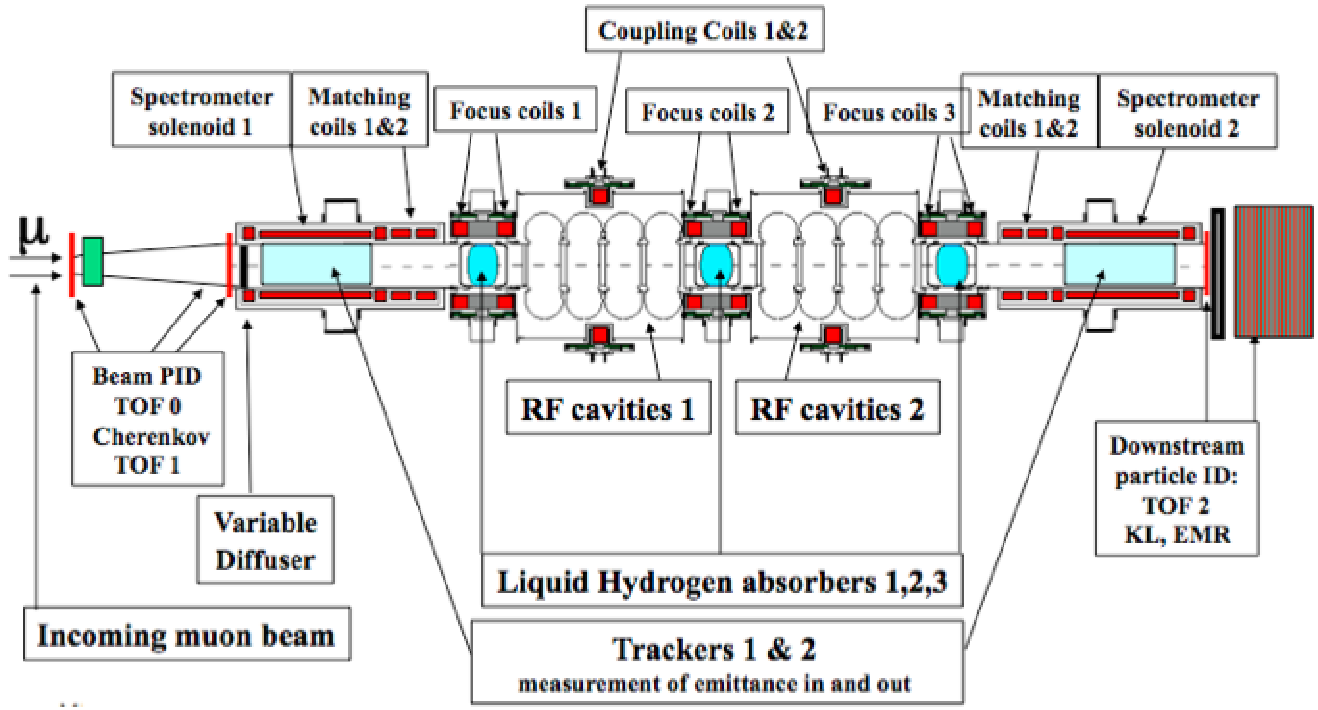
Nufact Front End Experiments

MICE

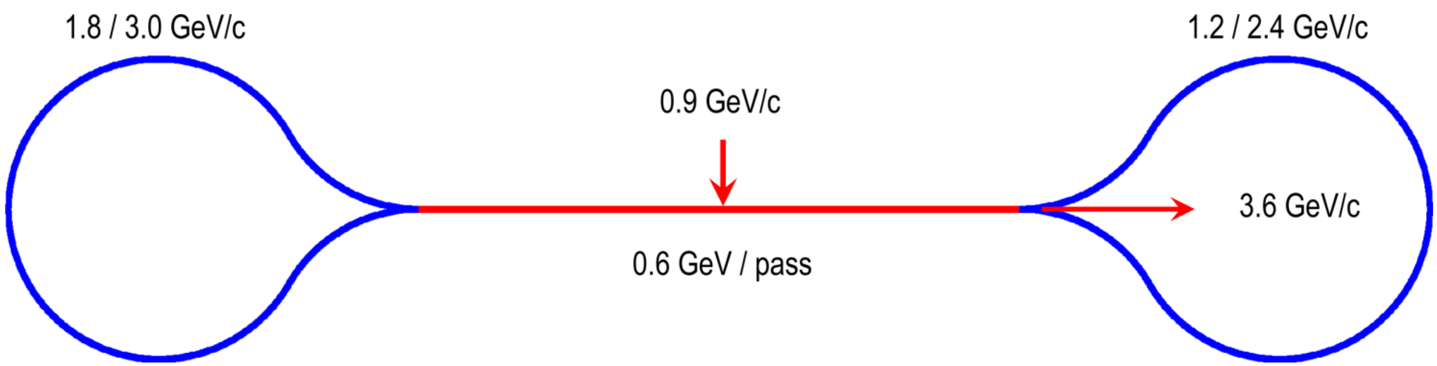
Experiment at RAL to