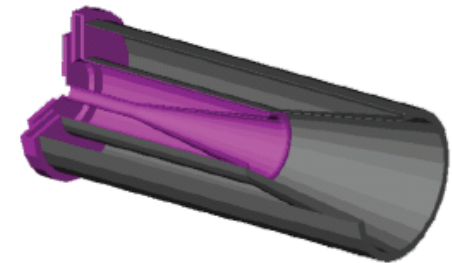
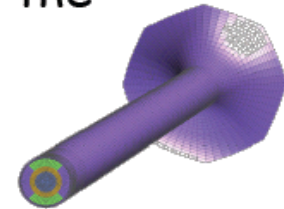


ESSNUSB WP5 SOFTWARE WORKSHOP

1. OVERVIEW
2. SIMULATION STATUS
3. DISCUSSION

OVERVIEW

- Can we conceive a neutrino beam based on a multi-MW proton beam ?
- At the start of EURO ν , no proven solution for the target and collector was proposed for this facility !
- 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**
 - 300-1000 J/cm³/pulse
 - Severe problems from: sudden heating, stress, activation
 - Solid versus liquid targets
 - cooling
- **Horn**
 - horn+reflector integration
 - pulser (up to 600 kA)
- **Safety**
- **Lifetime** (supposed to run for 10 years)



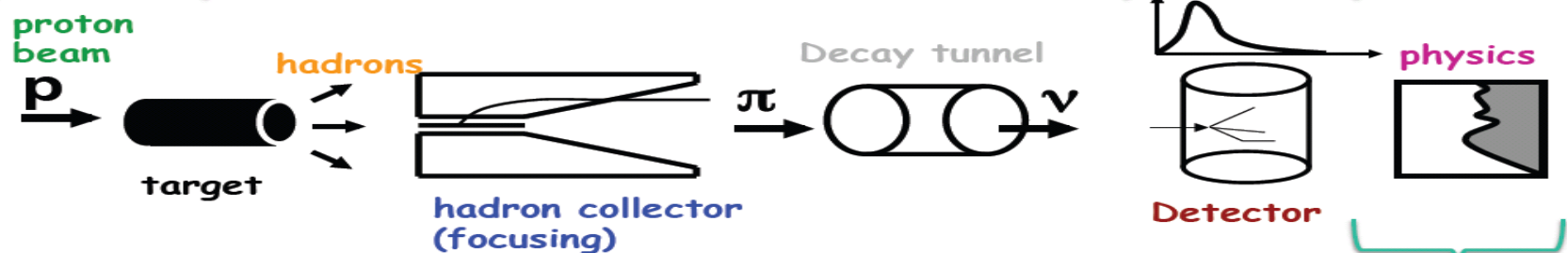
OVERVIEW

- Superbeam simulation:
 - Particle production
 - Horn design optimisation
 - Decay tunnel optimisation
 - Flux Computation
 - Sensitivity Estimation at Water Cherenkov detector location

