Collection system for future neutrino beams

horn and target integration

- 2 LoI's sent
  - CERN
  - Strasbourg

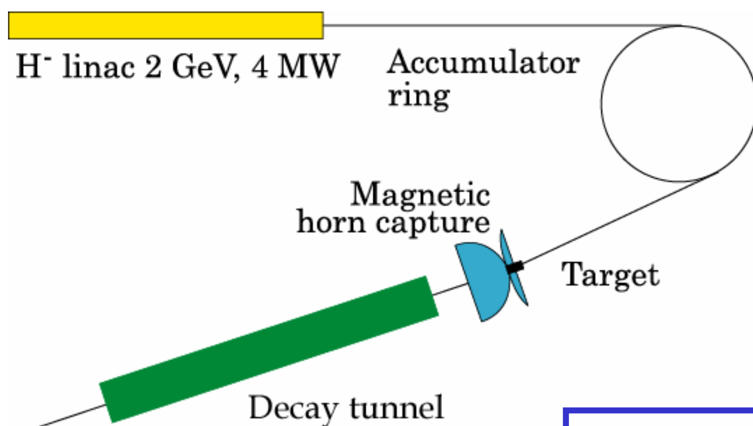
Who is working in Europe on solenoid for Neutrino Factory?

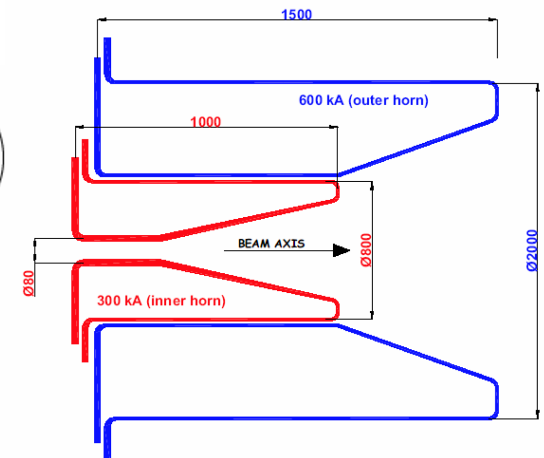
After some discussion between CERN and Strasbourg

- Start the collection study for SuperBeam option
- Taking into account previous tests done at CERN, prepare a setup to pulse the horn at 50 Hz (nominal value) and a current as high as possible

CERN horn design

- Proton beam
  - 2.2 GeV
  - 4 MW
  - 50 Hz rep. rate
- Horn focusing
  - First horn 300 kA
  - Reflector 600 kA
- Low energy pion beam: ≈ 500 MeV
  - proton energy below kaon threshold
  - Short decay channel < 100 m
- Low energy neutrino beam: ≈ 250 MeV





tests already done at CERN:
- pulse repetition frequency: 1 Hz
- Imax: 30, 100 kA
- C: 1 mF
- pulse duration: 100 µs

CERN LoI

- Target R&D
- Horn and solid target integration

1. Improve existing infrastructure (at BA7) to allow realistic tests of a NuFact prototype horn at nominal conditions. Analysis of fatigue tests and possible corrective actions.
2. Investigation of the material structure of the existing Nufact horn (480 k€, available) with a 50 Hz power supply (300 kA, 5 kV, <100 μs). The investigation will be based on laser vibrometer (100 k€, available) measurements of the horn's resonance frequencies and of their damping constants with increasing number of cycles. A mechanical analysis (mechanical engineers from Poland/Krakow via T. Kurtyka) should be derived to assess the fatigue of the system (horn and strip line) and its life time (expected to be few month of operations at nominal parameters).
3. Development of a test bench using the NuFact horn and the 50Hz power supply to validate multi-physics simulations in order to reduce the experimental working load and costs (collaboration with Strasbourg).
4. Address the integration issues of the horn. Complete the design of the existing horn including possibly the studies for a target station located in the inside. Investigate the cooling issues involved. (collaboration with BNL).

total cost for the collector: 1.35 M€

Strasbourg LoI

The cavity is submitted to: an electromagnetic wave, thermo-mechanic stresses, vibrations, fatigue, radiation damages.

The proposed project intends to quantify all the above parameters in order to propose a robust collector design.

- Main challenges:
  - design of a high current pulsed power supply (300 kA/100 μs/50 Hz),
  - 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.
- Goal
  - establish an experimental setup in Strasbourg,
  - proceed to the qualification and ageing tests
  - develop numerical simulation tools in parallel
- Estimated cost for 3 years R&D: 2 M€ (less if some parts of the power supply could be provided by CERN)

Super-Beams

W. Marciano

Neutrino Superbeams
and
Leptonic CP Violation

Santa Fe
17/06/2006 (Neutrino06)

Neutrino Superbeam: "Conventional" Horn Focused
ν_μ or $\bar{\nu}_\mu$ beam from a 1-4 MW proton source.

~ 10× Current Flux Of Accelerator Neutrinos

1-2 MW Relatively StraightForward
2-4 MW Liquid Targets, Robotics, Special Horns... (Hard)

Recent Studies

JPARC (Phase II)		→	4 MW	L = 295 km
CERN (Super Linac)		→	4 MW	L ≃ 130 km
BNL (AGS)	0.16 MW	→	1-2 MW	L ≃ 2540 km
FNAL (MI)	0.3 MW	→	1-2 MW	L ≃ 800 km + 1280 km

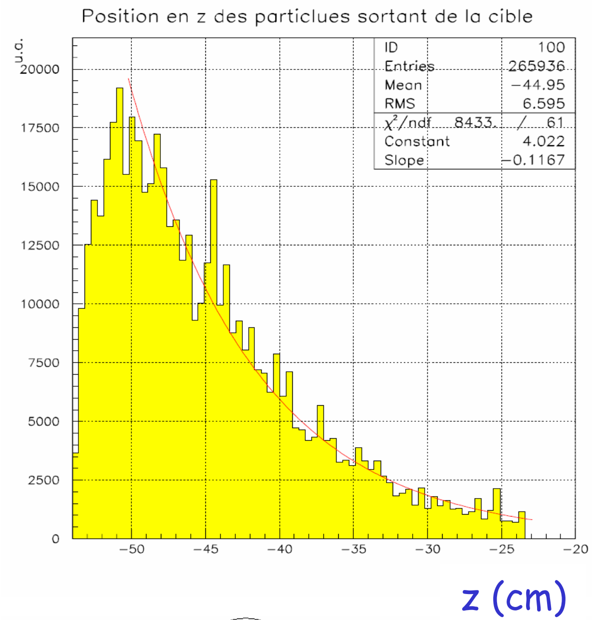
strengthen the collaboration with these institutes

