EUROν
Super Beam studies

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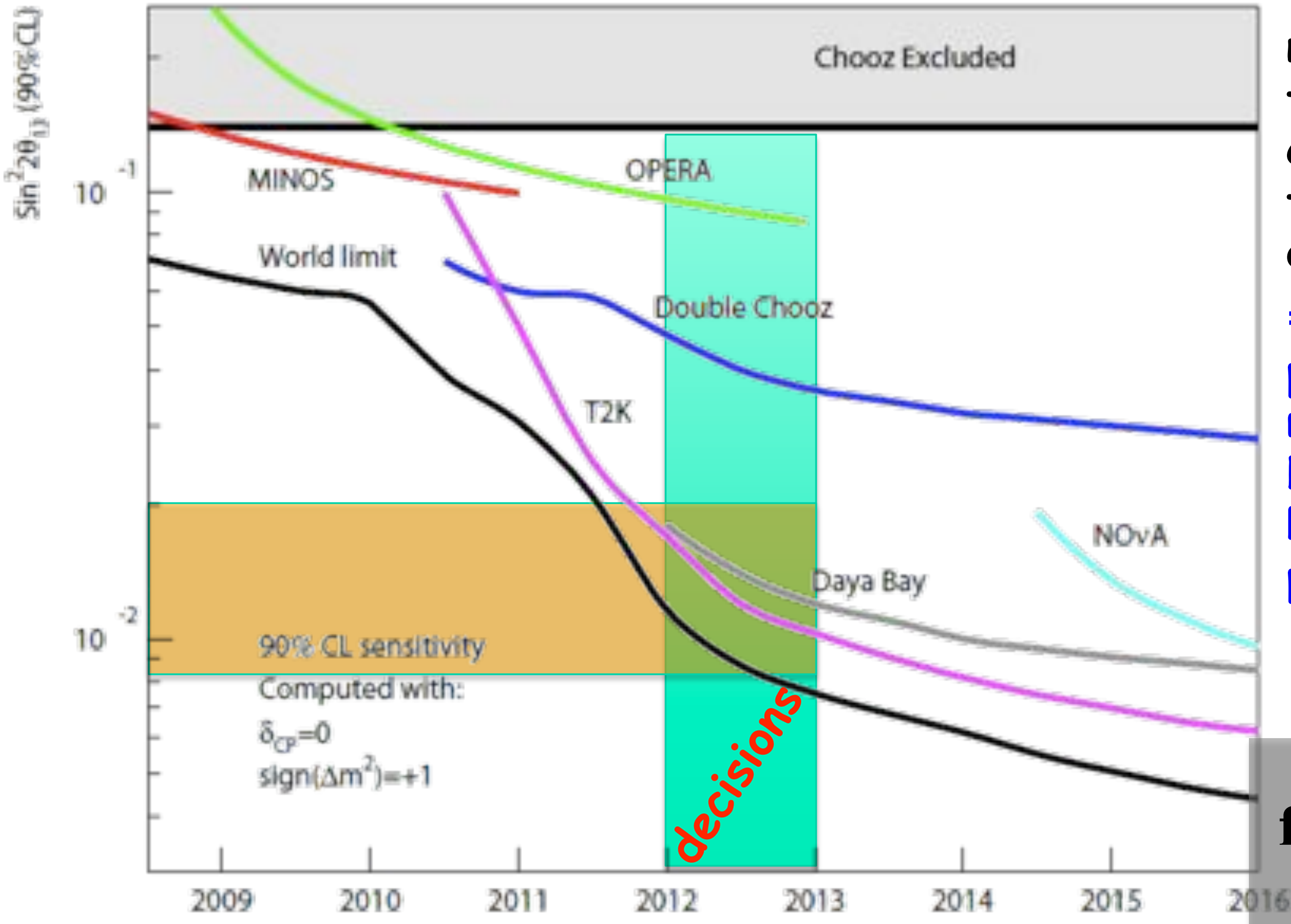
θ_{13} limit expectations up to 2016

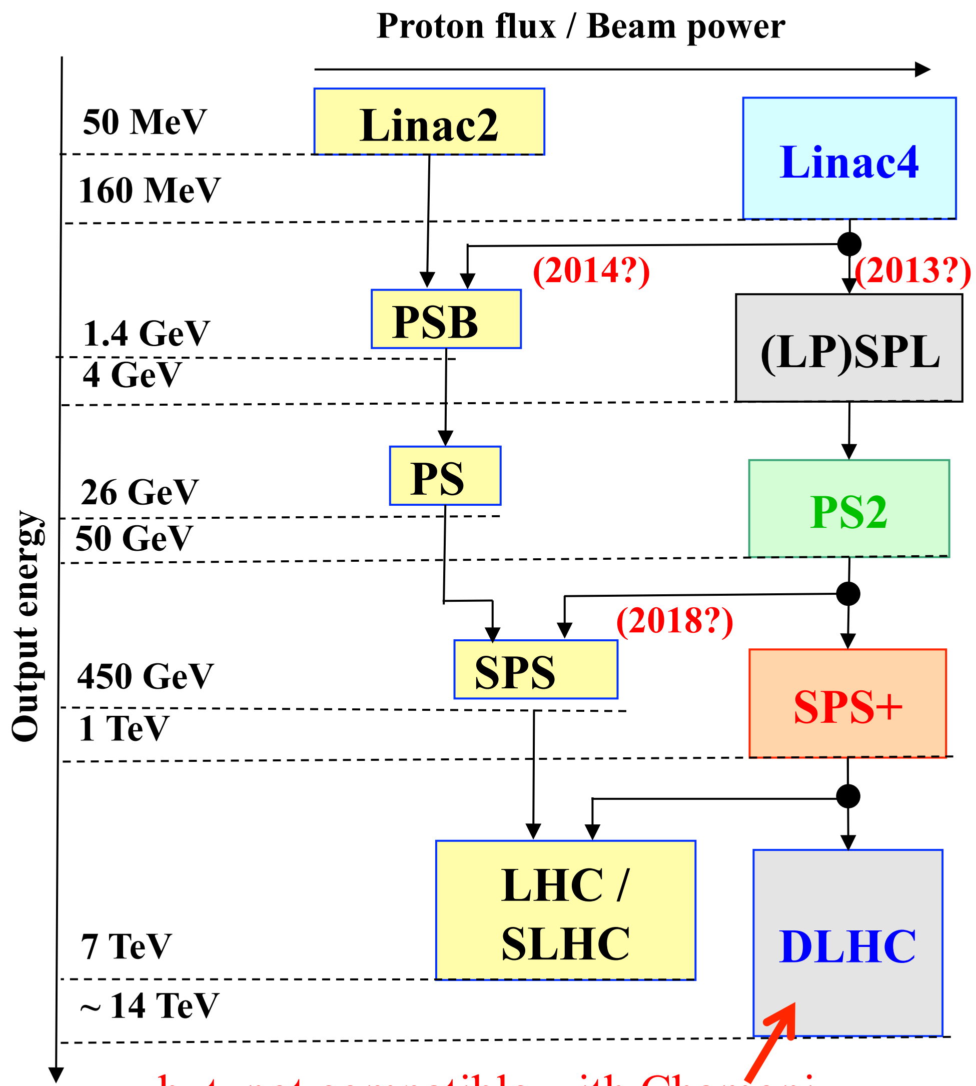


never forget that these projects could also observe the 1→3 oscillation

⇒ in this case precision measurements have to be done by the next projects

future facilities

Take profit of an upgrade of CERN accelerator complex



but, not compatible with Chamonix workshop conclusions

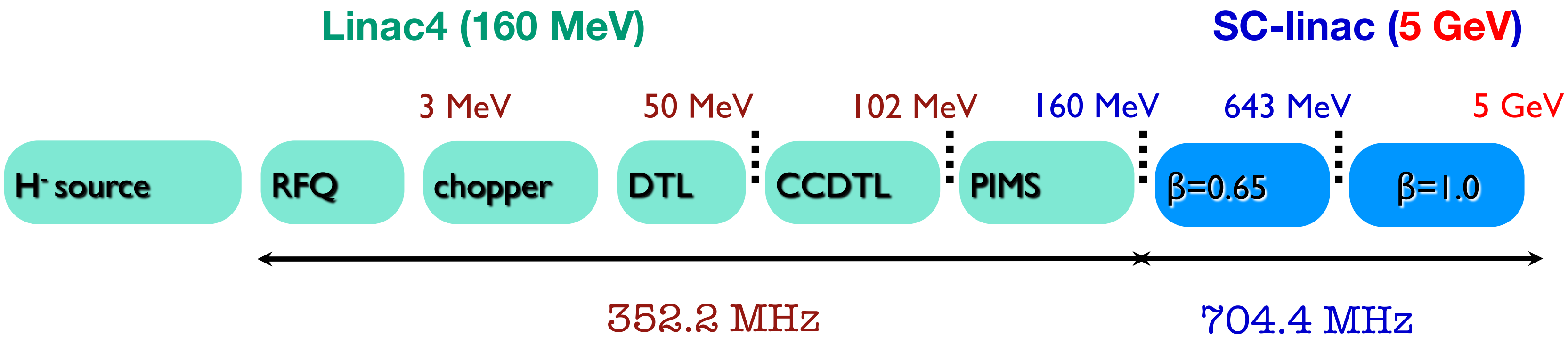
Motivation

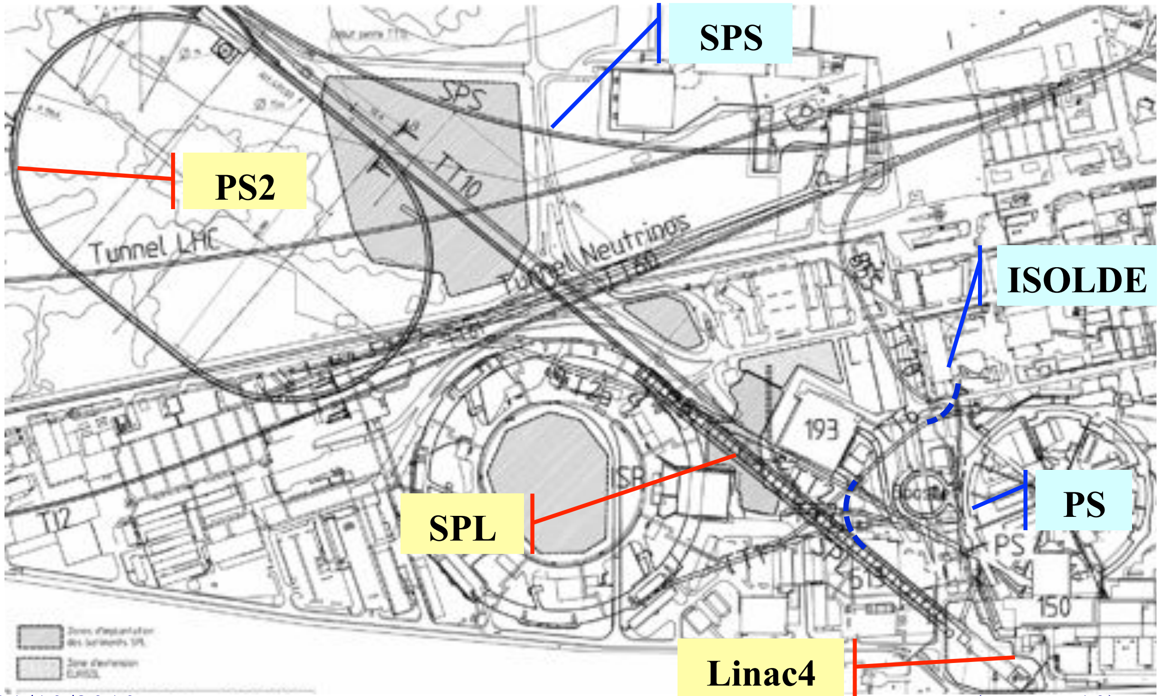
1. **Reliability: Present CERN accelerators too old ⇒ need for new accelerators designed for the needs of SLHC**
2. **Performance: Increase of brightness of the beam in LHC to allow for phase 2 of the LHC upgrade. ⇒ need to increase the injection energy in the synchrotrons**

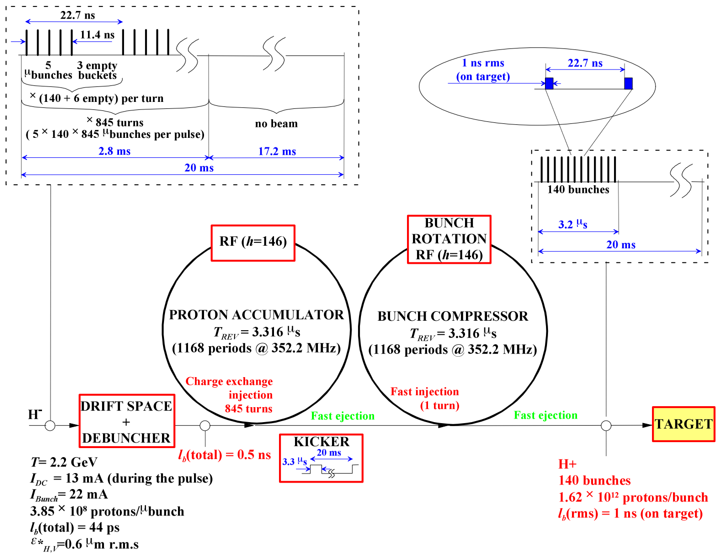
LP-SPL: Low Power-Superconducting Proton Linac (4-5 GeV)
PS2: High Energy PS (~ 5 to 50 GeV – 0.3 Hz)
SPS+: Superconducting SPS (50 to1000 GeV)
sLHC: "Super-luminosity" LHC (up to 10^{35} $cm^{-2}s^{-1}$)
DLHC: "Double energy" LHC (1 to ~14 TeV)