EUROnu Simulation
4.5 GeV, 4 MW
GEANT 4.9.10

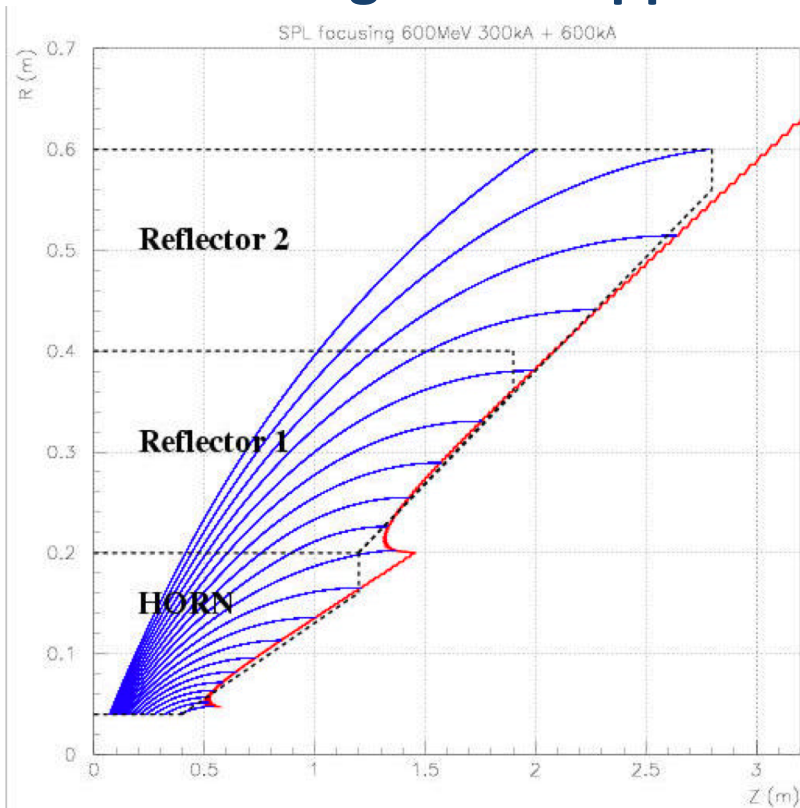


GENERATE GLOBES
INPUT FILES

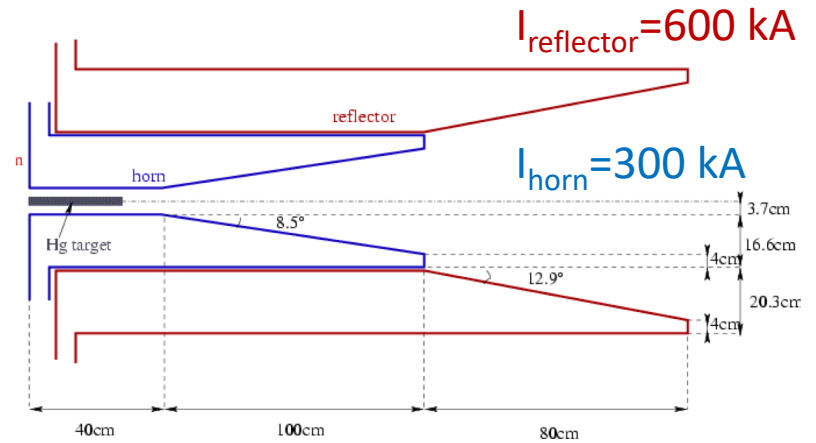


HORN DESIGN

Horn Design First Approach



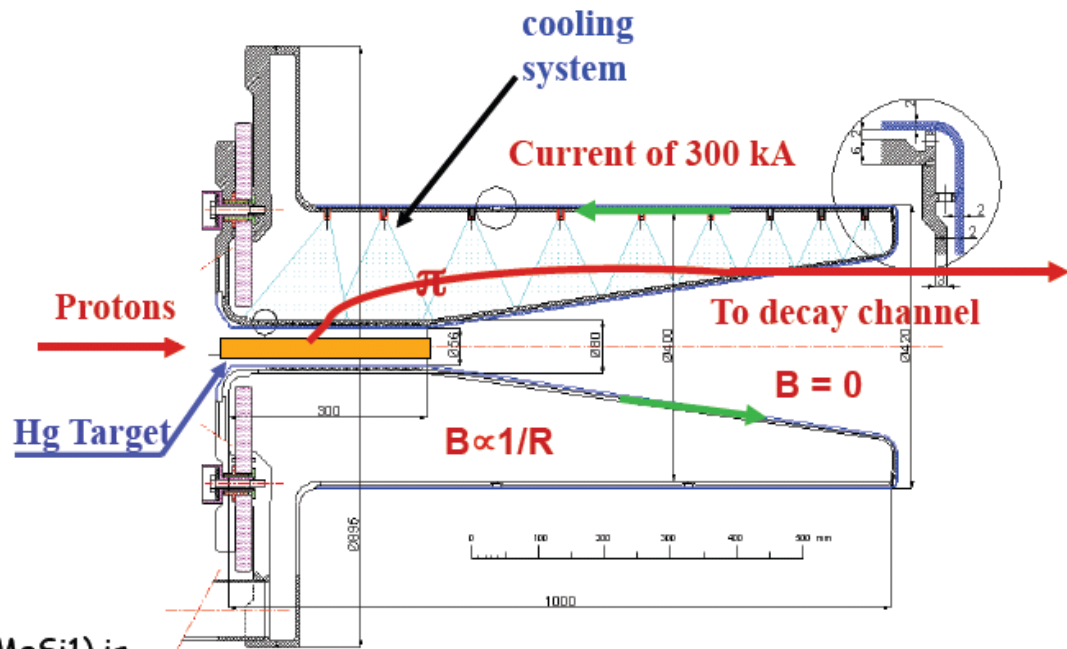
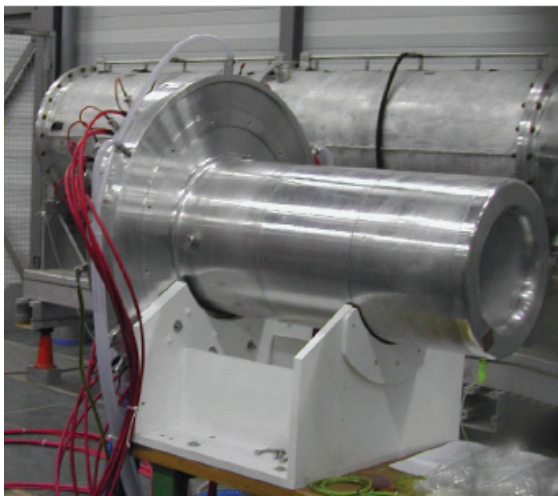
The outer conductor is placed where the slope becomes parallel to the beam ($dr/dz = 0$) (A. Cazes, J.E Campagne)



PROTOTYPE AT 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:

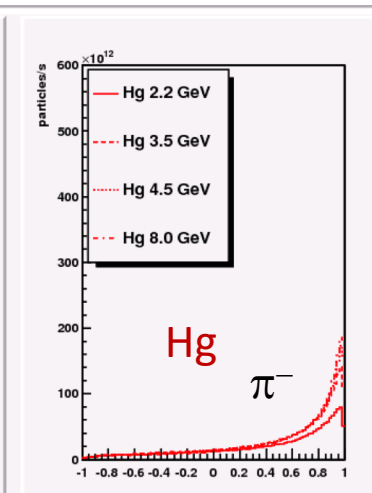
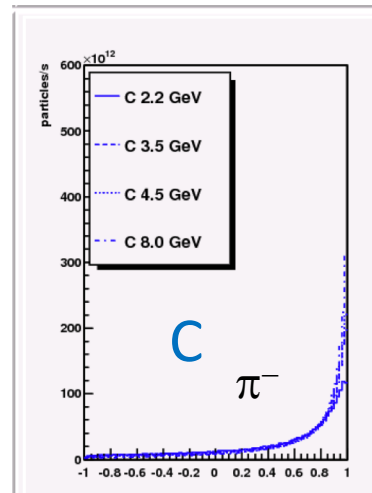
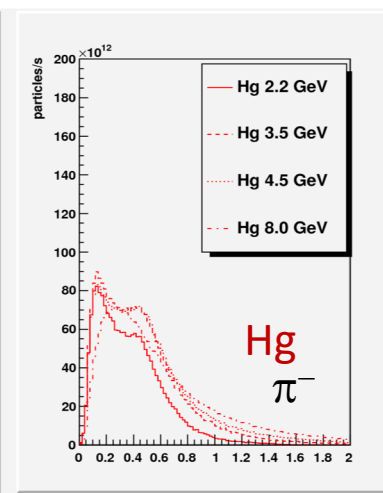
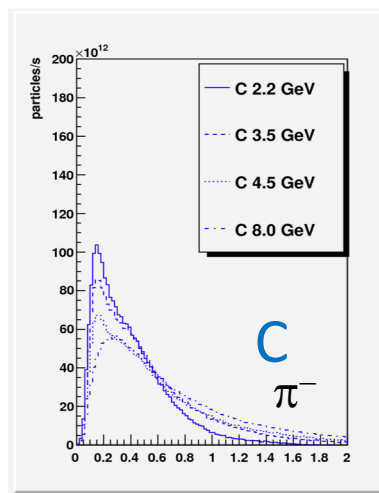
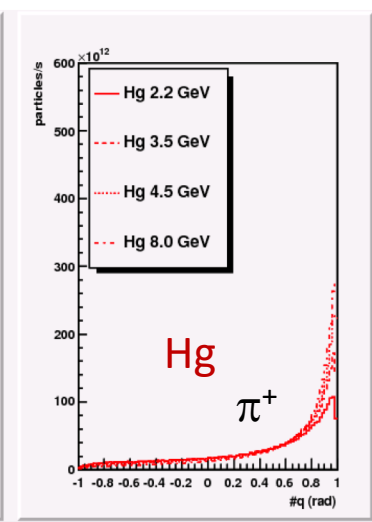
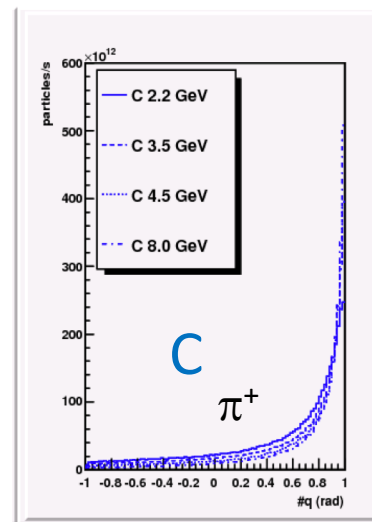
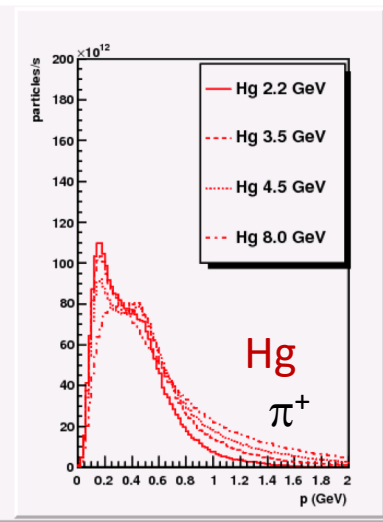
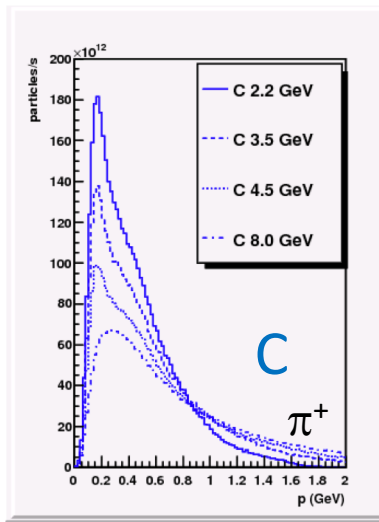
- Mechanical properties
- Welding abilities
- Electrical properties
- Resistance to corrosion
- Same for CNGS