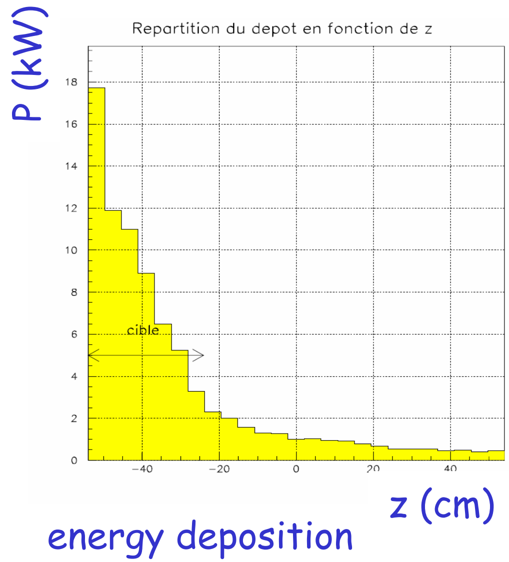
Physics Goals: *CP Violation, Matter Effects - Hierarchy
$\sin^2 2\theta_{13}$, $\theta_{23}+\theta_{12}$ Precision, Δm^2_{ij} Precision
New Physics - Sterile ν's, Extra Dim., Dark Energy...

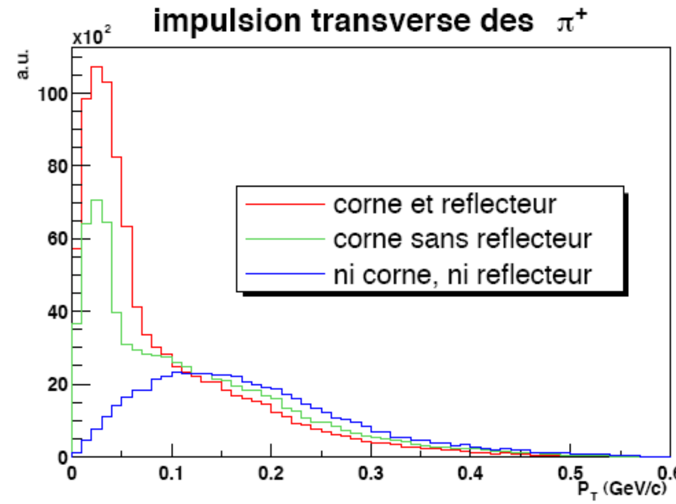
+ Large Detector → Proton Decay, Atm. ν, Supernova ν, n-$\bar{n}$ osc....