SPL for Neutrino Beams

HP-SPL

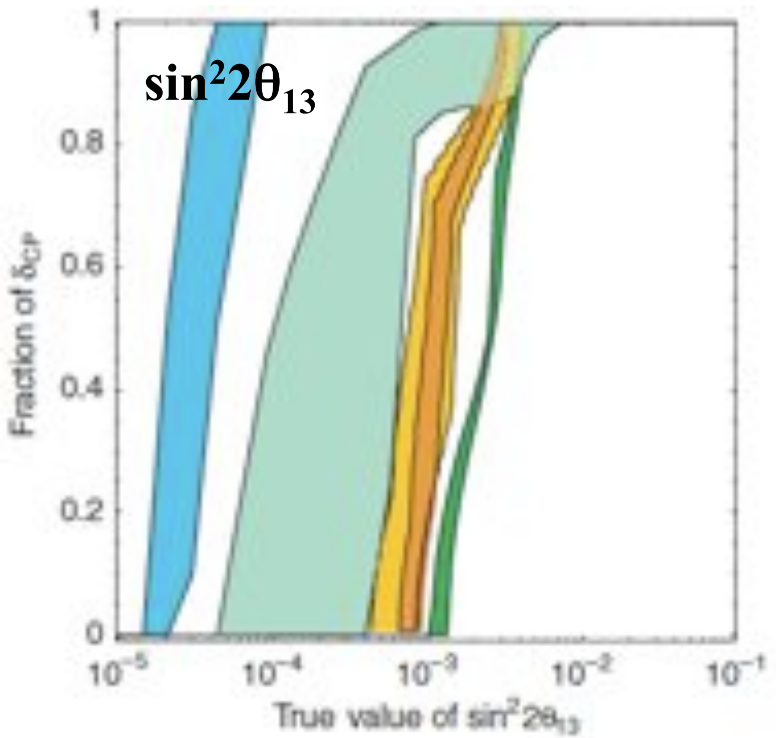


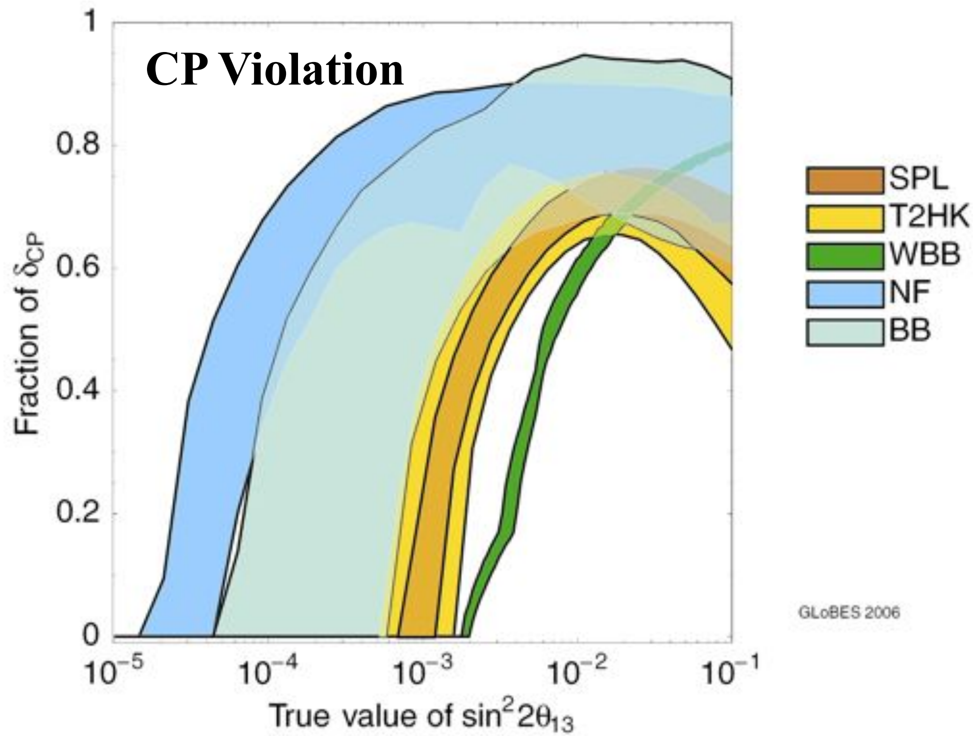




+ accumulator and compressor for NF

Sensitivity of future projects (ISS)





- **Physics Report: Rept.Prog.Phys.72:106201,2009.**
- **Accelerator Report: JINST 4:P07001,2009.**
- **Detector Report: JINST 4:T05001,2009**
- **already many citations for these 3 publications**

In this context, study extensively in Europe the 3 options:

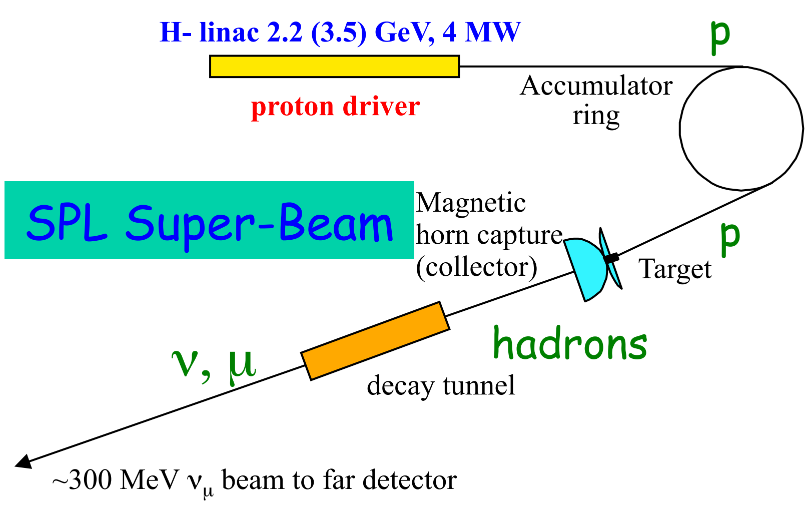
- Super Beam (SPL to Fréjus)
- Beta Beam (after EURISOL)
- Neutrino Factory

Objectives of EUROν DS

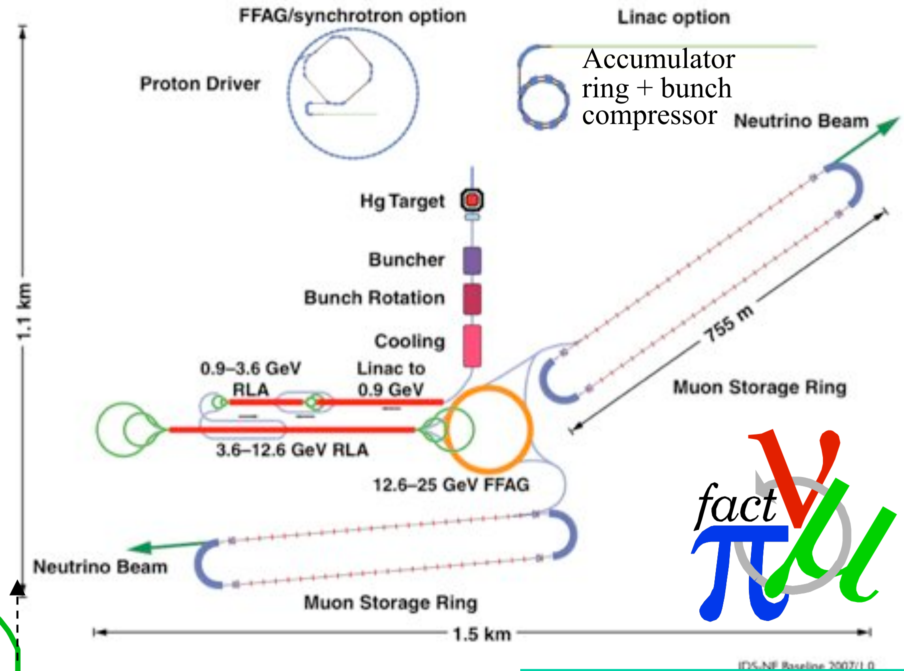
(2008-2012)

- Studies on neutrino facilities to perform precise measurements of the parameters governing neutrino oscillations.
- **Necessity of new high intensity beam-based neutrino oscillation facility** in which neutrino beams are generated using new and highly challenging concepts.
- **This Design Study has to review all three currently (2006) accepted methods of realizing this facility** (the so-called neutrino Super Beams, Beta Beams and Neutrino Factories).
- It includes a detailed study of the key technical challenges of the accelerator facilities, of the **detector** options necessary to measure the neutrino oscillation parameters and a comparison of the **physics** reach of these facilities.
- The design study also has to perform a **cost/safety** assessment that, coupled with the physics performance, will permit the European research authorities to make a timely decision on the lay-out and construction of the future European neutrino oscillation facility.