initial design satisfying both, Neutrino Factory and Super Beam

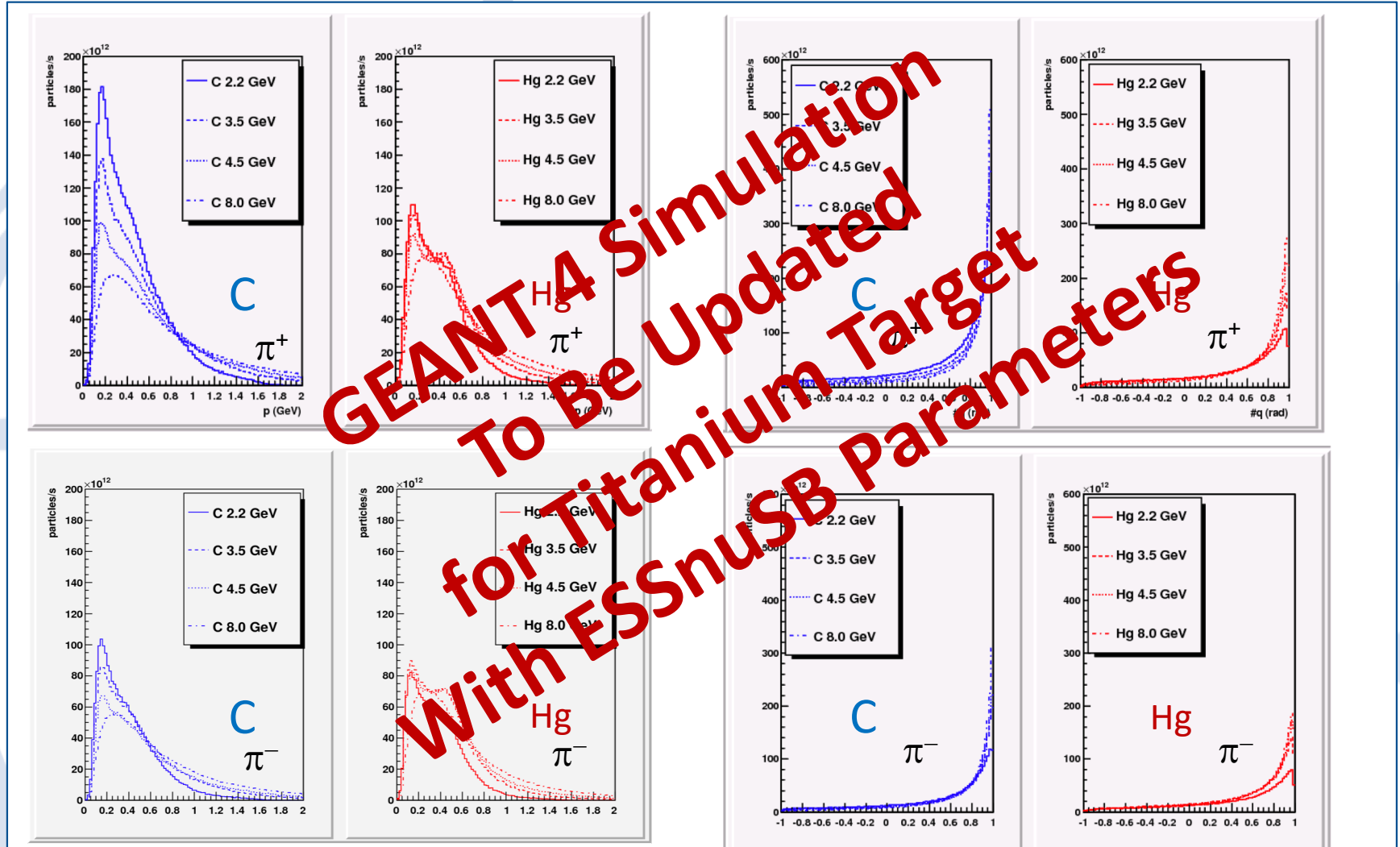
(see S. Gilardoni's thesis)

...but Al is not compatible with Mercury!