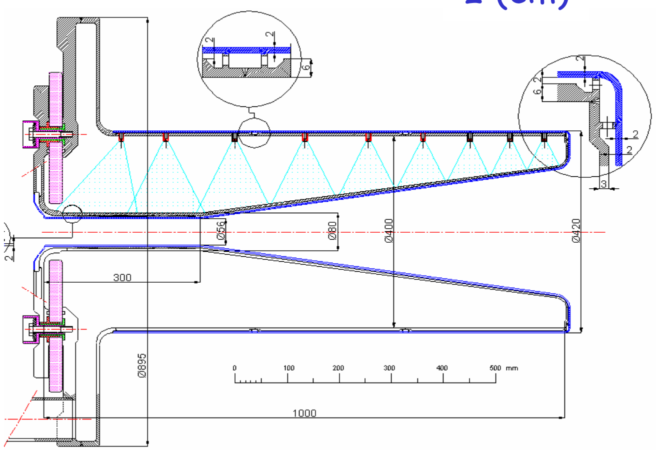
Very Rich Program

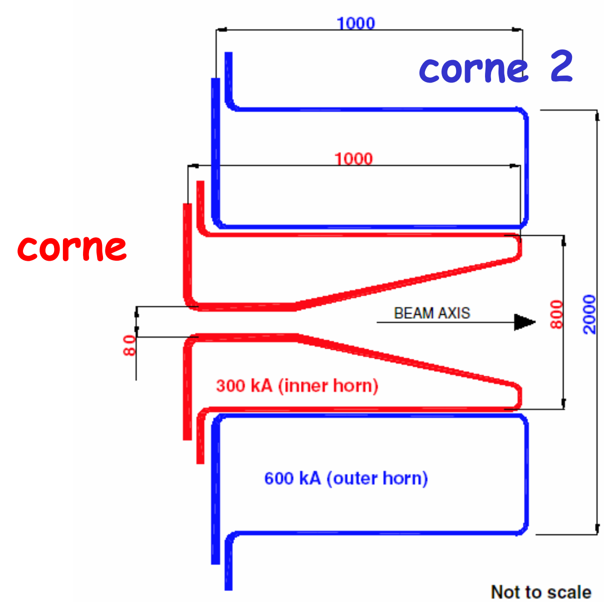
"Physics" studies to be restarted



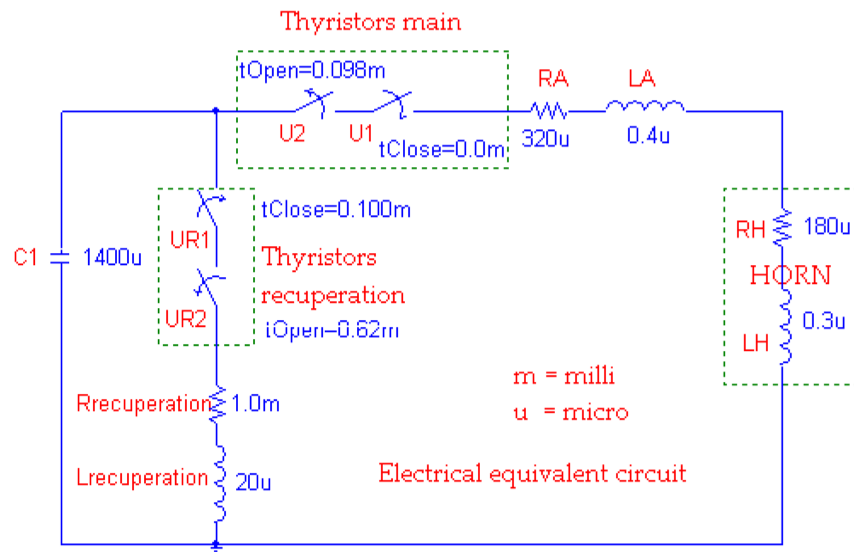


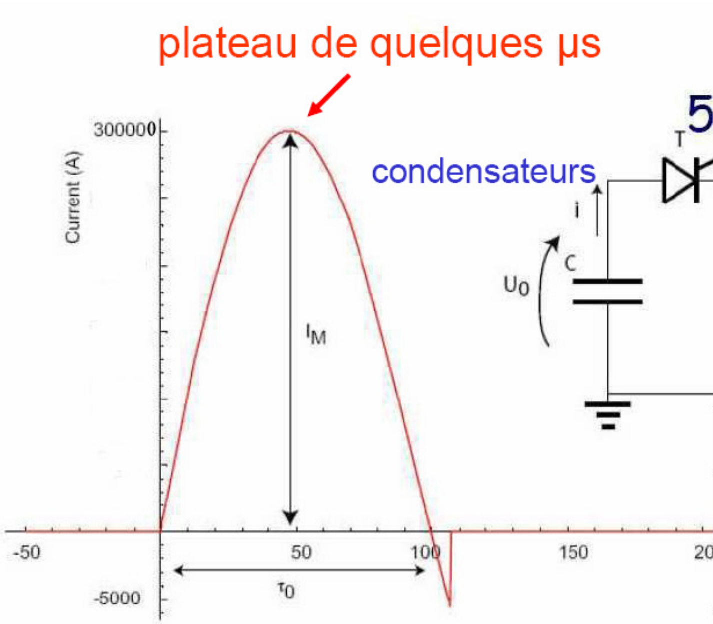


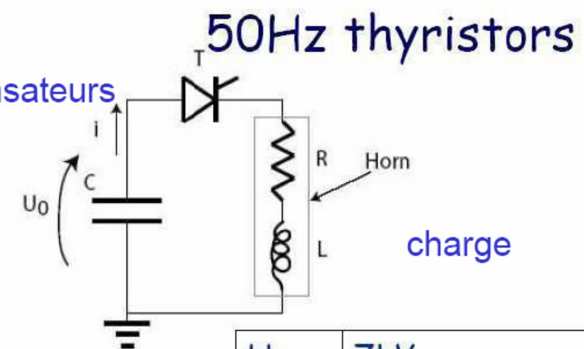




the power supply



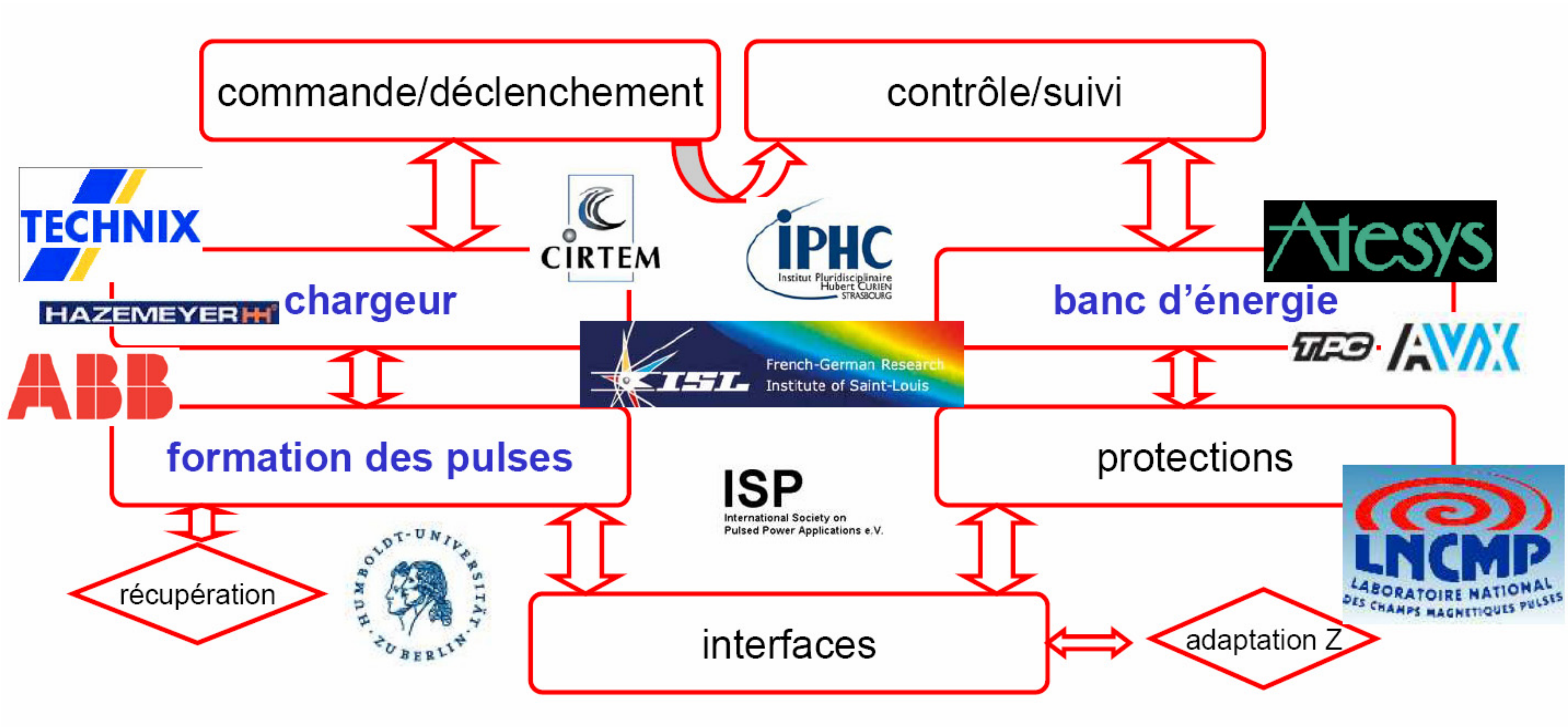




U_o	7kV
I_M	300kA (14,5 rms)
τ_o	100µs
L	0.6 (0.4 Horn)µH
R	500 (180 Horn) µΩ
C	1500µF

values considered by CERN

the power supply



Due to the high price go to a modular system and increase small by small the current