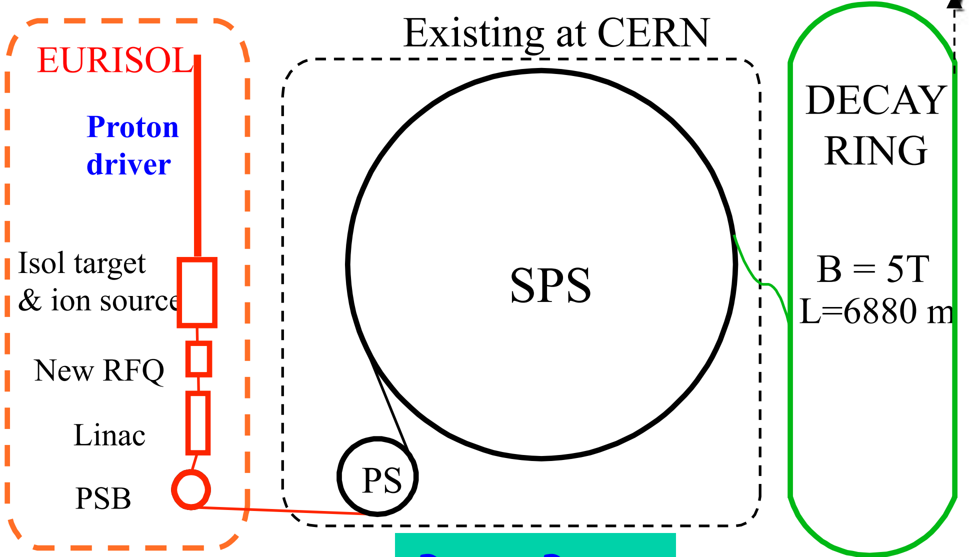
Neutrino Facilities included in EUROν

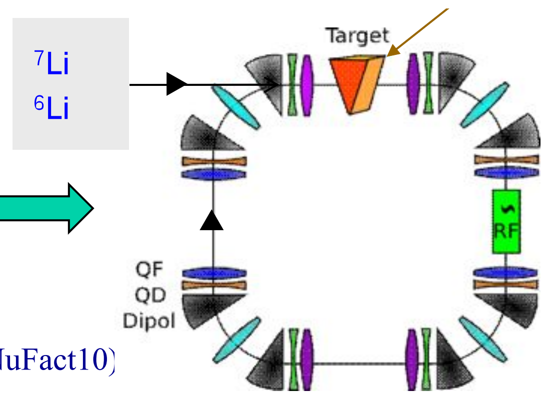


SPL Super-Beam



Neutrino Factory

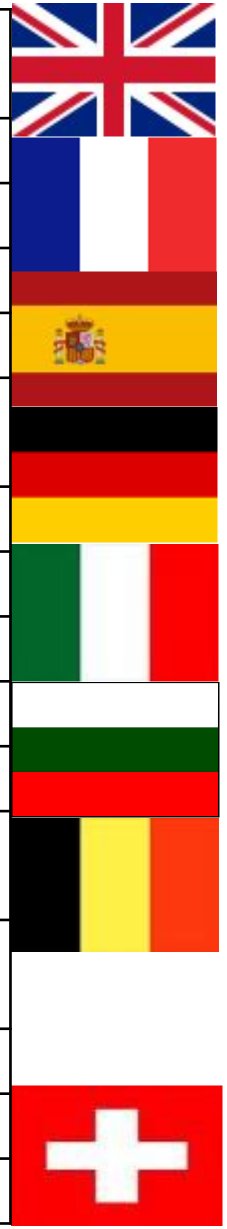




Beta-Beam

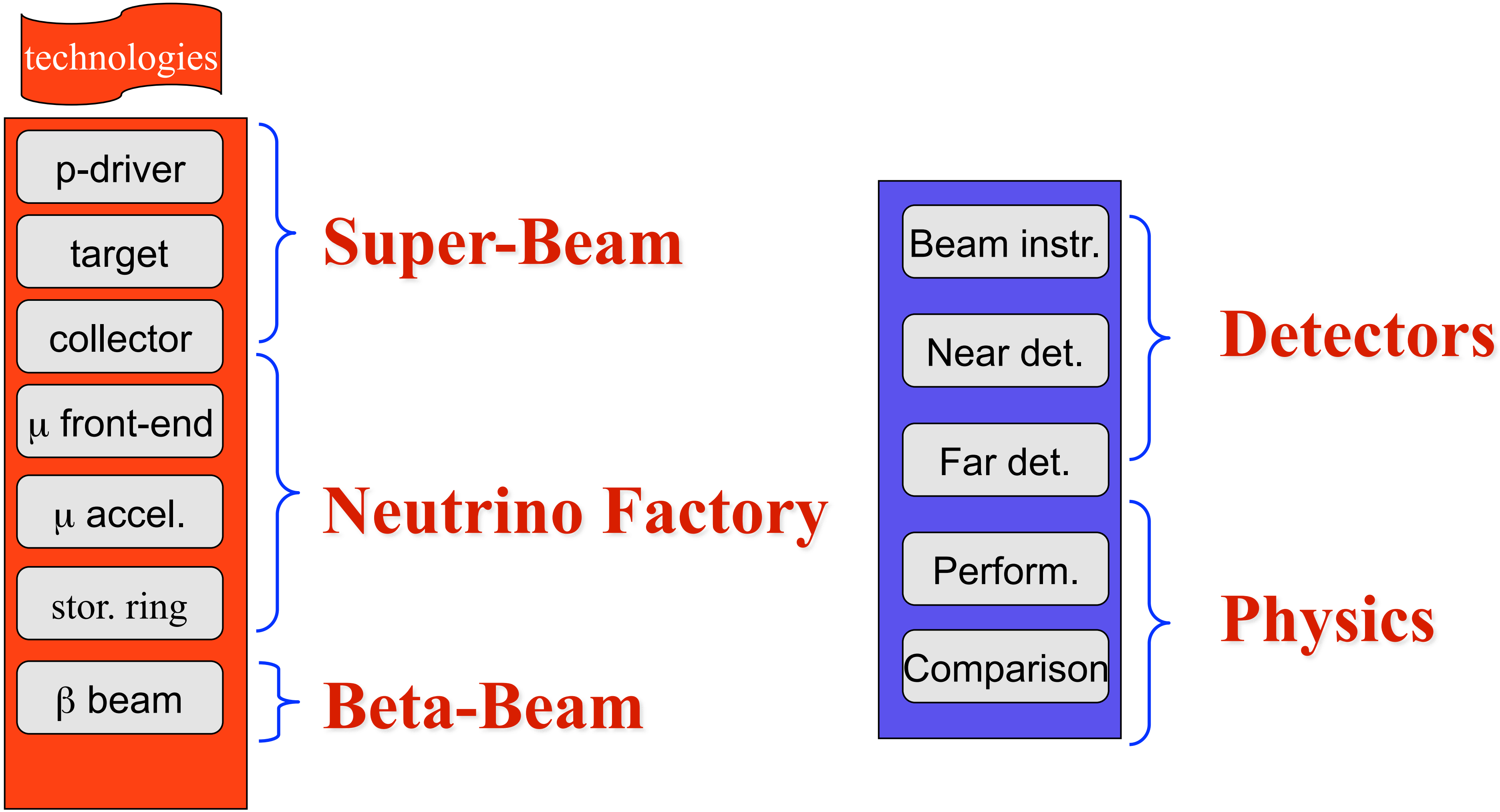
Participants

Participant no.	Participant organisation name	Part. short name	Country
1 Coordinator	Science and Technology Facilities Council	STFC	UK
2	Commissariat à l'Energie Atomique	CEA	France
3	European Organisation for Nuclear Research	CERN	Switzerland
4	University of Glasgow	Glasgow	UK
5	Imperial College of Science, Technology and Medicine	Imperial	UK
6	Consejo Superior de Investigaciones Cientificas	CSIC	Spain
7	Centre National de la Recherche Scientifique	CNRS	France
8	Cracow University of Technology	CUT	Poland
9	University of Durham	UDUR	UK
10	Istituto Nazionale di Fisica Nucleare	INFN	Italy
11	Max-Planck-Gesellschaft zur Frderung der Wissenschaften e.V.	MPG	Germany
12	The Chancellor, Masters and Scholars of the University of Oxford	UOXF.DL	UK
13	Sofia University St. Kliment Ohridski	UniSofia	Bulgaria
14	University of Warwick	Warwick	UK
15	Université Catholique de Louvain	UCL	Belgium



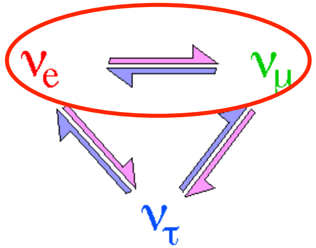
Work Packages

in order to underline synergies…

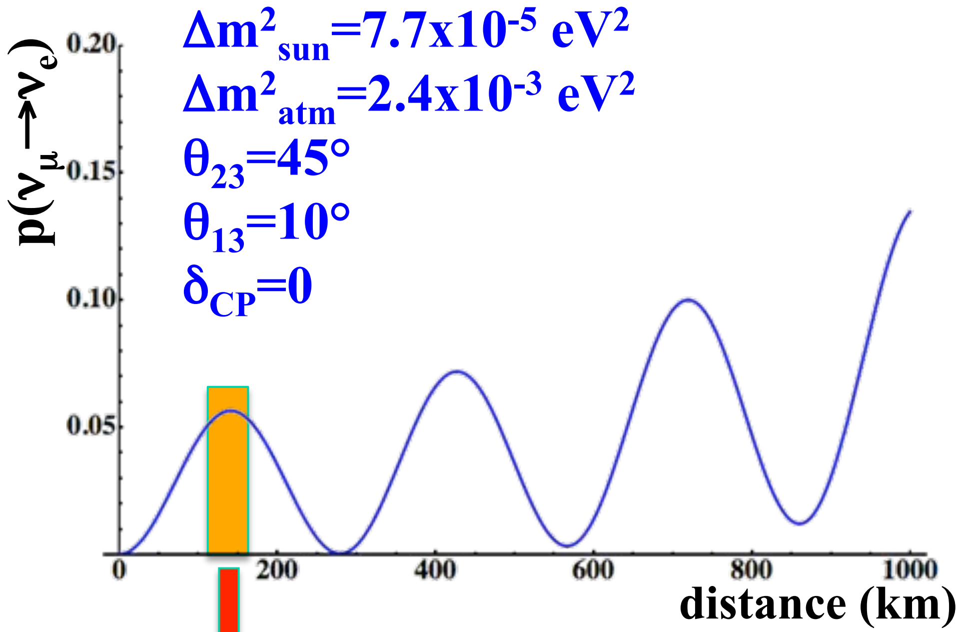


Neutrino Super Beam from HP-SPL

SPL proton kinetic energy: ~4 GeV



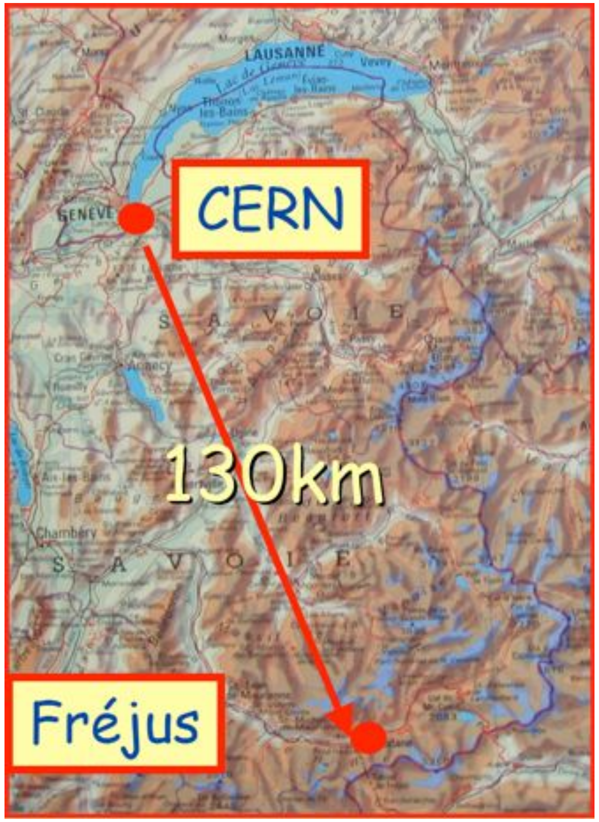
Neutrino energy: ~300 MeV



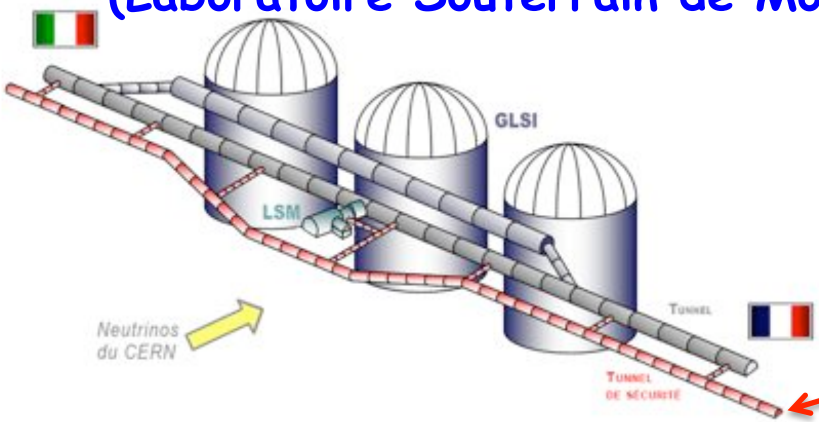
~130 km

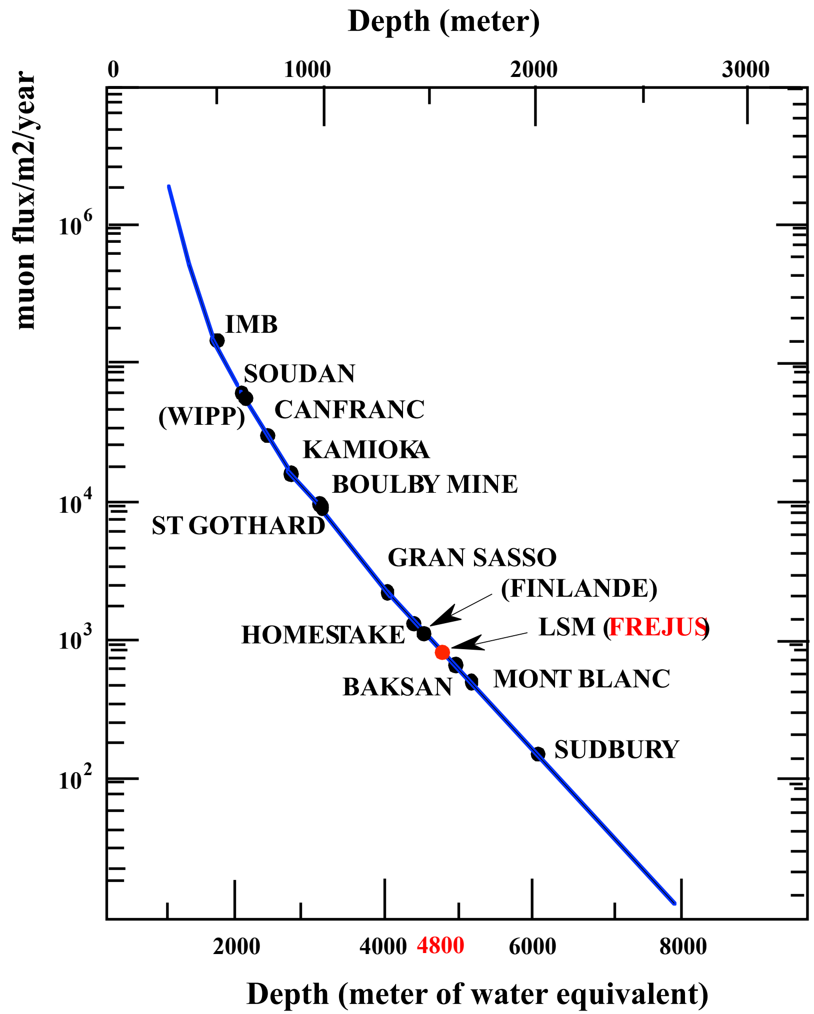
Fréjus tunnel

Fréjus underground laboratory



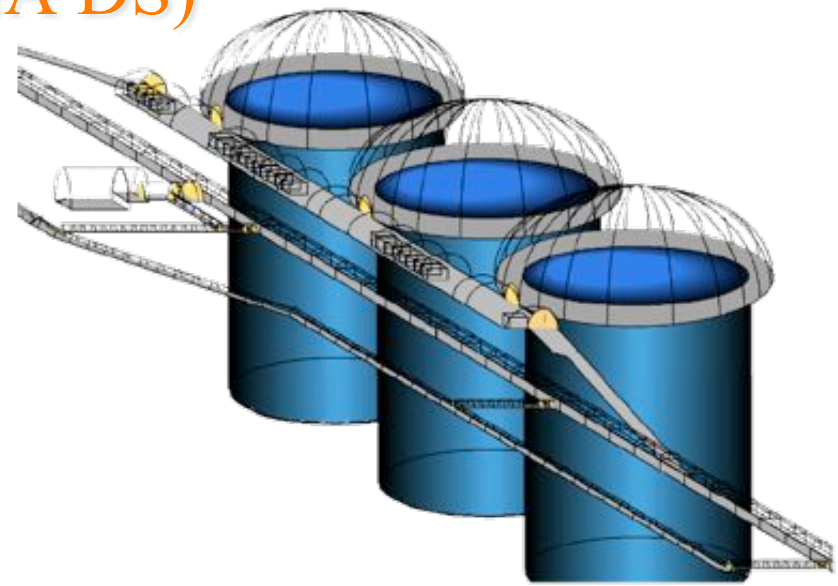
(Laboratoire Souterrain de Modane)





new safety gallery under construction, profit of this opportunity to enlarge LSM

The MEMPHYS Project
(within FP7 LAGUNA DS)