PARTICLE PRODUCTION FROM EURONU FROM



PARTICLE PRODUCTION FROM EURONU FROM



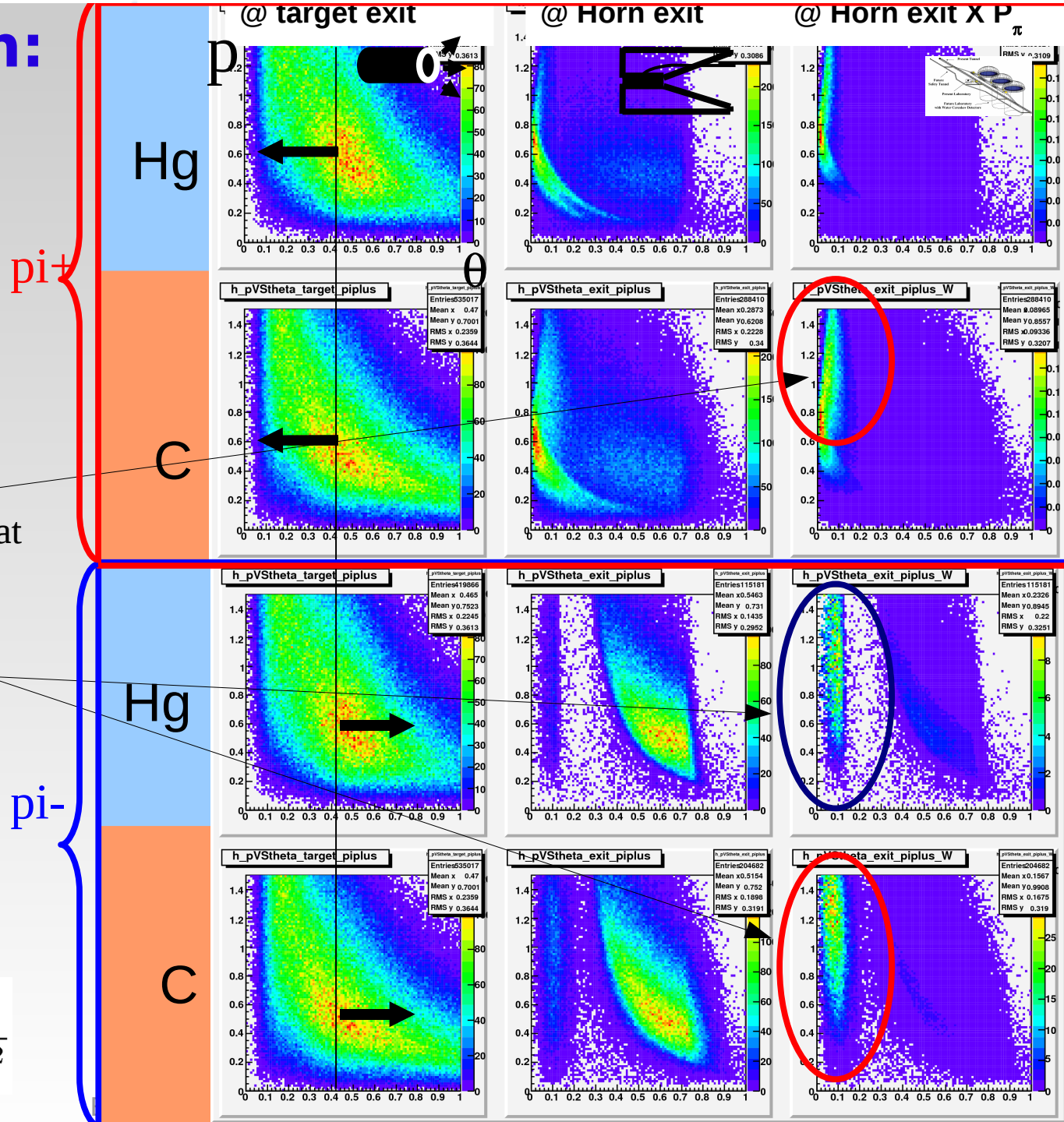
**GEANT4 Simulation
To Be Updated
for Titanium Target
With ESSnUSB Parameters**

Pi collection: Hg-C

- P vs θ plots
- Positive focusing (negative defocusing)
- Carbon:
 - focused pi+ less “monochromatic” (tail at high momentum)
 - larger fraction of not defocused pi-
- 4.5 GeV

P_π := probability to reach the detector

$$P_\pi = \frac{1}{4\pi} \frac{A}{L^2} \frac{1 - \beta^2}{(\beta \cos \alpha - 1)^2}$$

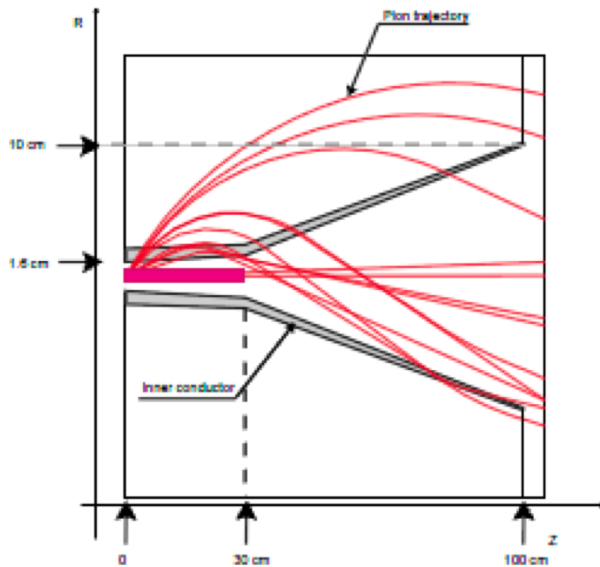
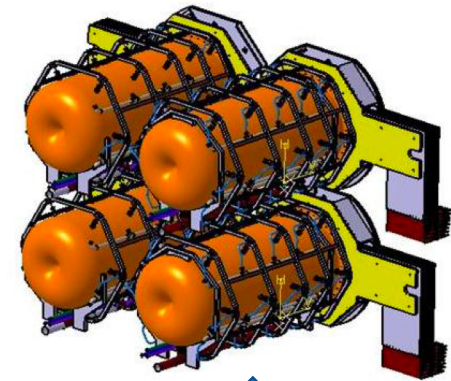