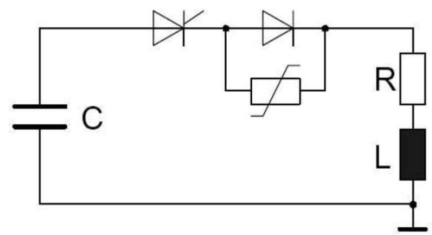
Charger and commutation

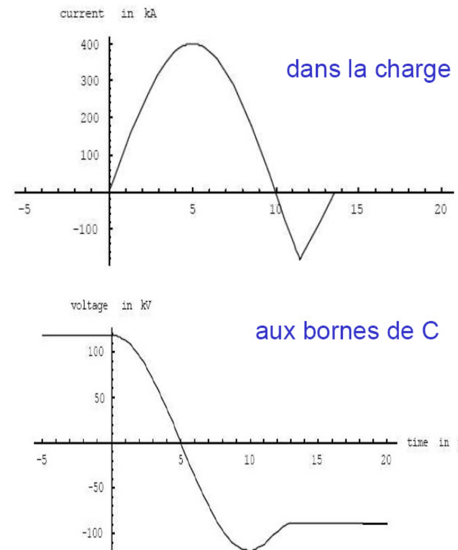
- 2 MW proposed by Technix
- 43 racks of 40 kW
- 400 V / 11 A
- 40 k€/rack

one of the three solutions proposed by ABB

- option 1 :

version de principe !





courant inverse à cause du délai de commutation de la diode

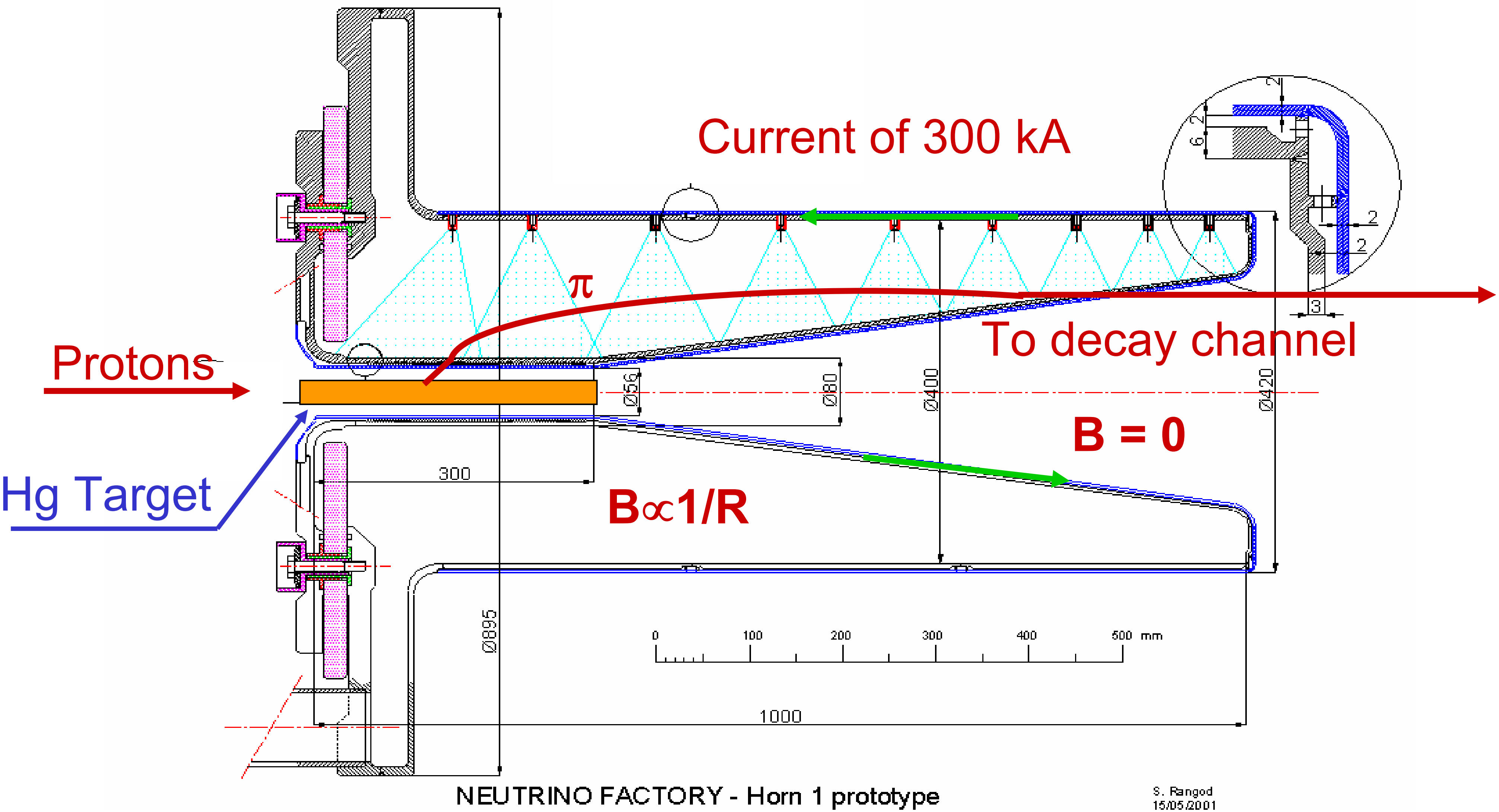
(amplitudes arbitraires)