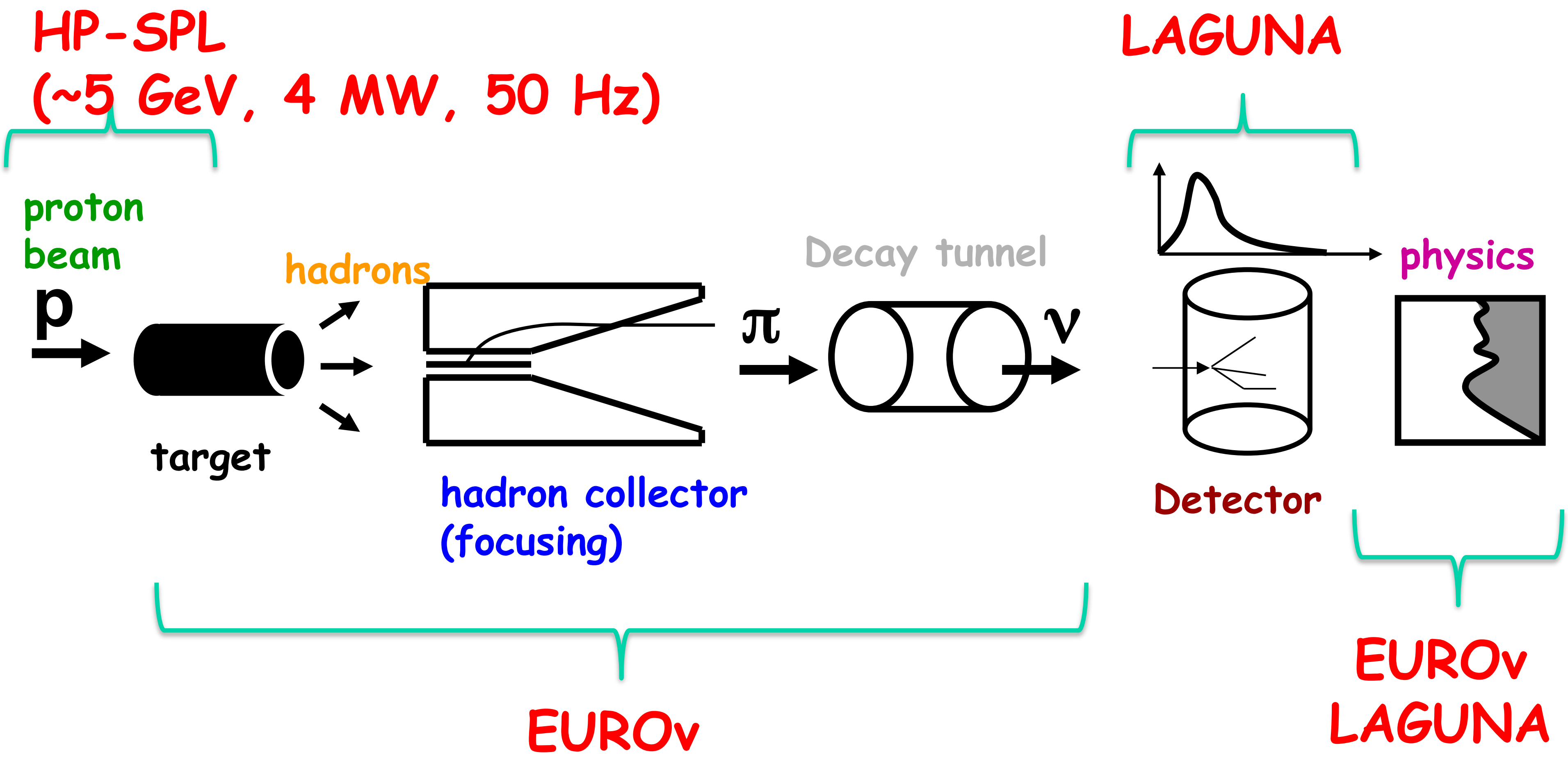
Mainly to study:

- **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).**

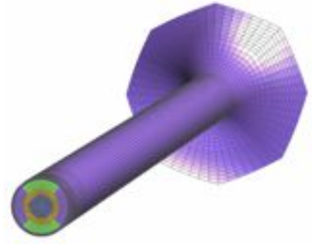
(arXiv: hep-ex/0607026)

Conventional Neutrino Beams



Technological Challenges

Target

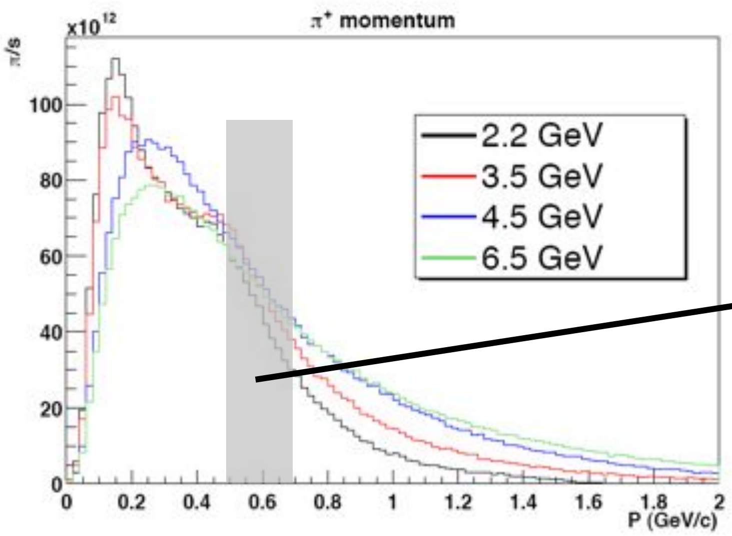


- 300-1000 J cm^{-3}/pulse
- Severe problems from : sudden heating, stress, activation
- Safety issues (profit of installations to exist by then like T2K, ESS, SNS)!
- Solid versus liquid targets:
  - Extremely difficult problem :
    - Liquid metal target (mercury, Merit experiment), better cooling
    - Solid target, better handling
- Envisage alternative solutions

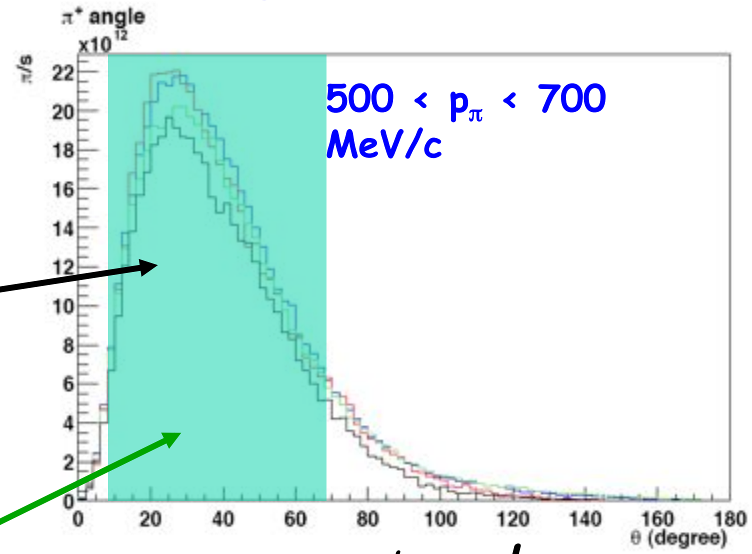
Proposed design for SPL

for pions coming out of the target

for a Hg target, 30 cm length, ∅15 mm



π^+ momentum



$500 < p_\pi < 700$ MeV/c

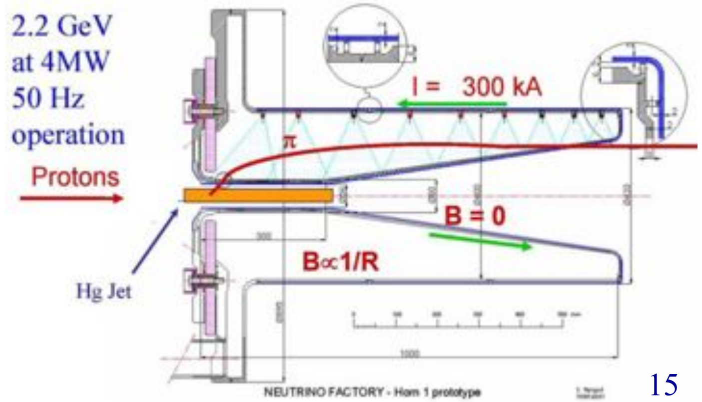
π^+ angle

horn region

relatively better collection when p_{proton} ↗

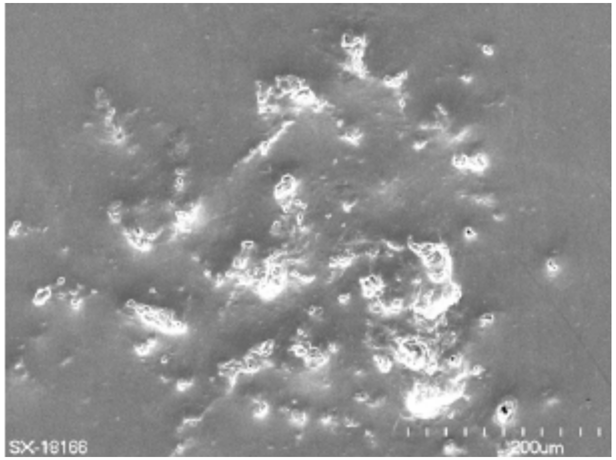
the target must be inside the horn!

severe cooling conditions



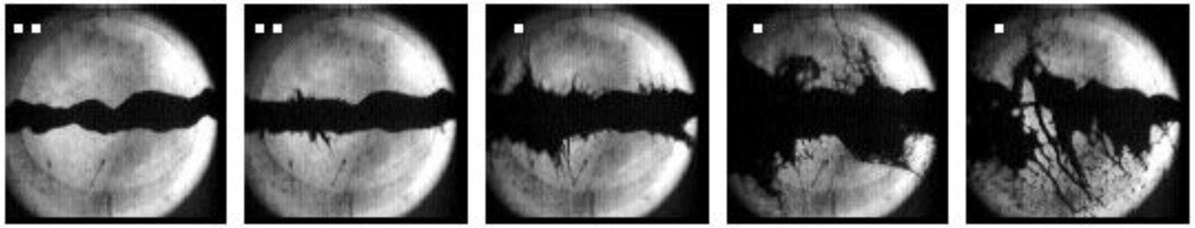
Studies on Hg targets

Contained mercury



Cavitation damage in wall of Hg target container after 100 pulses of 19 J/cc proton beam (WNR facility at LANL)

Free mercury jet



MERIT experiment: Beam-induced splashing of mercury jet (c.200 J/cc)

•Damping of splashes due to magnetic field observed as predicted

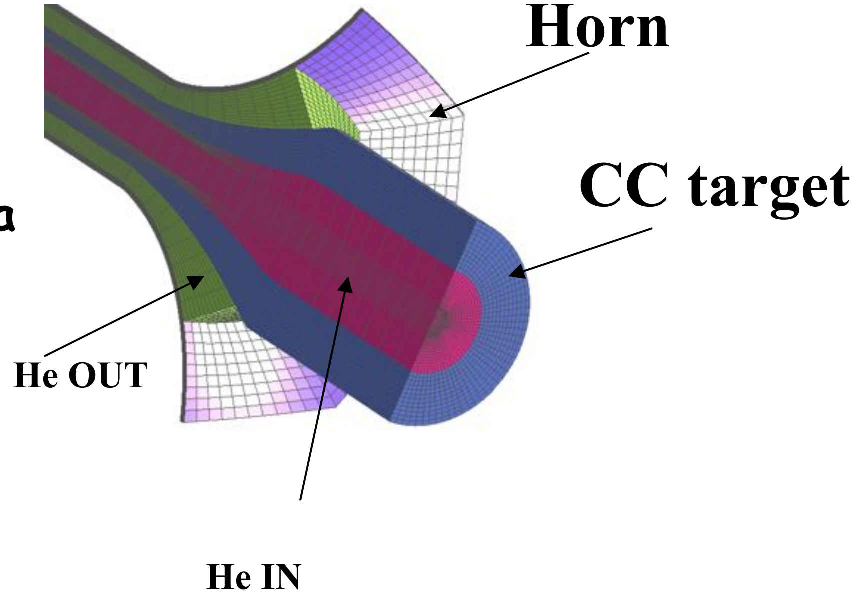
•More studies ongoing

no problem with target cooling but…

- Magnetic horns are typically manufactured from aluminium alloy not compatible with Hg (severe and rapid erosion in addition to the shock wave problem)
- Is it possible to protect a horn with a material compatible with liquid Hg?
- B=0 inside horn, ie no magnetic damping of mercury jet as in MERIT experiment
- Combination of a mercury jet with a magnetic horn would appear to be extremely difficult.

Solid Targets

- Graphite is conventional and already used for conventional neutrino beams
- Easier to combine with a magnetic horn (e.g. T2K target)
- Questions include:
  - How does particle production for C compare with Hg?
  - Can a static graphite target dissipate heat from a 4 MW beam?
  - What is the expected lifetime for a graphite target in a 4 MW beam?
  - According to studies done at BNL, no problem with 1MW proton beam.