HORN DESIGN

Optimization:

- Depend on beam proton energy range,
- Rejection of wrong sign mesons
- Limited energy deposition
- Reliability

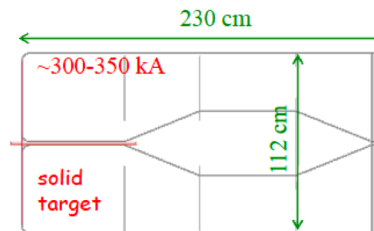
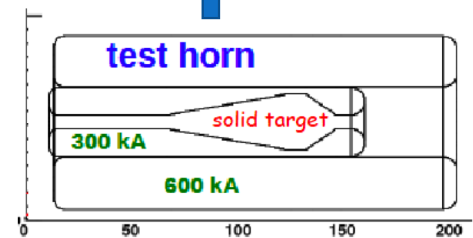
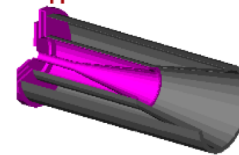
=> MiniBoone-like horn => Four Horn System



initial design

horn+reflector

Hg target



simpler optimized shape with reduced current!

final design

HORN DESIGN

Horn shape and SuperBeam geometrical Optimization I

Horn geometrical model

à la MiniBoone ("forward closed")

large acceptance for forward produced particles

This shape is well suited for long targets

Good suppression of wrong charge pion dangerous in "-" focusing mode due to ν_e from $\pi^+ \rightarrow \mu^+ \rightarrow e^+ \nu_e \bar{\nu}_\mu$ and $K^+ \rightarrow \pi^0 e^+ \nu_e$

EUROnu-WP2 note 05

A. Longhin Third EUROnu annual meeting, RAL 19 Jan 2011

studies by A. Longhin, C. Bobeth

Optimization strategy

- Parametric model of magnetic horns
- Random sampling of parameters
- Ranking of configurations based on achievable θ_{13} limits

Figure of merit: $\lambda = \theta_{13}$ sensitivity limit at 99% C.L. averaged over the δ_{CP} phase

$$\lambda = \frac{10^3}{2\pi} \int_0^{2\pi} \lambda_{99}(\delta_{CP}) d\delta_{CP}$$

We want as low as possible λ .

- Broad sampling of the (many) parameters to identify the most relevant variables. Then restrict the ranges of variation and iterate.

A. Longhin Third EUROnu annual meeting, RAL 19 Jan 2011

- ✓ parameterise the horn and the other beam elements as decay tunnel dimensions, etc...
- ✓ parameters allowed to vary independently
- ✓ minimize the δ_{cp} -averaged 99%CL sensitivity limit on $\sin^2 2\theta_{13}$

Horn Studies, WP2 @ APC, EUROnu 2012

HORN DESIGN

Horn Shape and SuperBeam geometrical Optimization II

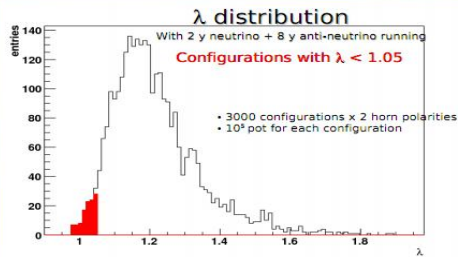
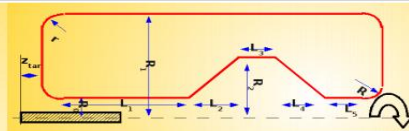
Broad scan

Allow parameters to vary independently

Limit	value
L_{max}	250 cm
R_{max}	80 cm
R_{min}	1.2 cm

Parameter	Interval
L_1	[50, L_{max}] cm
L_2, L_3, L_4	[1, L_{max}] cm
L_5	[1, 15] cm
R, R_1, R_2	[R_{min}, R_{max}] cm
R_0	[$R_{min}, 4$] cm
z_{tar}	[-30, 0] cm
L_{tun}	[35, 45] m
r_{tun}	[1.8, 2.2] m

Parameter	Value
L_{tar}	0.78 m
r_{tar}	1.5 cm
i	300 kA
s	3 mm
r	5.08 cm



L_{max} and R_{max} : keep the horns small to allow for the 4-horns in parallel to fit