demonstrate and measure cooling

MuCool

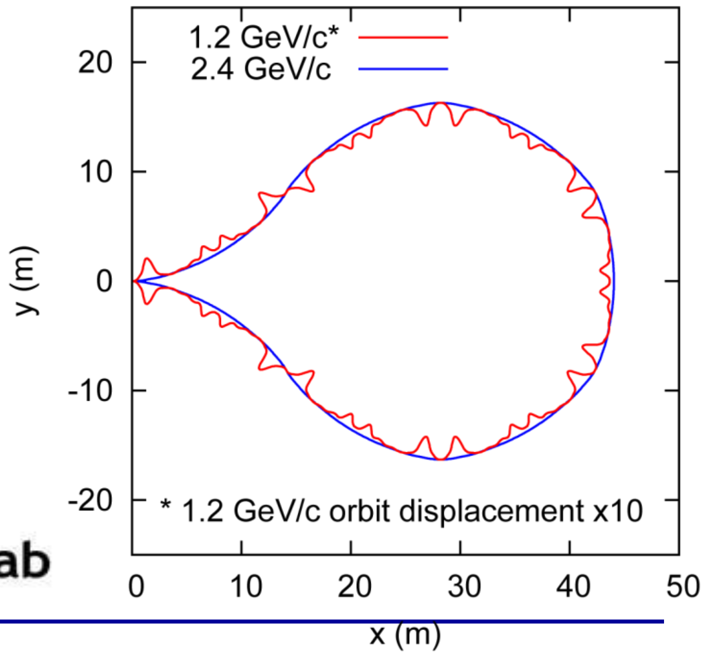
R&D program at Fermilab to develop ionization cooling components