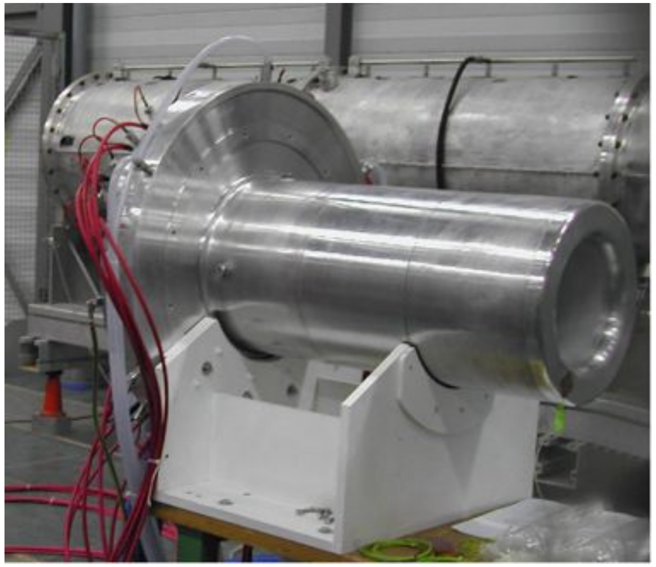


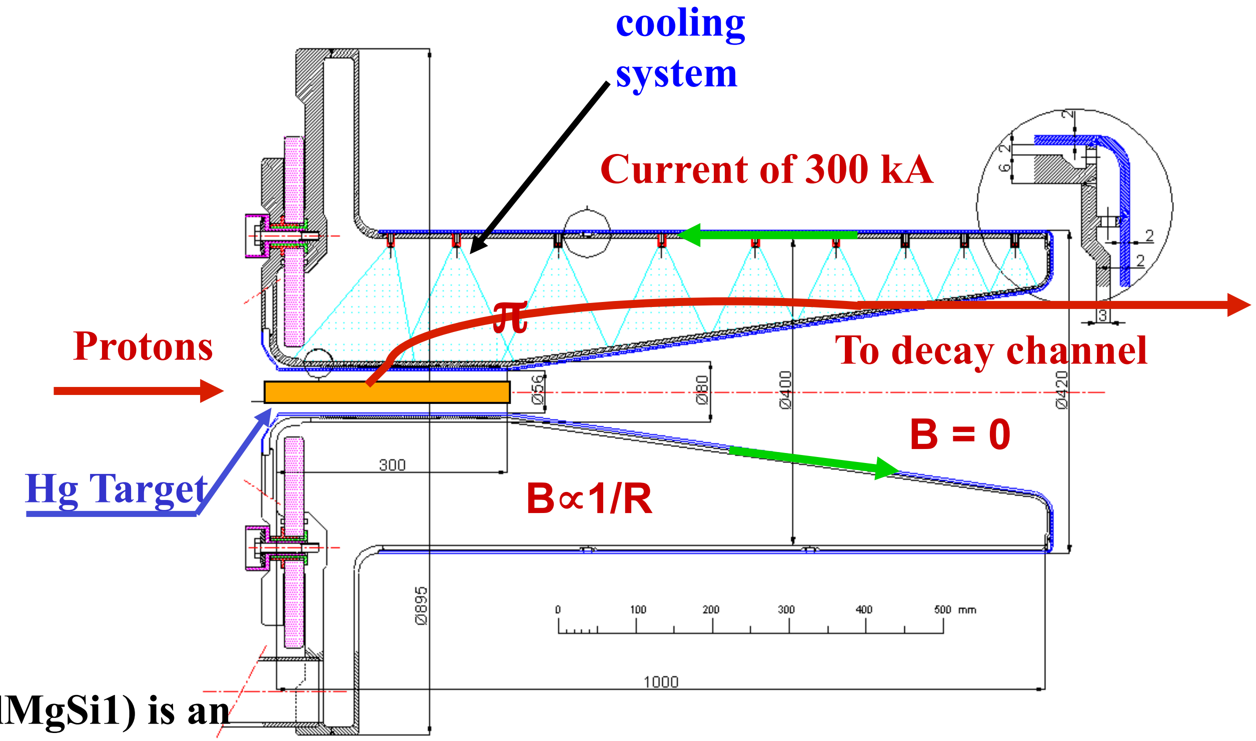
cooling is a main issue…

Horn prototype (CERN)

First studies with old SPL characteristics

- 2.2 GeV proton beam





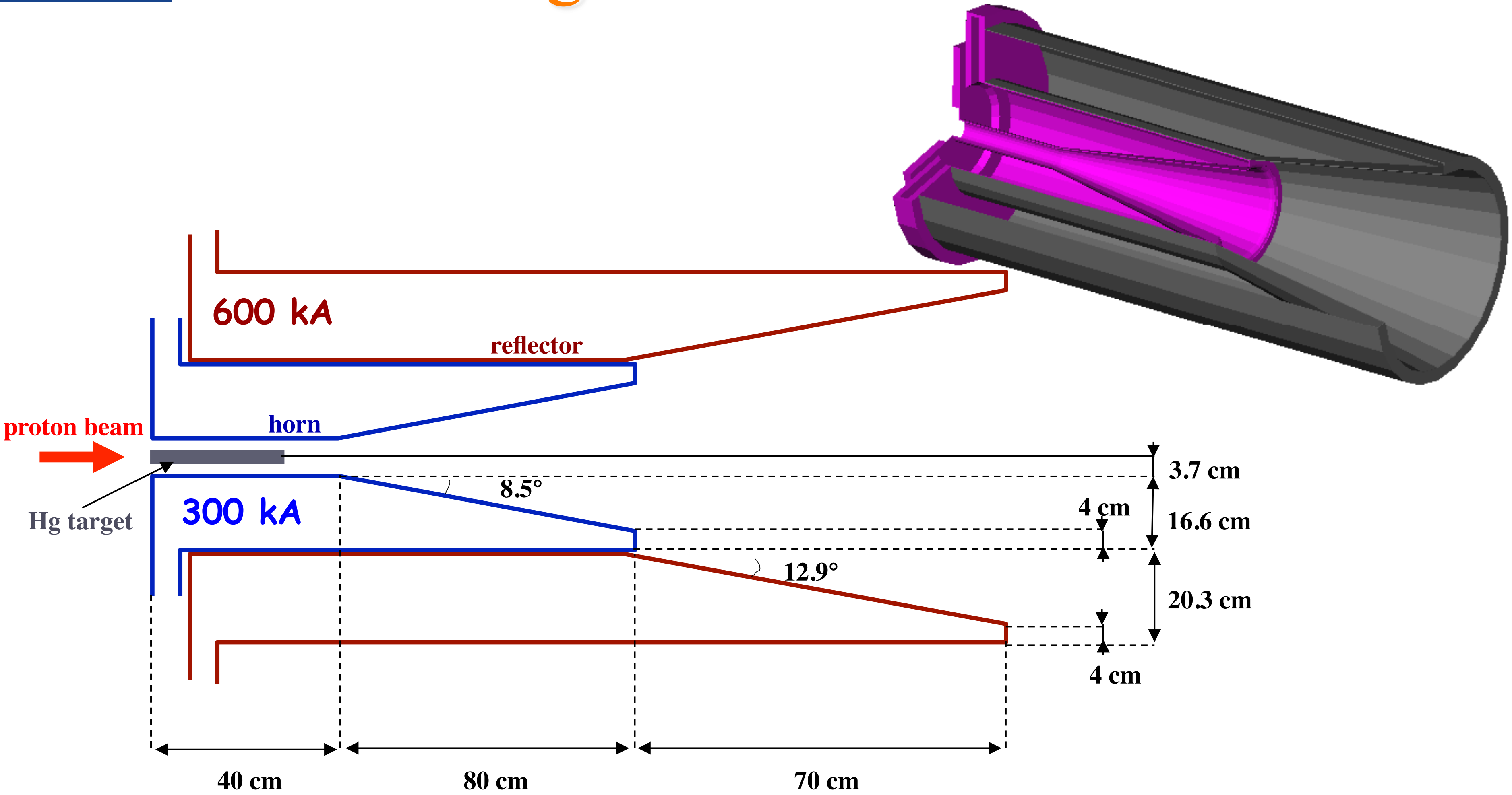
For the horn skin AA 6082-T6 / (AlMgSi1) is an acceptable compromise between the 4 main characteristics:

- Mechanical properties
- Welding abilities
- Electrical properties
- Resistance to corrosion
- Same for CNGS

initial design satisfying both, Neutrino Factory and Super-Beam

...but Al not compatible with Mercury!

New design for SPL 3.5 GeV



- very high current in reflector inducing severe problems
- build and operate one object in the other in severe conditions (radiations, cooling, vibrations etc.) very difficult

Main Collector Challenges

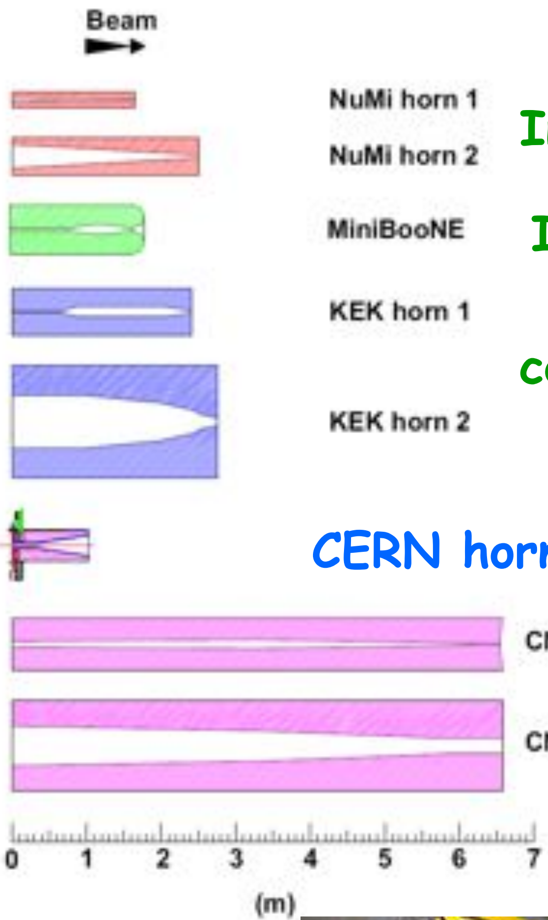
- Horn : as thin as possible (3 mm) to minimize energy deposition,
- Longevity in a high power beam,
- 50 Hz (vs a few Hz up to now),
- Large electromagnetic wave, thermo-mechanical stress, vibrations, fatigue, radiation damage,
- Currents: 300 kA (horn) and 600kA (reflector)
  - design of a high current pulsed power supply,
- cooling system in order to maintain the integrity of the horn despite of the heat amount generated by the energy deposition of the secondary particles provided by the impact of the primary proton beam onto the target,
- definition of the radiation tolerance,
- integration of the target.

How to deal with all these problems?

- Beam power (4 MW),
- Repetition rate (50 Hz),
- Target/horn integration,
- Cooling,
- Currents: 300 kA (horn) and 600kA (reflector),
- Lifetime of the system,
- Radiation tolerance.

Present Collectors

Experiment	Current	Rep. Rate	Pulses per time period
Numi (120 GeV)	200 kA	0.5 Hz	6 Mpulses 1 year
MiniBoone (8 GeV)	170 kA	5 Hz	11 Mpulses 1 year
K2K (12 GeV)	250 kA	0.5 Hz	11 Mpulses 1 year
Super-Beam (3.5 GeV)	300 kA	50 Hz	200 Mpulses 6 weeks
CNGS (400 GeV)	150 kA	2 pulses/ 6 sec	42 Mpulses 4 year



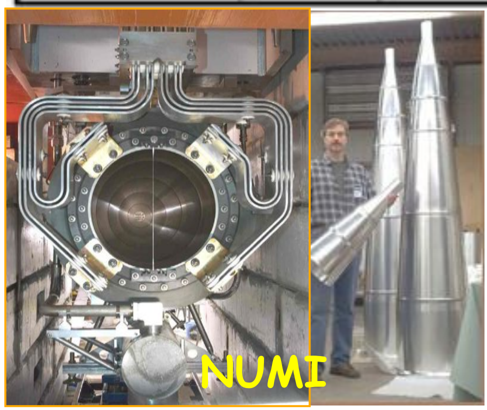
In operation

In operation

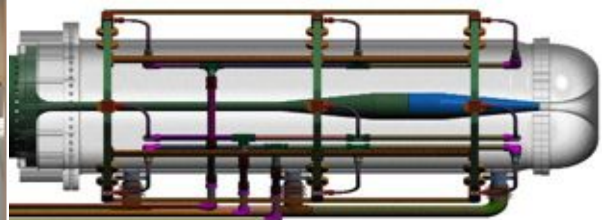
completed

CERN horn prototype for SPL

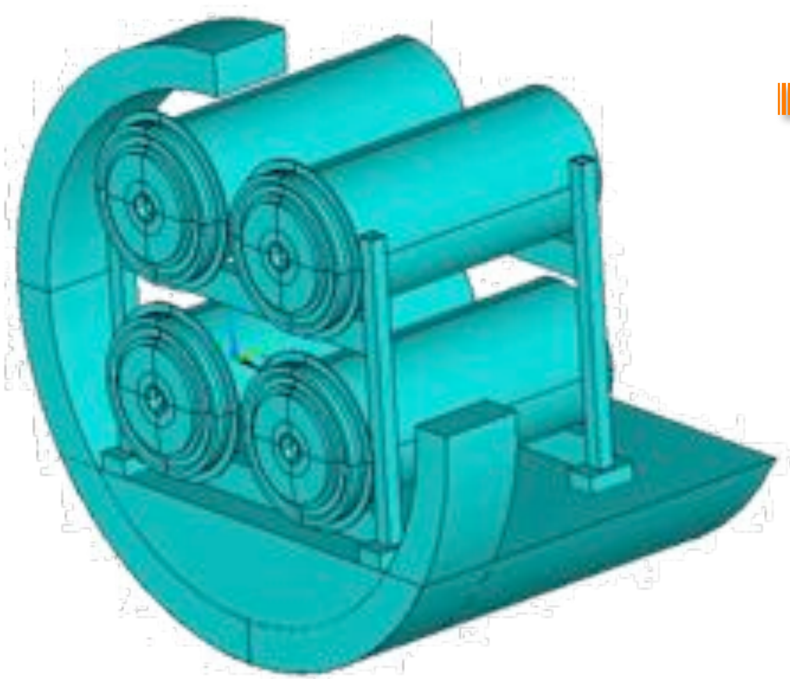
In operation



MiniBooNE



How to mitigate the power effect



4 target/horn system ($3x3\ m^2$) with single decay tunnel (<50 m)