commutation

Previous Studies

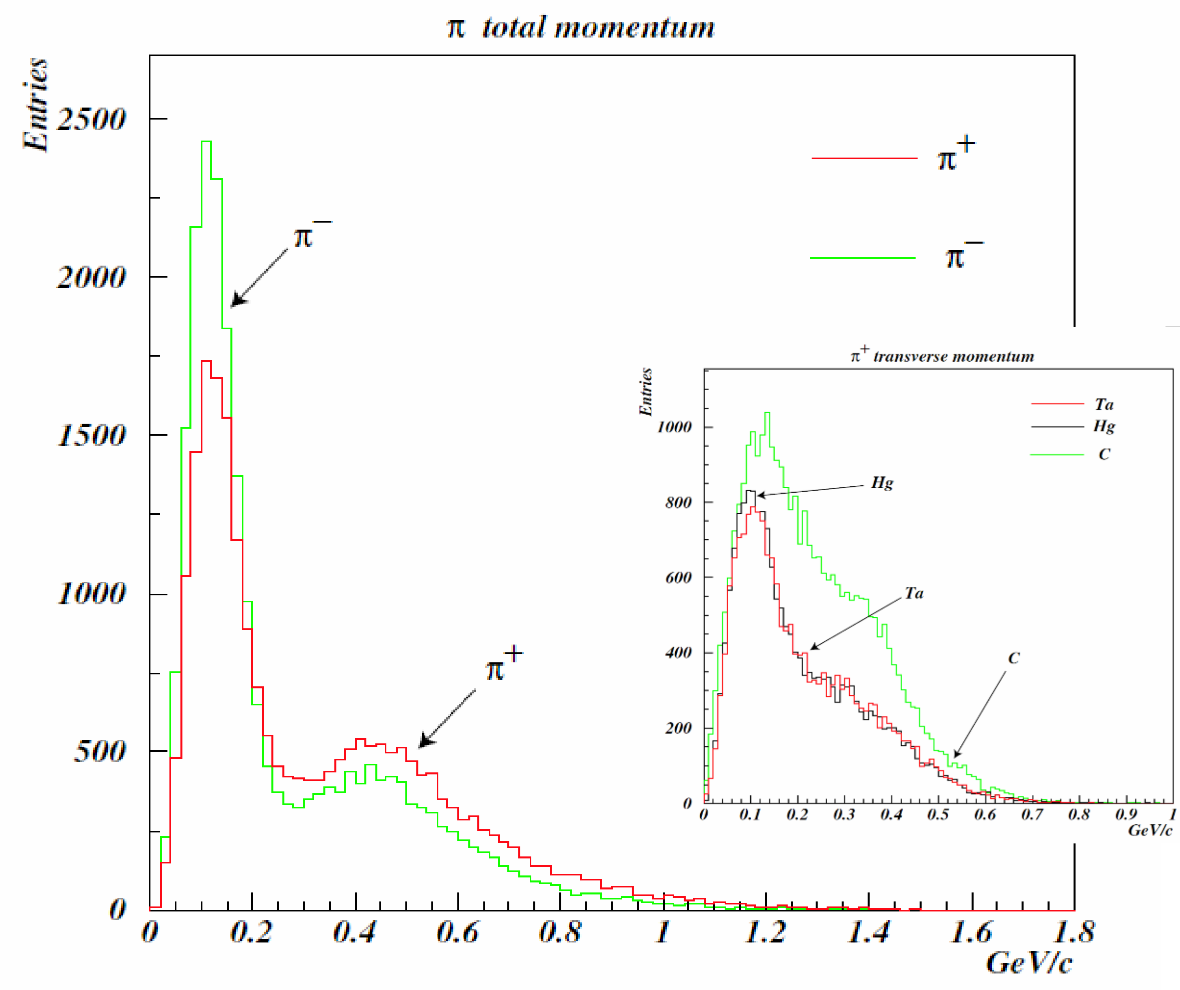
- S. Gilardoni: Horn for Neutrino Factory and comparison with a solenoid
  - http://doc.cern.ch/archive/electronic/cern/preprints/thesis/thesis-2004-046.pdf
  - http://newbeams.in2p3.fr/talks/gilardoni.ppt
- A. Cazes: Horn for SPL
  - http://tel.ccsd.cnrs.fr/tel-00008775/en/
  - http://slap.web.cern.ch/slap/NuFact/NuFact/nf142.pdf
  - http://slap.web.cern.ch/slap/NuFact/NuFact/nf-138.pdf