Two Pass Arc in "Dogbone" RLA

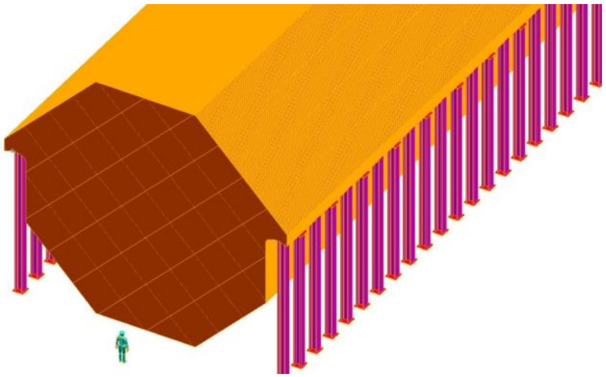


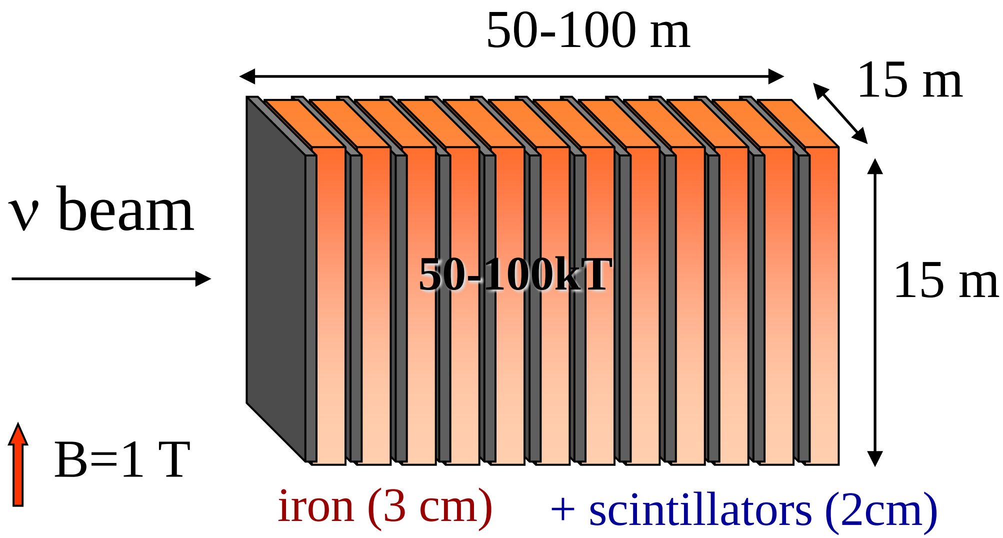
- Innovative 2-pass 'droplet' arc composed of symmetric super-cells consisting of linear combined-function magnets
- Large Dynamic Aperture for two discrete energies (up to factor of two energy ratio)
- Synchronization with linac accomplished via path-length adjustment - harmonic jump
- Simultaneous transport of $\mu^{\pm}$