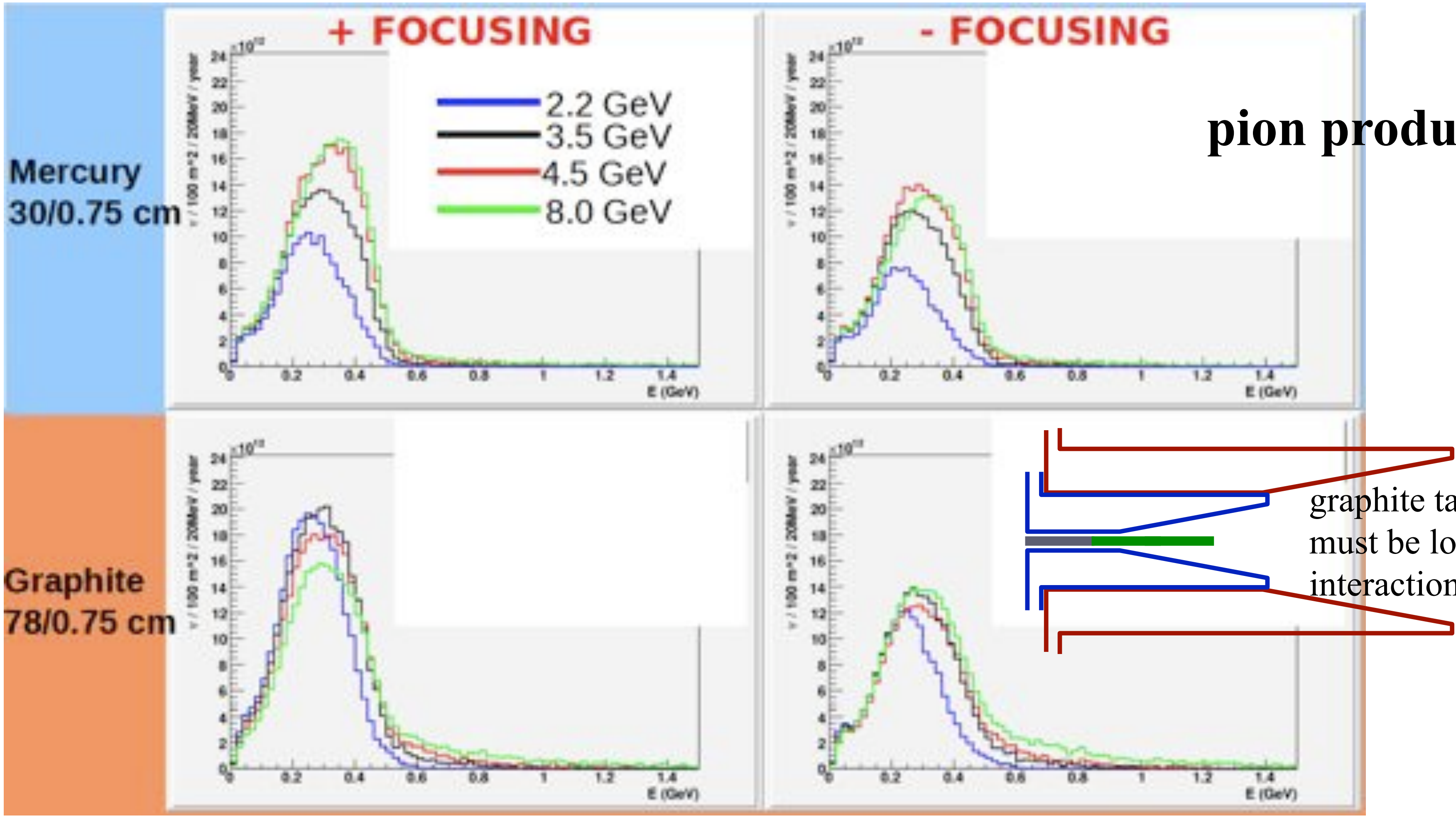
→ back to solid targets able to afford up to ~1.5 MW proton beam

3 options (only one pulser?):
- send at the same time 1 MW per target/horn system
- send 4 MW/system every 50/4 Hz
- change target/horn every Δt (min.?)

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

more expensive but more reliable system

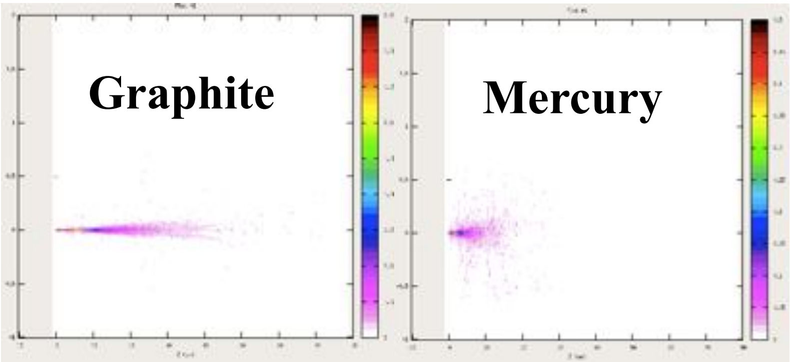
Comparison Mercury/Carbon

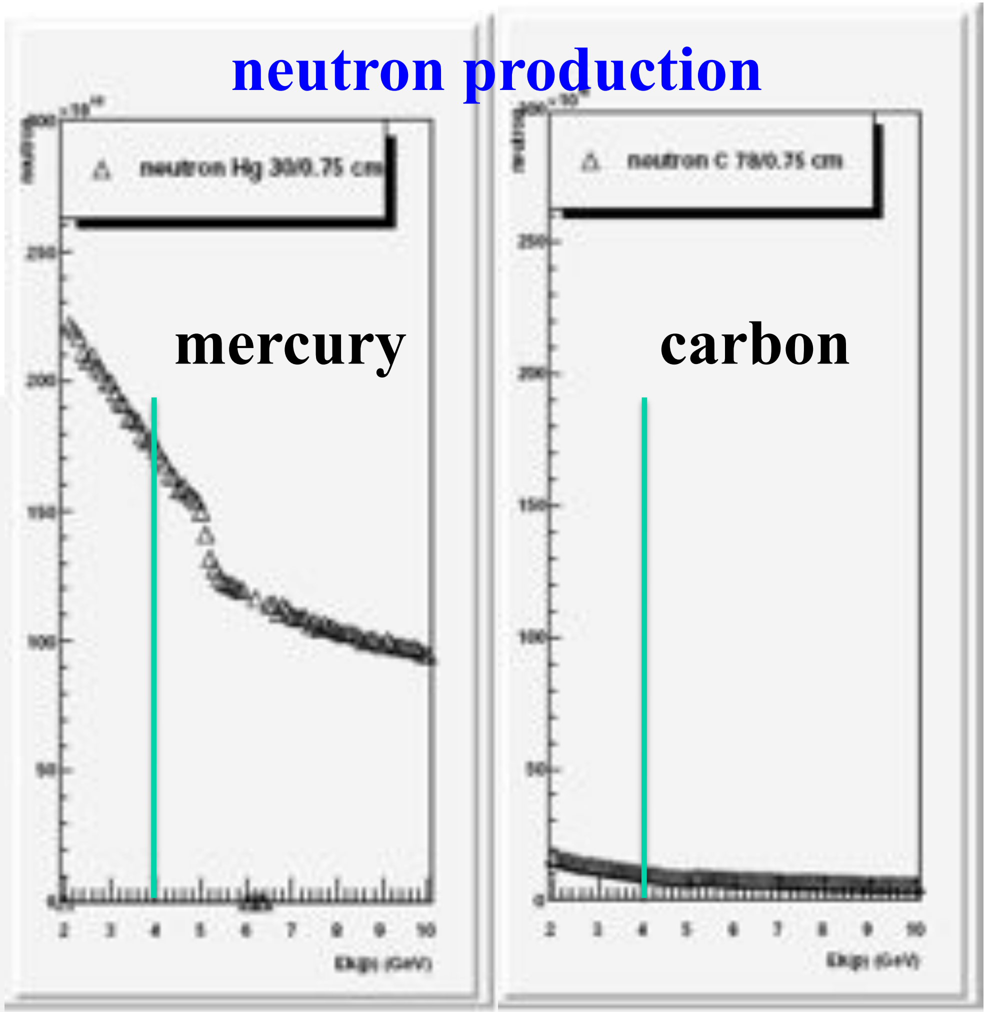


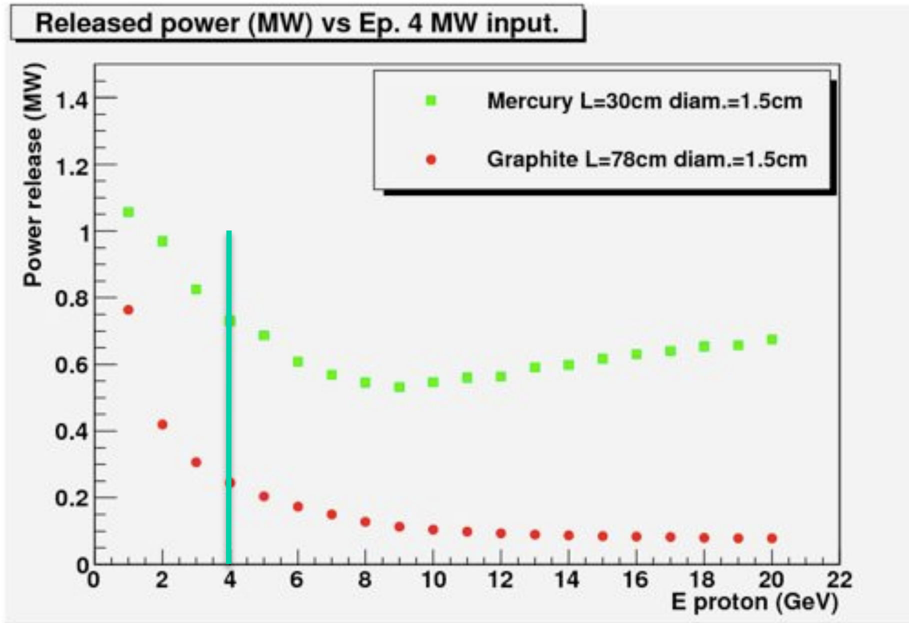
pion production

- **neutrino intensities are comparable despite non optimized focusing for long Graphite target**
- **higher high energy tail for Graphite (not optimized focusing)**

The Bonus…



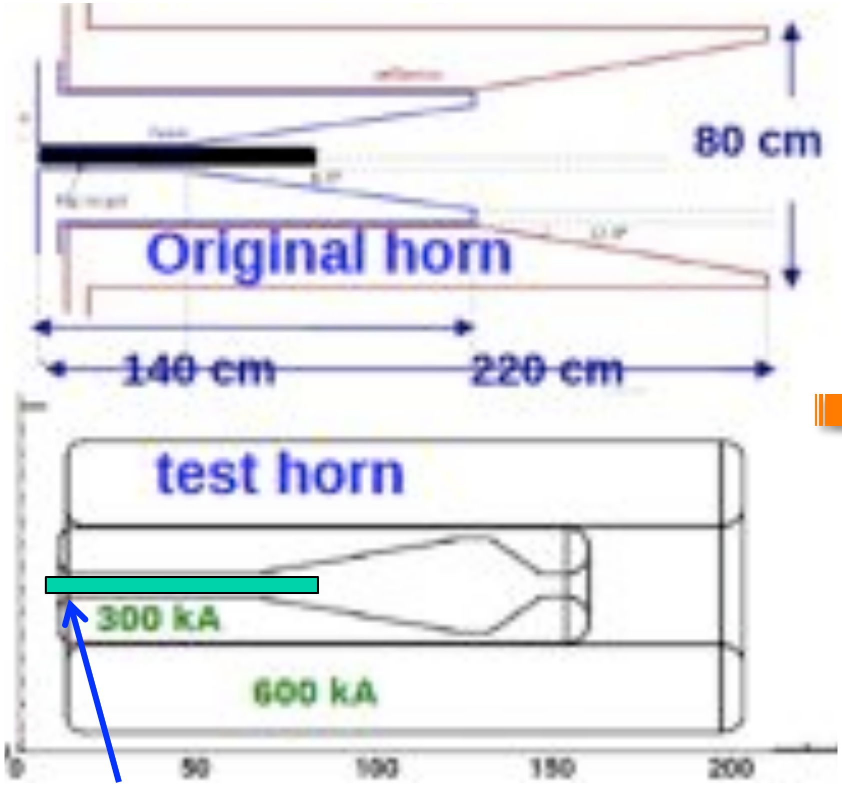


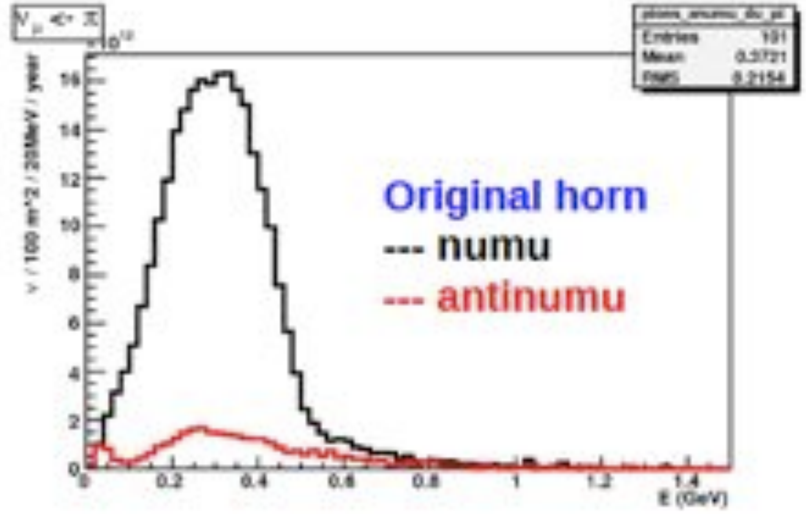


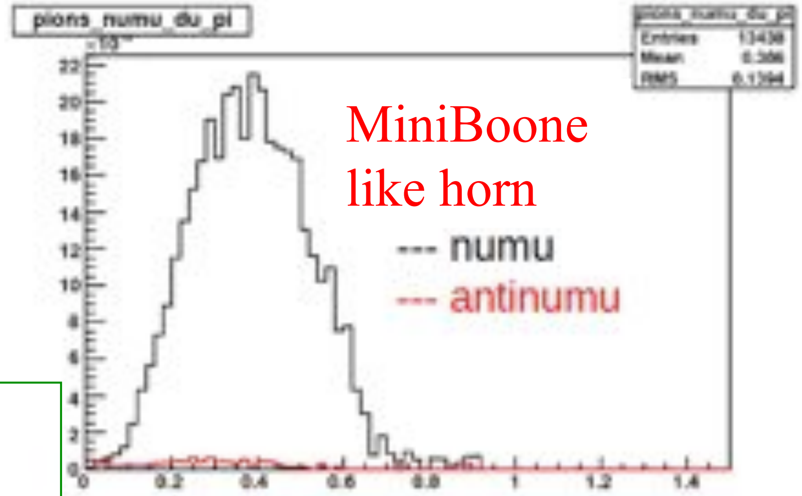
Hg: ~ 1 - 0.6 MW
C : ~ 0.8 - 0.1 MW
considerably lower for Carbon !

n flux dramatically reduced wrt Hg! (~ 15 x)

Can we optimize the horn shape for the solid target?