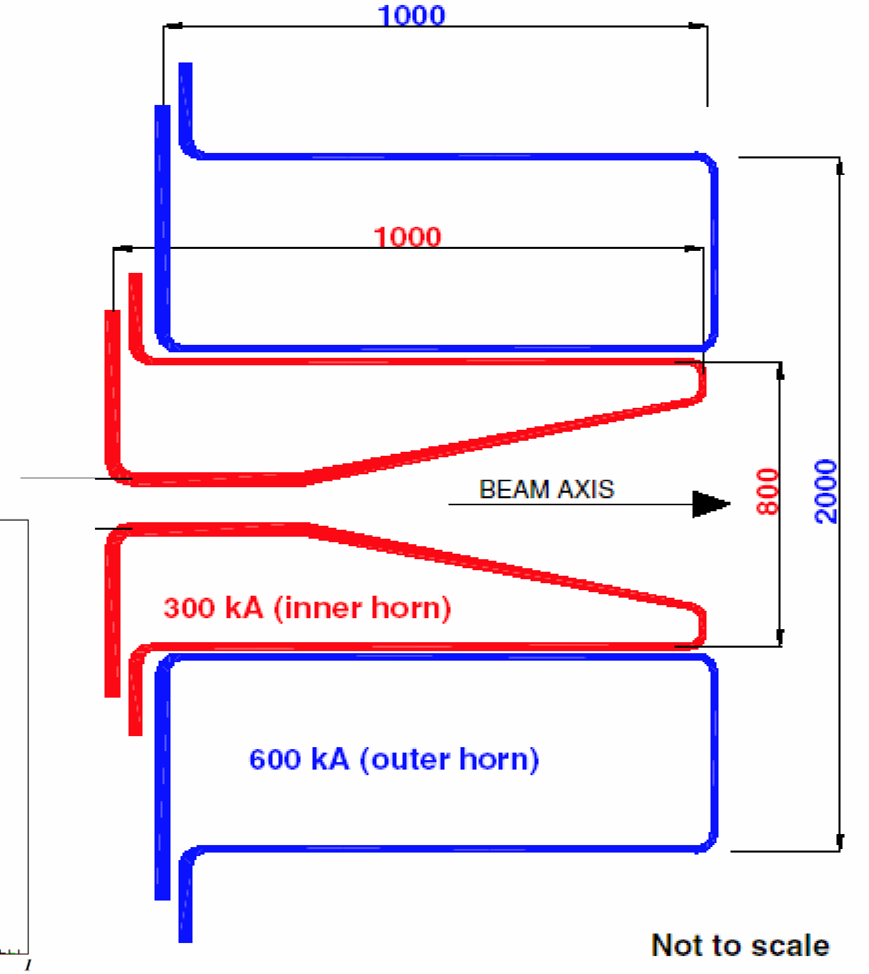
Focusing system: magnetic horn



Proposed design

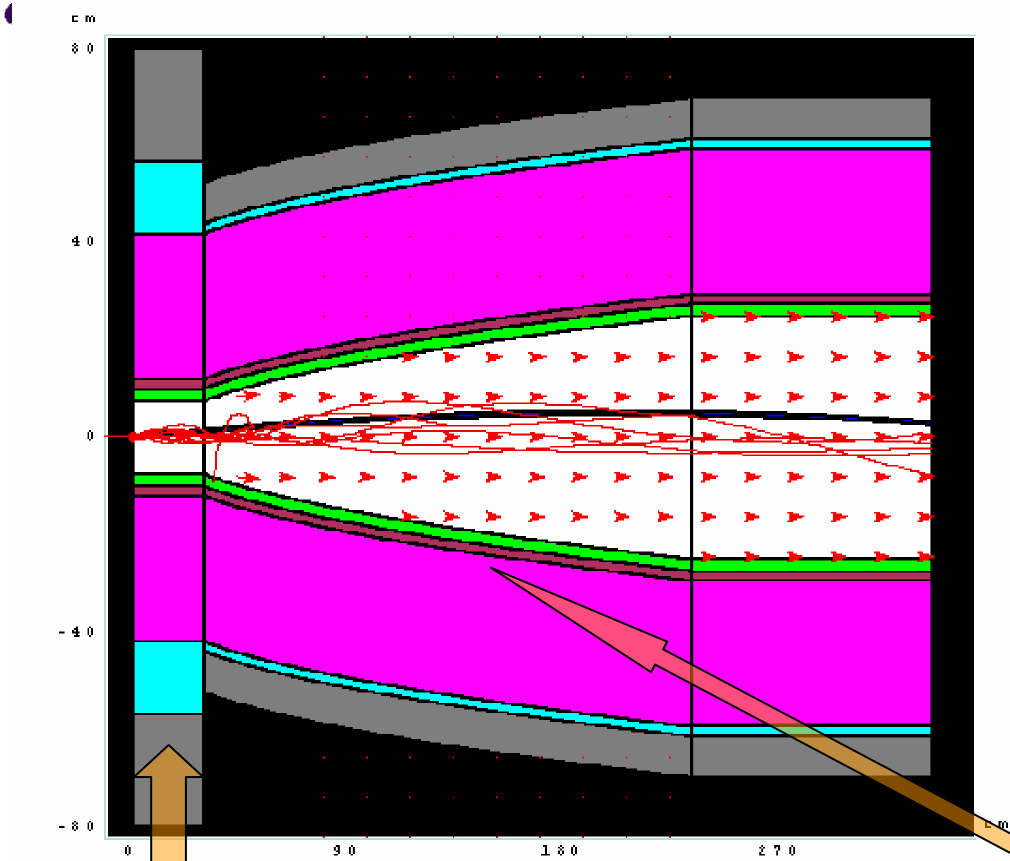
Particle at target





In collaboration with LAL

The reference: US-NuFact 20 T Solenoid



Different optimization for RAL front end

•Focusing:

Tapered field **20 T → 1.25 T**

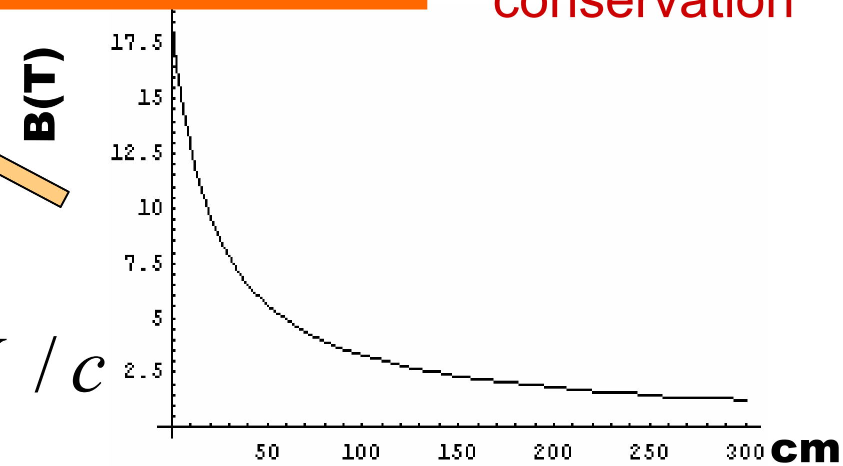
$$B_z(z) = \frac{B_0}{1 + \alpha * z}$$

$$B\rho^2 = const$$

•Magnetic flux conservation

$$\frac{B}{p_\perp 2} = const$$

•Angular momentum conservation

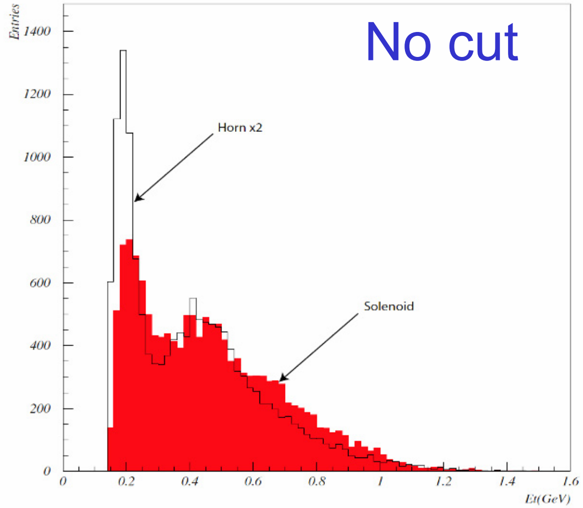


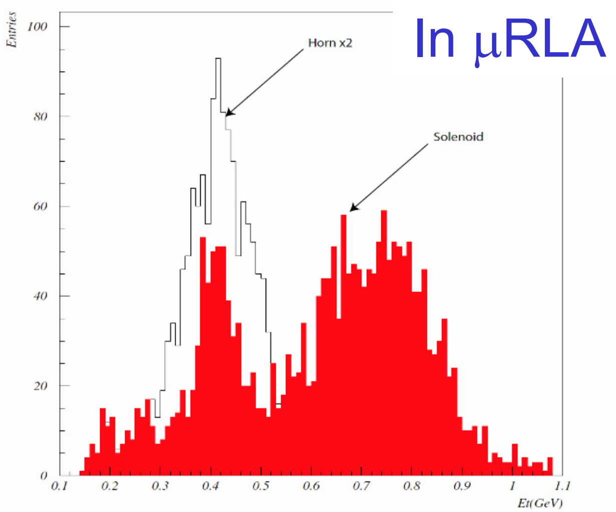
Capture B=20 T

Φ = 15 cm, L=30 cm

$$P_\perp \leq 0.075\,\varphi(m)\,B(T) \approx 225\,MeV\;/\,c$$

Horn vs 20 T solenoid



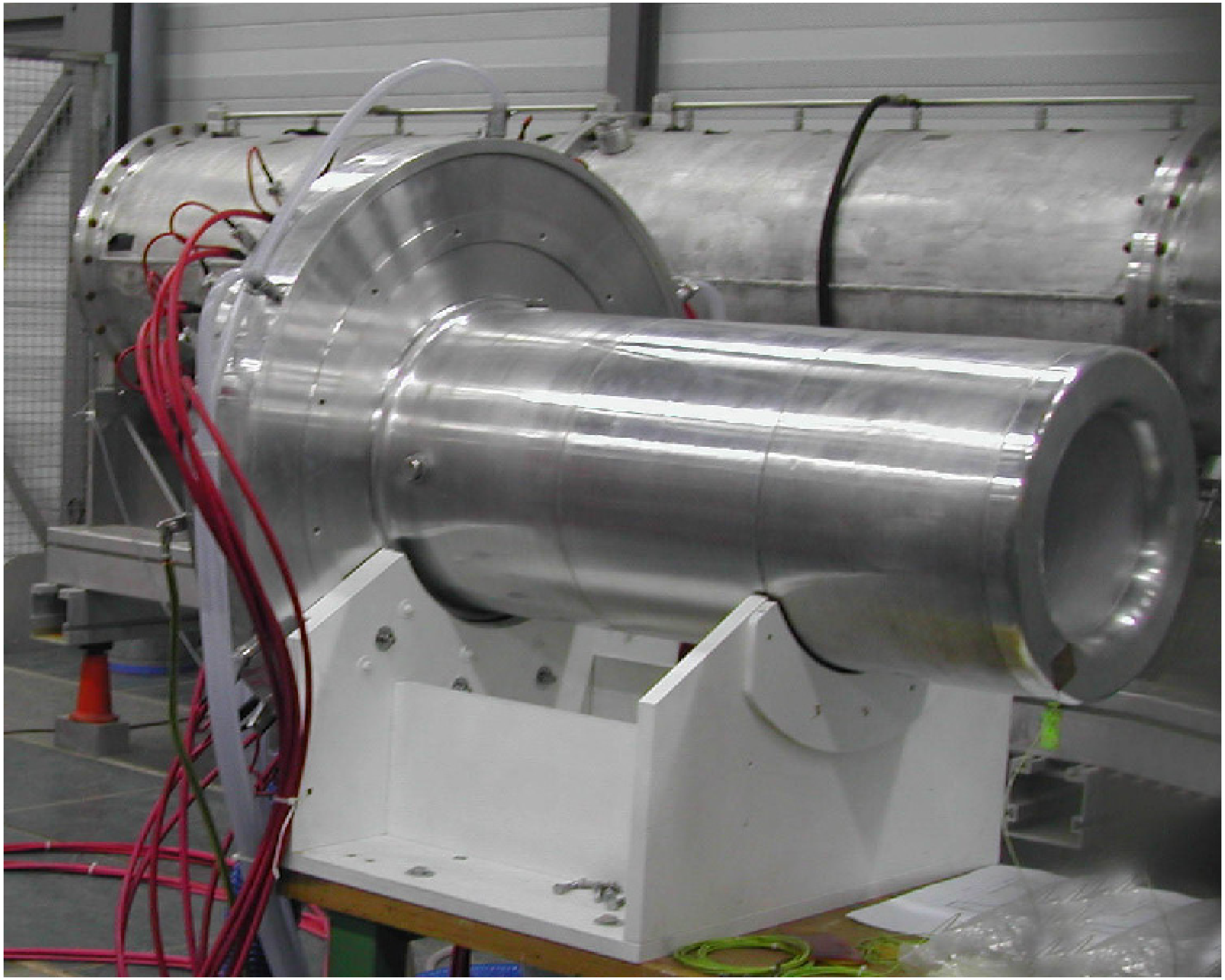


Device	No Et cut	$0.2 < Et(GeV) < 0.8$	$0.3 < Et(GeV) < 0.6$
Horn	0.0015	0.0014	0.0013
Sol.	0.0045	0.0036	0.0015

Horn features:

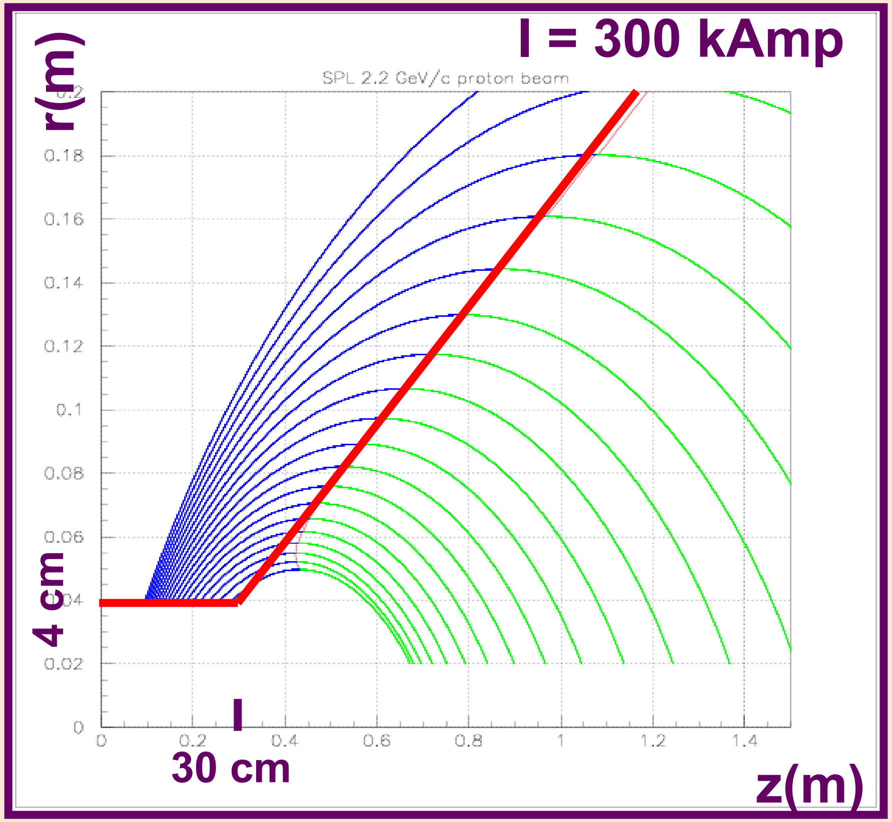
- Same efficiency as 20 T solenoid
- Focus only one particle sign
  - no charge selection section in the machine
  - necessary for the SuperBeam
- Shape adjustable to capture only a selected pion energy range
- Low Cost
  - Cost of the horn without the power supply: **200 kCHF**
  - Cost of the solenoid: **38 M$**