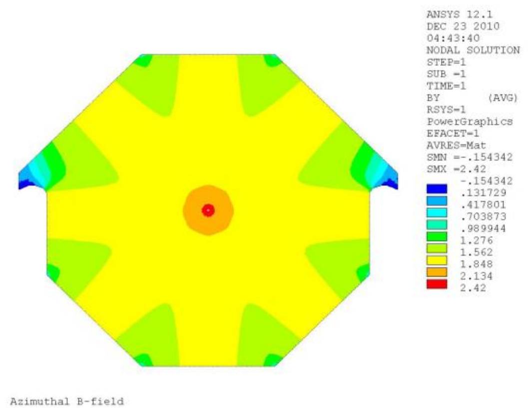
A. Bogacz Jefferson Lab

Detectors: MIND for NF, 25 GeV



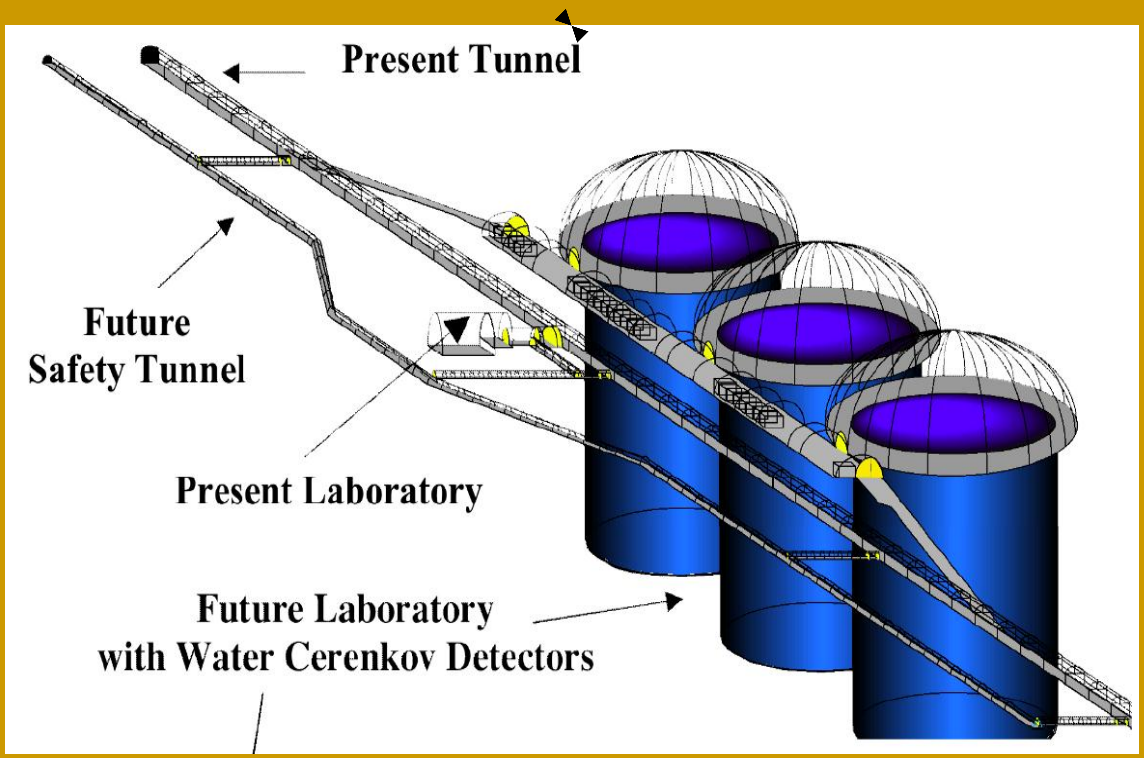


- Far detector: 100 kton at 2000-4000 km
- Magic detector: 50 kton at 7500 km
- Appearance of “wrong-sign” muons
- Segmentation: 3 cm Fe + 2 cm scintillator
- 1 T magnetic field



The MEMPHYS Detector

MEMPHYS Water Cherenkov detector



1 shaft = 215 kt

Water target

Possible location: extension of Fréjus laboratory

Ongoing R&D for single photo detection

Synergy with
HK (Japan) and UNO (USA)