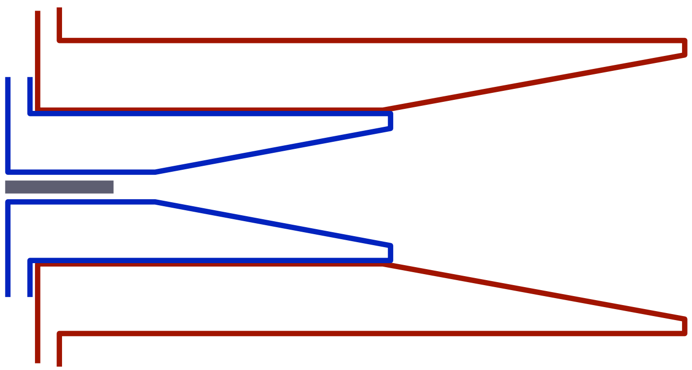


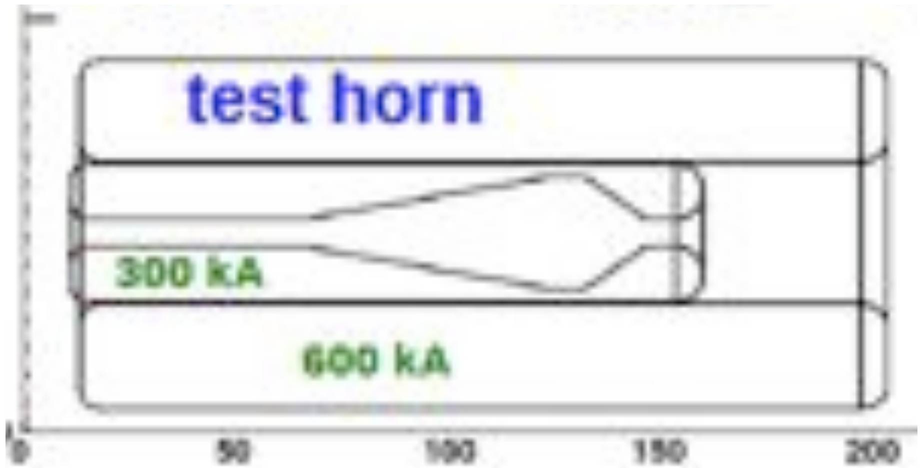


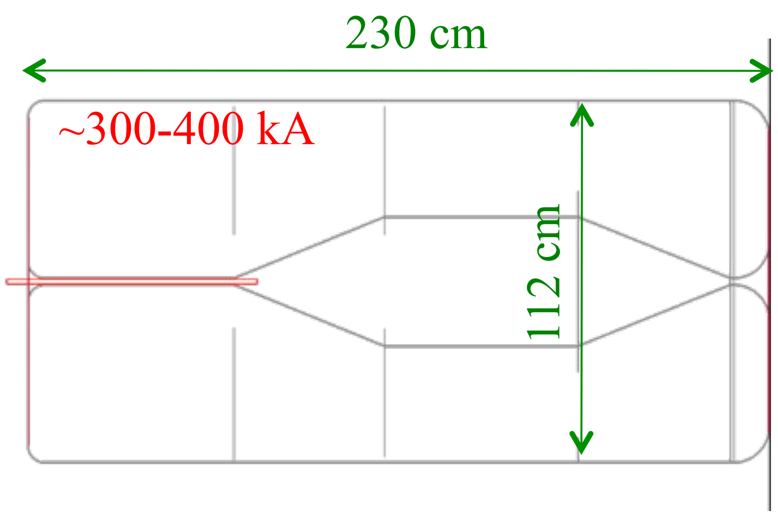
solid target (2 X0)

~simpler focalisation system without compromising with the physics performance (with even less contamination)

Can we get rid of the reflector?

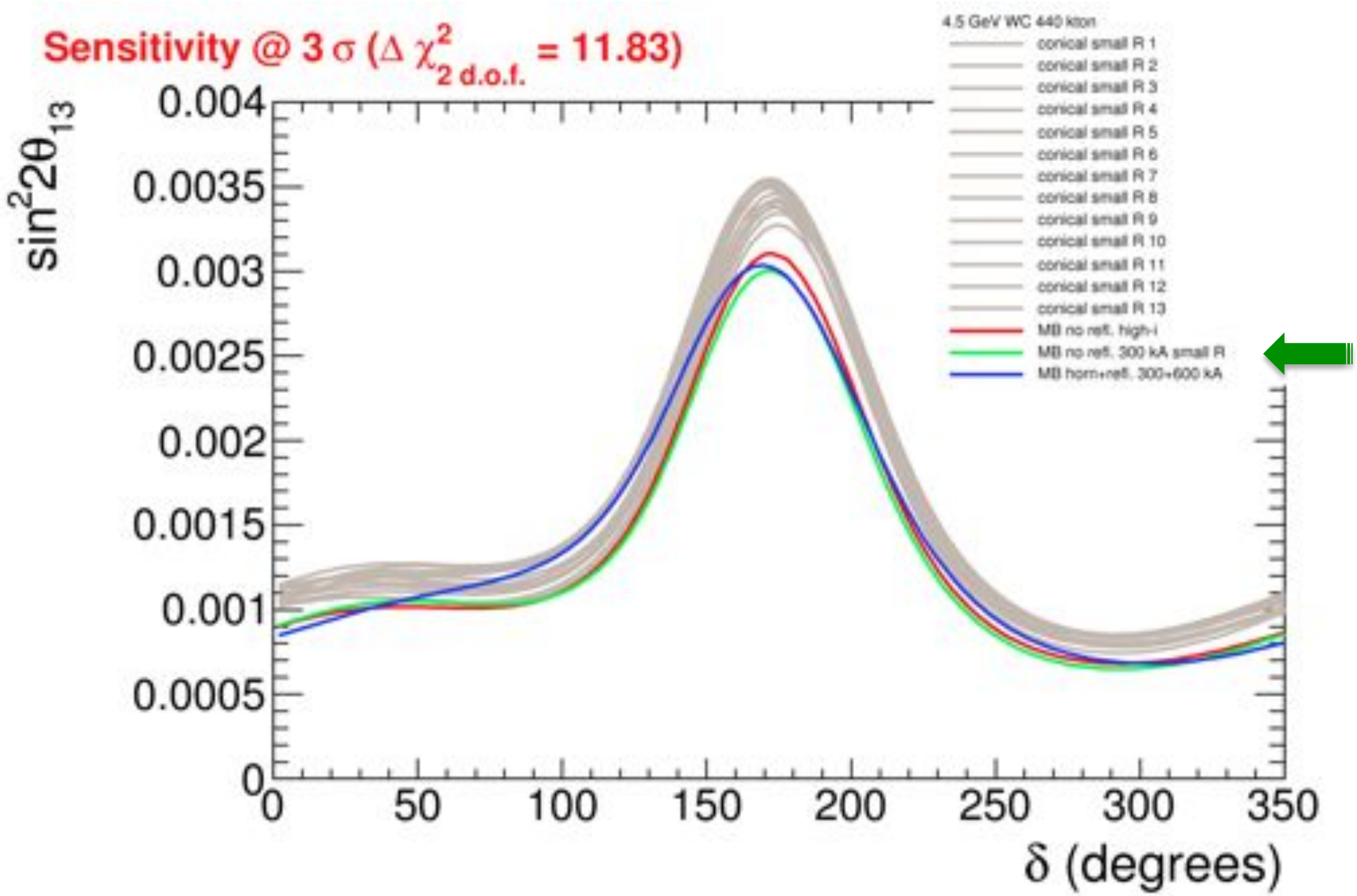






simple shape with reduced current!

Comparison between horns

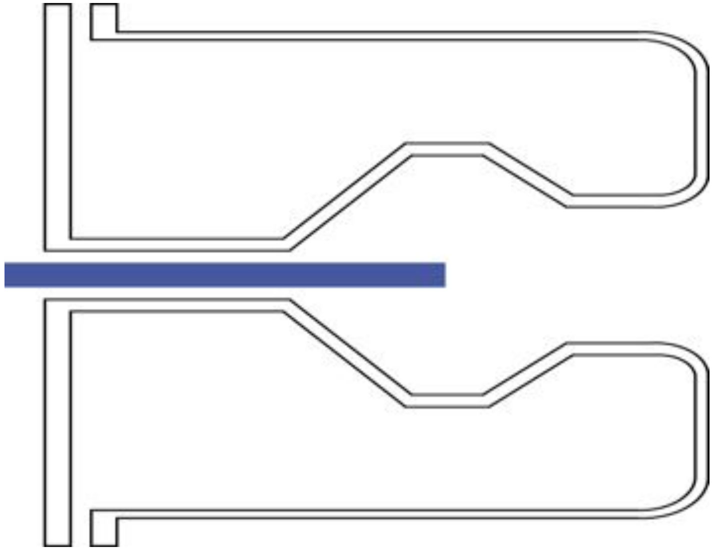


betters (best) results with the new horn geometry

➡

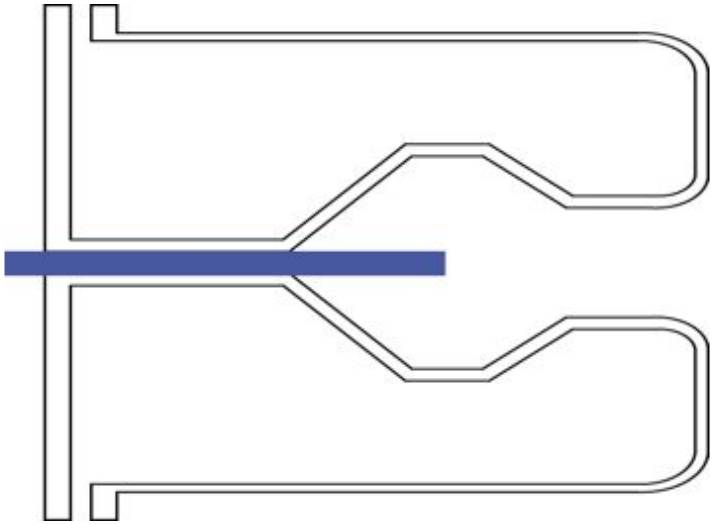
very promising (work ongoing)

Cooling is a critical point



<u>separate target and horn</u>

- easy target replacement
- cooling by gas He (probably not enough)
- supports have to be placed inside the horn to keep the target straight
- guides are needed for the target insertion
- relatively big horn inner cylinder (r~5 cm)



<u>integrated target and horn</u>

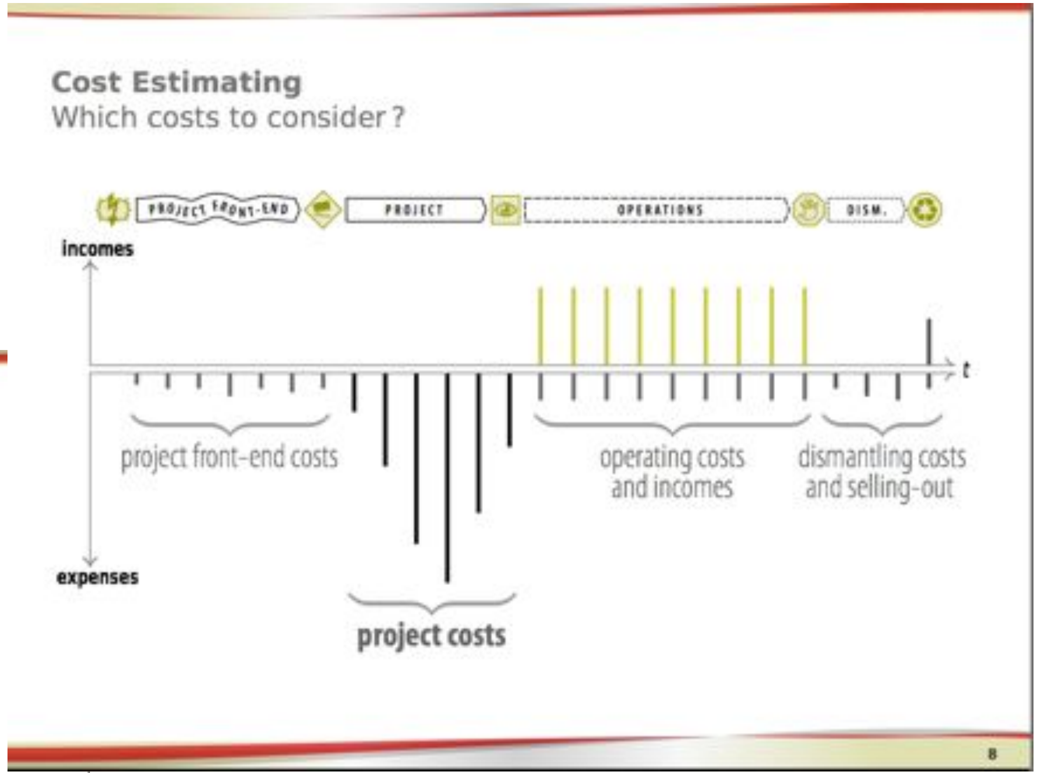
•target replacement not possible
•cooling by water sprays inside the horn
•the current will pass through the skin of the target (r~1.2 cm)
•magnetic field close to the target (better physics performance)
•no guiding system needed
•same material has to be used by the target and horn internal cylinder (Beryllium?)