A. Lonchín

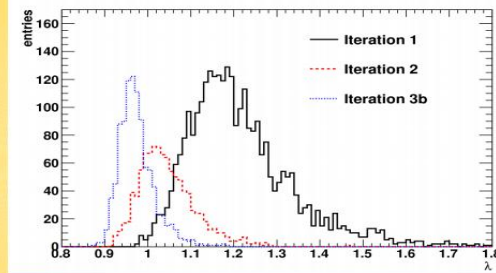
Third EUROnu annual meeting, PAL 19 Jan 2011



fix & restrict parameters then re-iterate for best horn parameters & SuperBeam geometry



Converging to better limits



- broad parameters' scan
- restricted intervals for effective parameters → horn with min λ
- vary tunnel parameters in L [15-35] m r [1.5-4.5] m

A. Lonchín

Third EUROnu annual meeting, PAL 19 Jan 2011

Parameters	value [mm]
L_1, L_2, L_3, L_4, L_5	589, 468, 603, 475, 10.8
t_1, t_2, t_3, t_4	3, 3, 3, 3
r_1, r_2	108
r_3	50.8
R^{tg}	12
L^{tg}	780
z^{tg}	68
R_2, R_3	191, 359
R_1 combined	12
R_1 separate	30



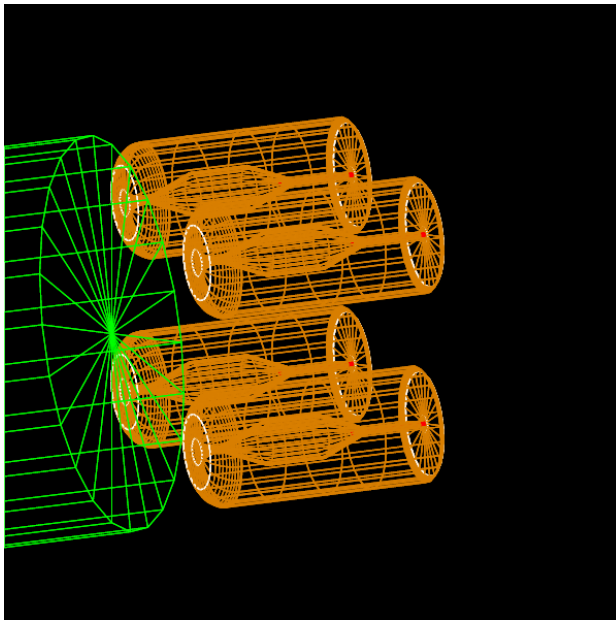
Horn Studies, WP2 @ APC, EUROnu 2012

SIMULATION

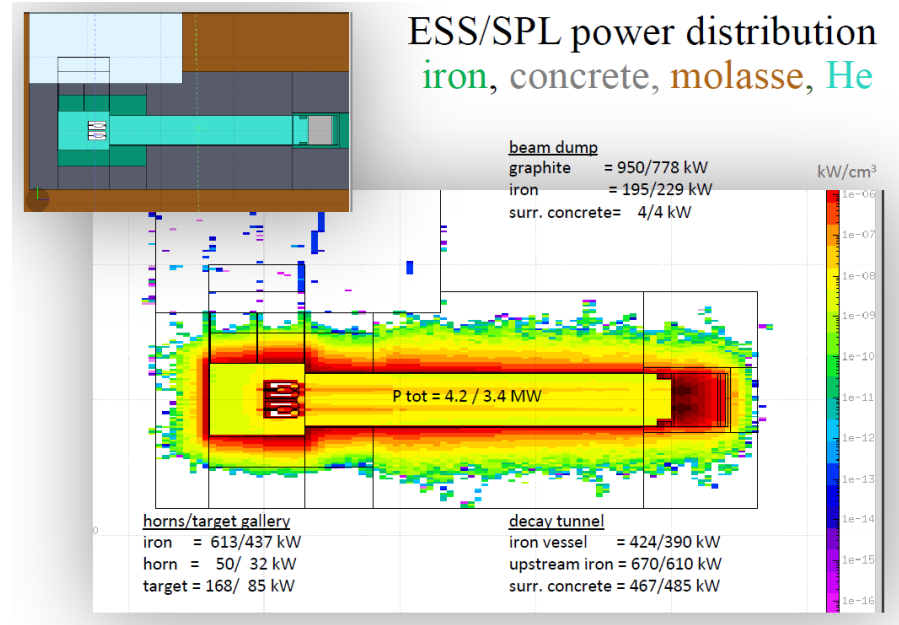
History :

- 2004 : SPL-Fréjus Superbeam Studies (A. Cazes and Al.)
- 2008-2012 : Euronu (A. Longhin and Al.)
- 2012- Present : N. Vassilopoulos (GEANT3 + FLUKA)

Available Frameworks:

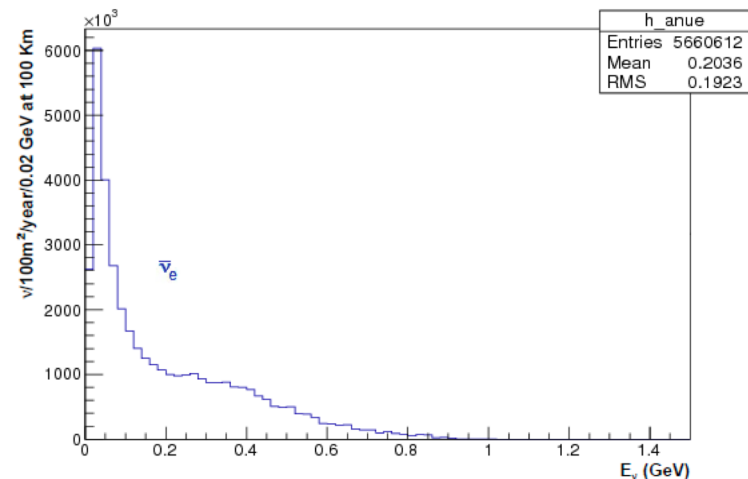
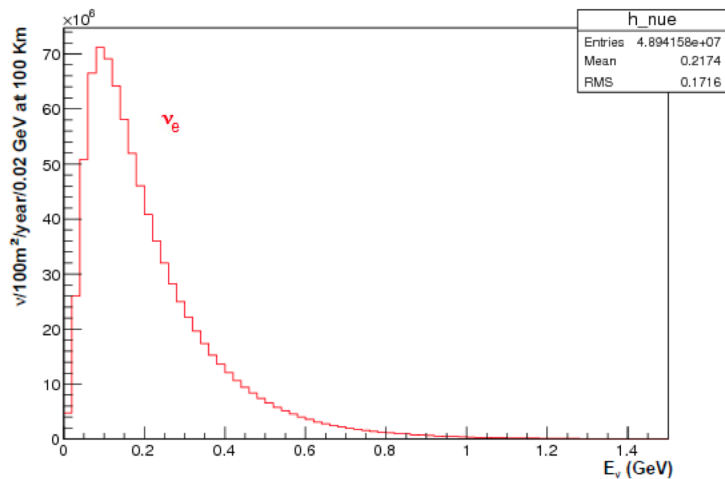
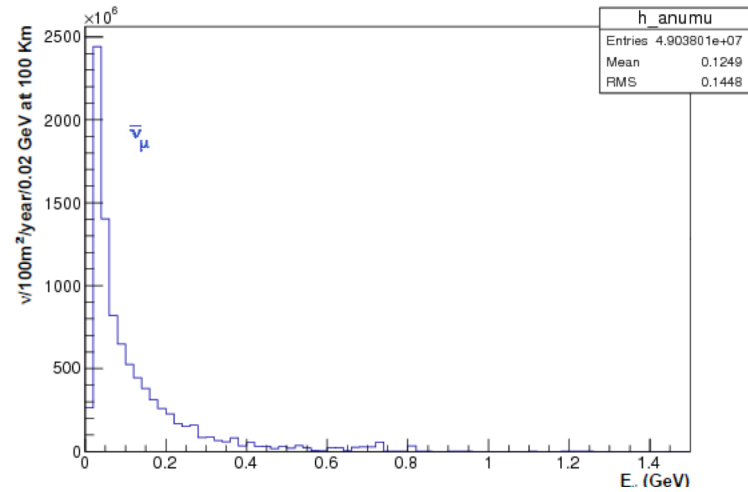
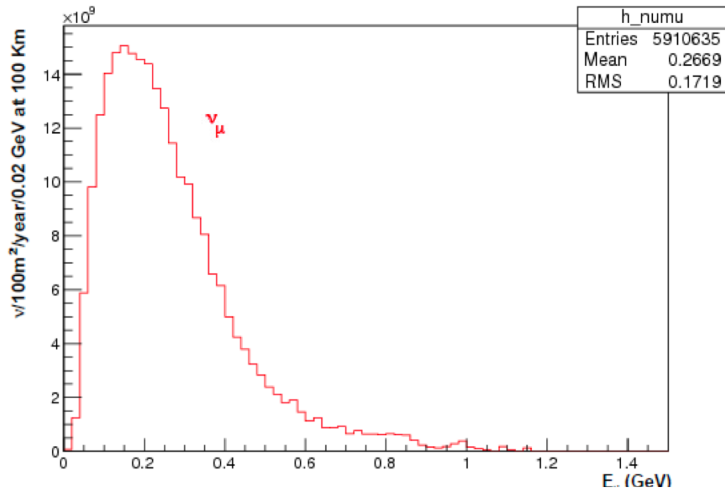


GEANT4 (Neutrino Flux)



FLUKA (Energy deposition/ Safety)

SUPERBEAM SIMULATION (GEANT4) : NEUTRINO FLUX (PI+ FOCUSED)



SUPERBEAM SIMULATION (GEANT4) : NEUTRINO FLUX (PI+ FOCUSED)