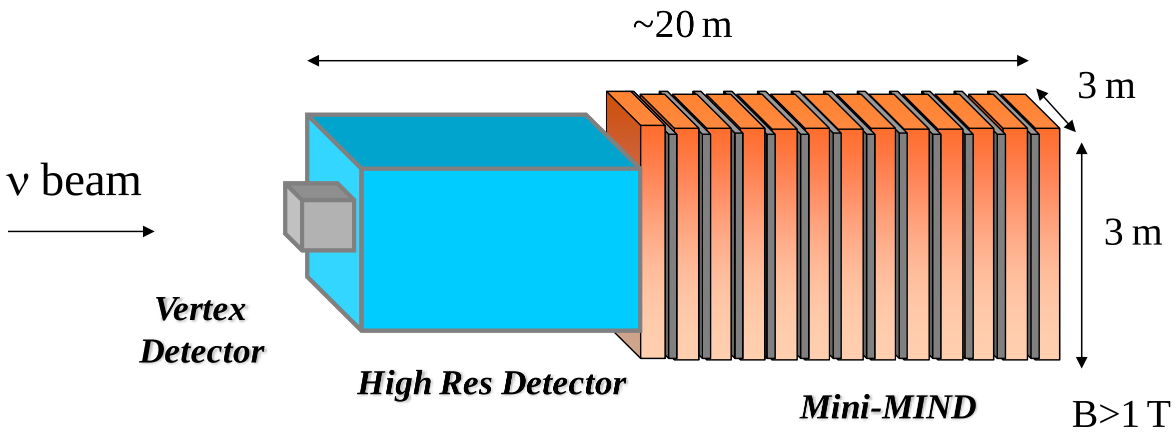
Near Detectors

Control of the systematics for the long baseline neutrino oscillation

* Characterize neutrino beam

in addition to moun/ion beam instrumentation

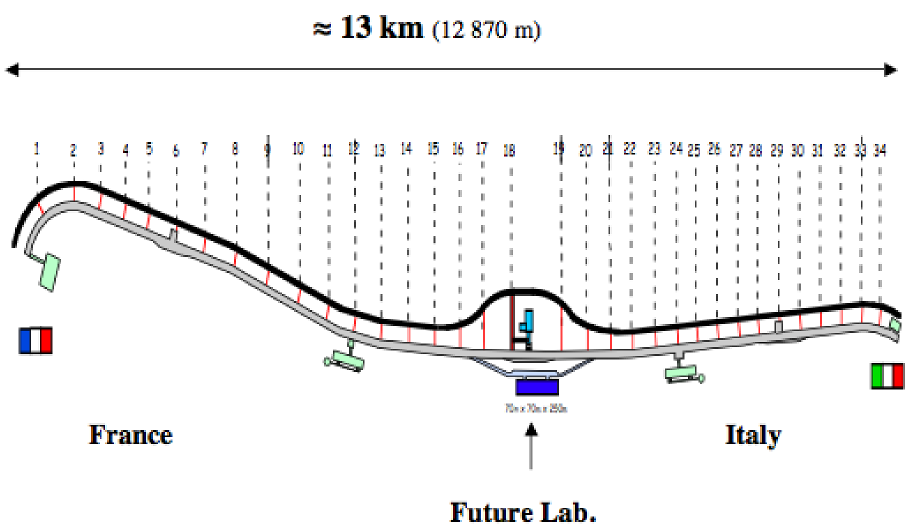
* Cross section measurements



Studied Options in LAGUNA

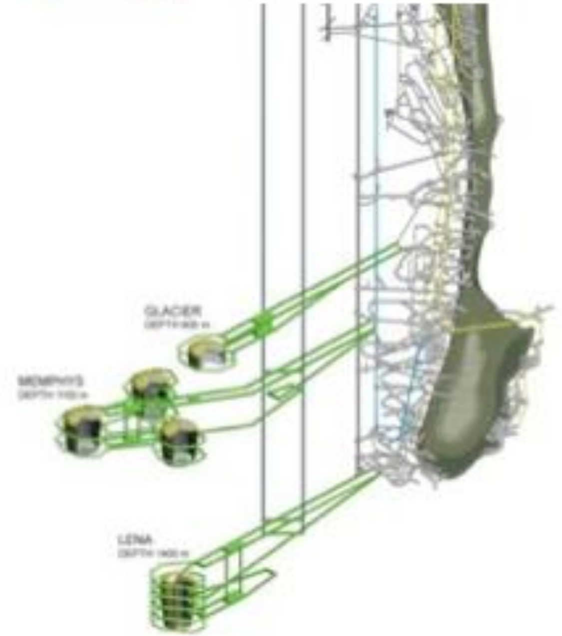
2300 km

Fréjus



Pyhäsalmi

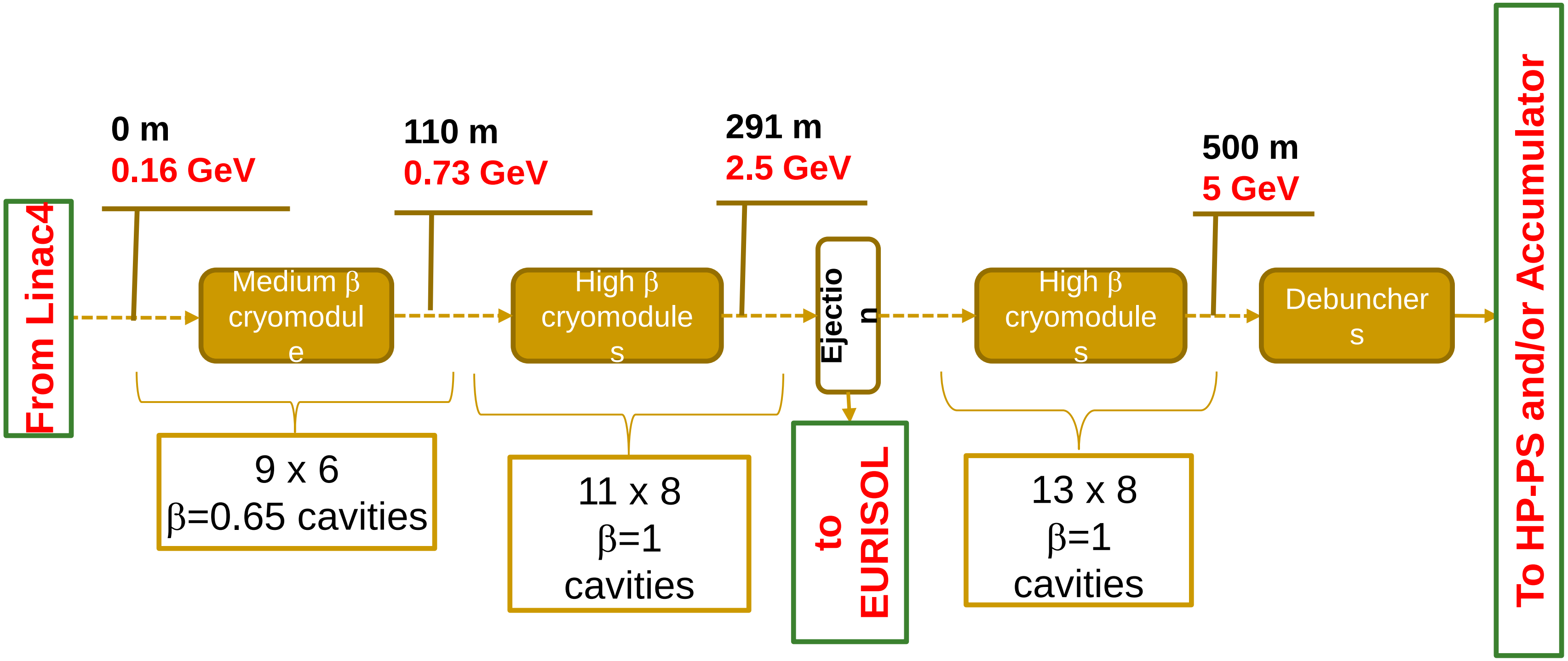
2500-4000 m.w.e



Synergies essential: Detectors/Beams

The outcome of the detector study may be decisive for the future of the neutrino-facilities due to cost of the detector and the cavern.

Proton Driver: HP-SPL



Segmented cryogenics / separate cryo-line / room temperature quadrupoles:

- Medium β (0.65) – 3 cavities / cryomodule
- High β (1) – 8 cavities / cryomodule

Needed for NFactory & SB (BB)

Costing and Safety

- Costing Exercise will assume implementation on CERN site
  - Better comparison
- Work Breakdown Structure set up
  - Costing tool (CERN) is used
- Cost of equipment will be estimated as well as possible
  - Some equipment need resources for design
- Layout & civil engineering cost driving
  - Beta Beam excersise started
  - Followed by Superbeam & Nufact
- Second safety workshop scheduled

EUROnu Status ¾ of duration

- Baselines largely defined
- Design work still continues
- Moving more towards “engineering”
- Costing, ongoing
- Safety and risk, ongoing

Next Steps

- ECFA Neutrino Panel: Report on review

- EUROnu participation in CERN Strategy Review
- Kick off this summer
- Finish next summer/autumn

- EUROnu contribution under discussion
  - Input before EUROnu finished
  - Agreement is combined info from:
    - EUROnu, LAGUNA-LBNO, IDS, etc

- EUROnu Final Report will go to CERN Council

- EUROnu future under discussion
  - Would like to continue, HOW needs to be determined