Costing and safety of the facilities

- The cost evaluation and safety issues of the proposed facilities is part of the design study.
- A first two days costing workshop has been organized at CERN last March (http://indico.cern.ch/event/EuroNuCostingMar2010)
  - presentation of the cost management techniques to the EUROν participants towards defining a strategy for what needs to be done within the design study.
  - The workshop was more of a tutorial and open discussion basis, where the experience from past and present/future HEP accelerator projects were presented along with methods, techniques and tools used in cost evaluation of big projects.

Costing of the facilities

P. Bonnal "Project Cost Management – what is all about?"



What you have and what you don't have to cost…

Costing of the facilities (error and risk estimates)

« *Best PM Practices* »

Project cost estimate must include :

- Resulting figure (incl. cost breakdown structure, schedule)
- Approach used (global, modular, detailed) ⇢ Accuracy
- Assumptions (incl. sourcing of economical rates and indices)
- Risks (threaths and opportunities) ⇢ ***Project Risk Register***.

Cost figures must be :

- Sourced (historical data, price inquiry…)
- Localised (location cost factor, FX rate…)
- Discounted (date stamped as if all items were bought now)
- Converted and hence given in the « Project Currency ».

Any project cost estimate should go with a risk register !

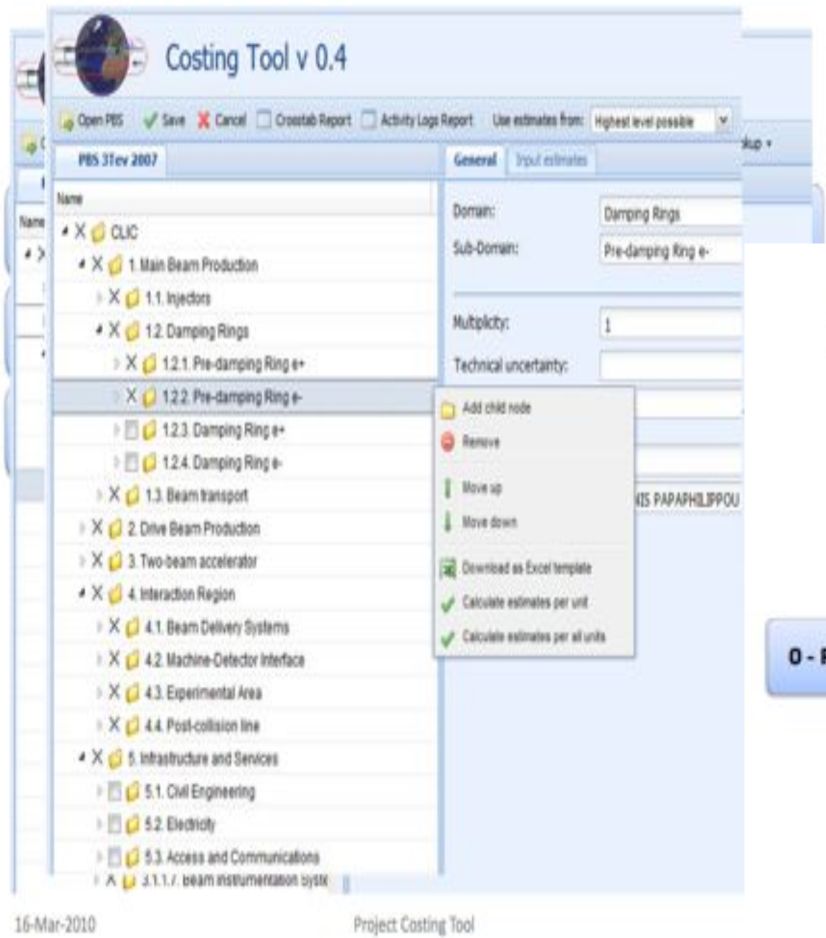
$$S = P \times C$$

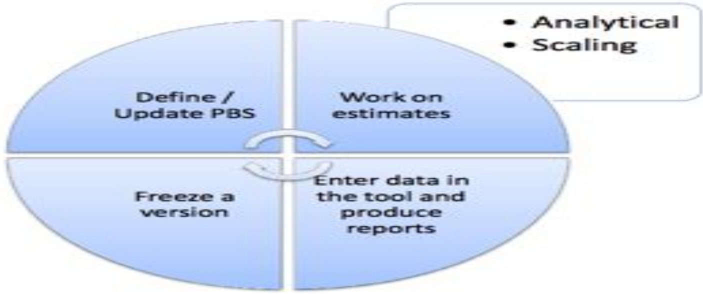
P \ C	.05	.1	.2	.4	.8
.9	.05	.09	.18	.36	.72
.7	.04	.07	.14	.28	.56
.5	.03	.05	.10	.20	.40
.3	.02	.03	.06	.12	.24
.1	.01	.01	.02	.04	.08

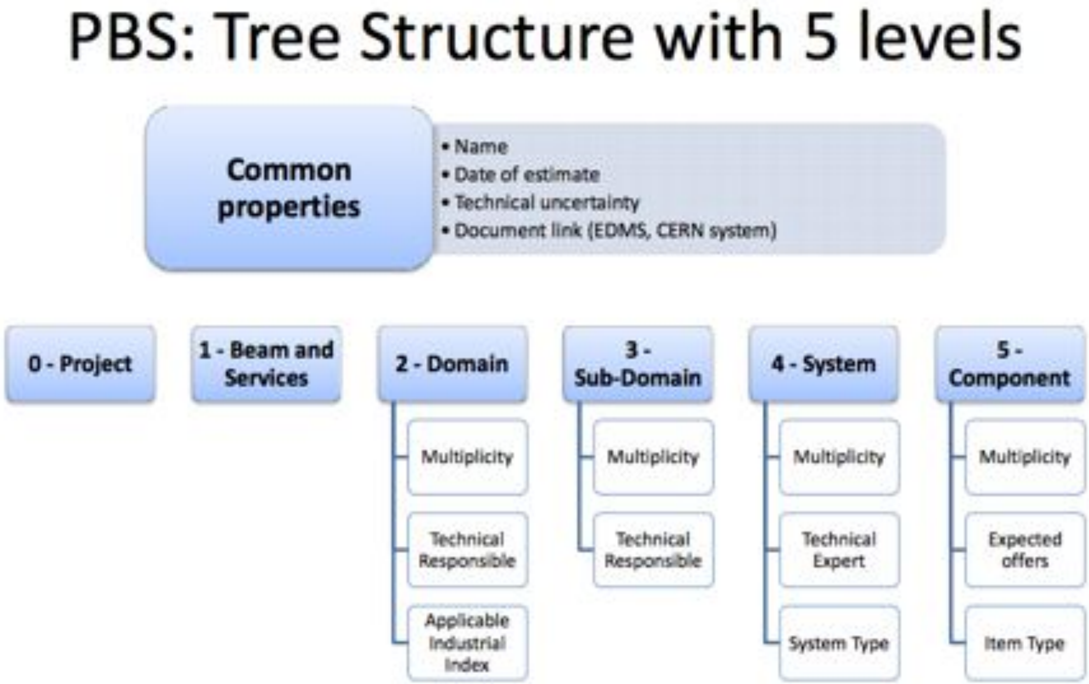
Accept Cancel Mitigate Transfer

13

Costing of the facilities (CERN tool for project costing)

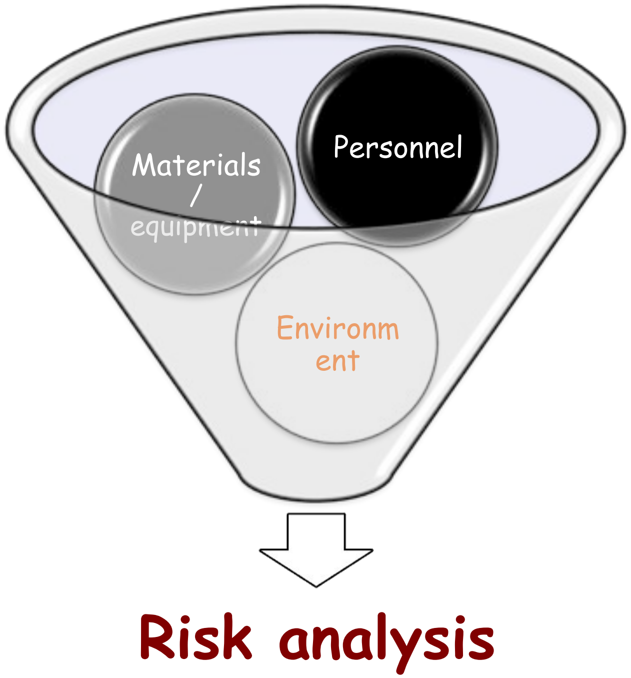






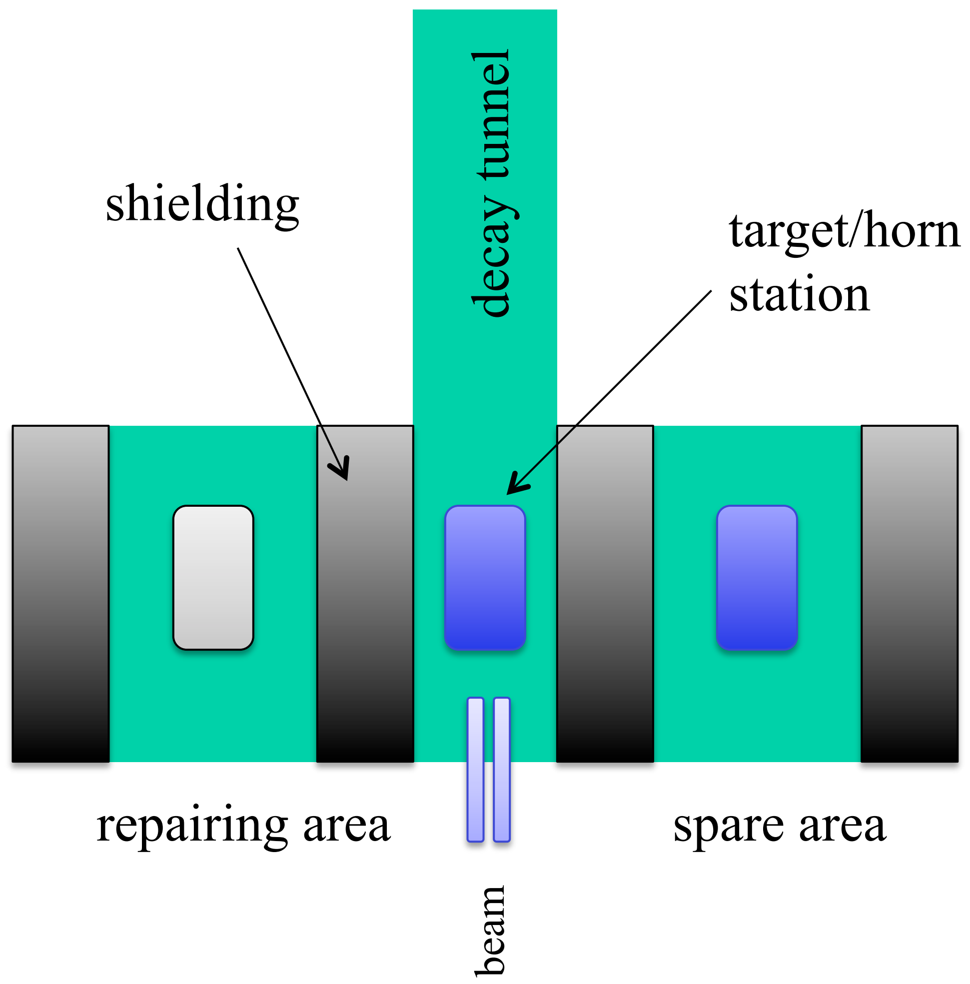
Safety
(workshop at CERN next ~February)

- ❑ Identify safety issues in the project
  - Safety of **personnel** during installation, operation, maintenance and dismantling actions
  - Safety to **materials/equipment** – assure their operation as required by the specs
  - Impact to the **environment** during installation, operation and dismantling of the facility
- ❑ Do risk analysis for each identified safety issue
  - Ways to mitigate the risk → incorporate in the design, include in the cost estimate
  - Classify the risks → setup the project risk register



Safety concerning WP2

- **Proton driver**
  - to be done by CERN
  - beam lines by WP2?
- **Target/horn station**
  - Shielding around
  - Air recycling
  - Cooling system
  - Tritium production
  - Lifetime
    - target
    - horn (+pulser)
- **Decay tunnel**
  - Shielding
  - Cooling
- **System repairing/exchange**
- **Retreatment**



After Chamonix CERN workshop about LHC injectors

- Recommendations to keep alive the present LHC injection chain.
- SPL has to be specifically studied for neutrino beams (High Power option).
- EUROν has to cost and study safety issues for the whole proton driver and not only the part to go from Low Power to High Power.

Conclusions

- EUROν is now at the beginning of the 3rd year (end of the Design Study: August 2012)
- The SPL to Fréjus Super Beam project is under study in FP7 EUROnu:
  - Conventional technology
  - "Short" schedule
  - Cost effective
  - Many synergies with other projects
  - Competitive CP sensitivity down to $\sin^2(2\theta_{13})\sim10^{-3}$
- For the Super Beam option
  - physics performance has been improved (still room for improvements?).
  - the proposed system is now more reliable
- The physics potential of this project is very high (also for astrophysics) especially in case of SB/BB combination.
- We have started freezing the main elements of all facilities.
- Comparison of the facilities not only on physics performance but also on costing and safety.

End