Horn prototype ready for tests

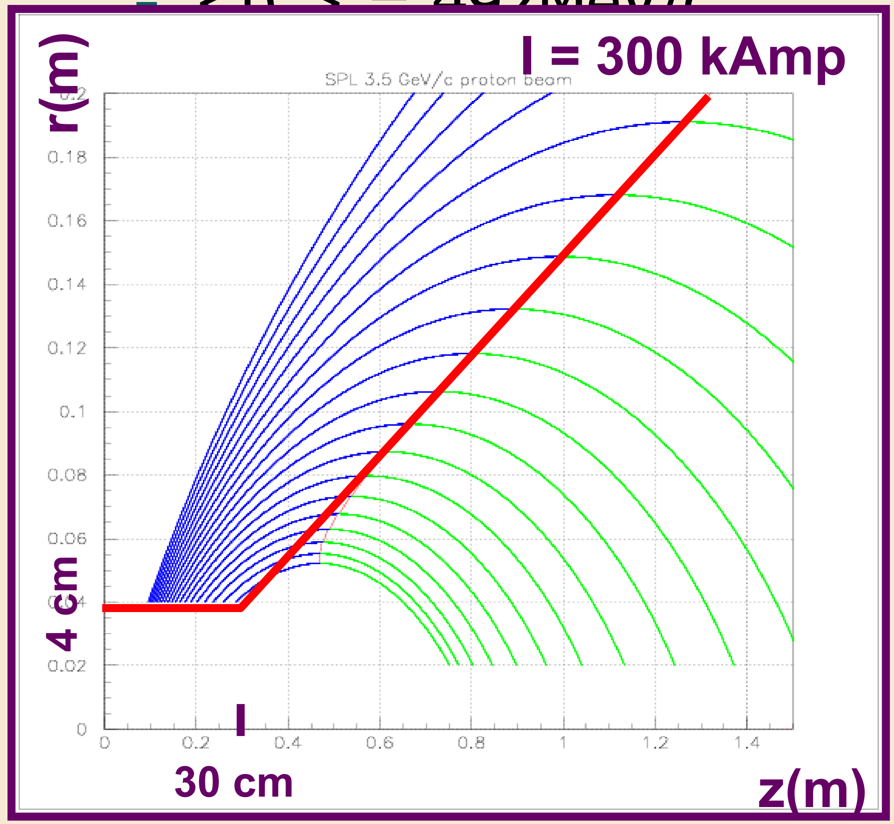


New Geometry

- 2.2 GeV proton beam :
  - $<p_\pi> = 405 MeV/c$
  - $<\theta_\pi> = 60°$

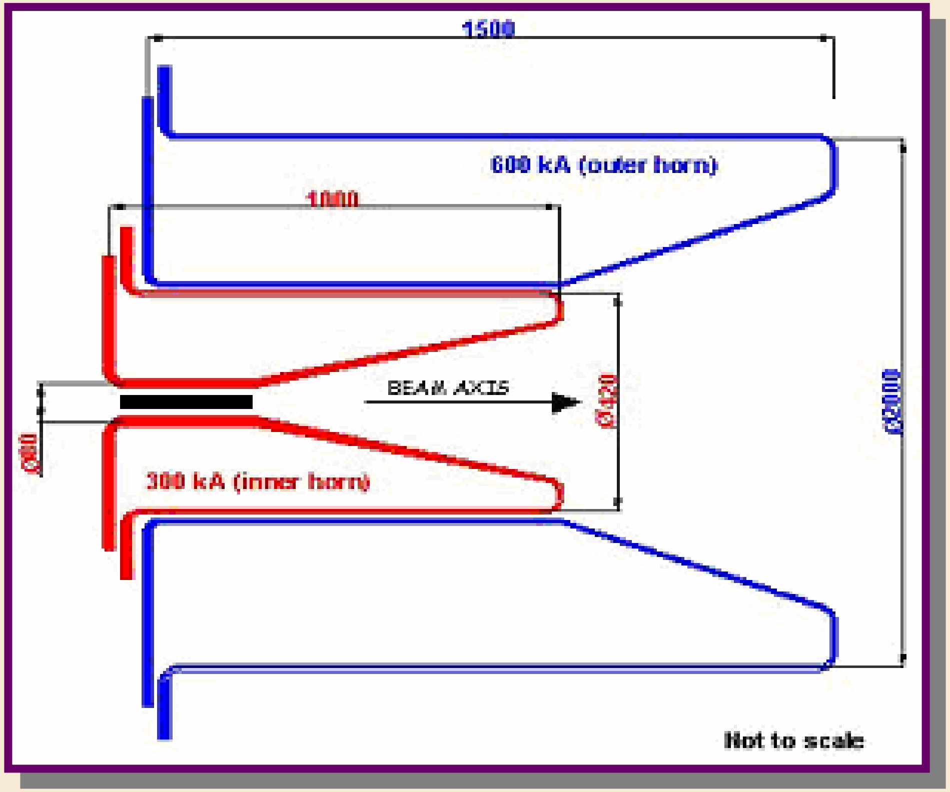


- 3.5 GeV proton beam :
  - $<p_\pi> = 492 MeV/c$



Reflector

- A reflector has been included
- It is not optimized yet
- diameter : 2m
- length :1.5m
- I = 600kAmp



Antoine Cazes

Neutrino production

- Decay tunnel
  - R = 1m
  - 20m < L < 80m
- Neutrino come from pion, muon and kaon decays in the horn and in the decay tunnel.
- number of neutrino at Fréjus per pot:
  - ν_μ : 4.10^{-10} /pot
  - $\overline{\nu_\mu}$: 3.10^{-11} /pot
  - ν_e : 2.10^{-12} /pot
  - $\overline{\nu_e}$: 1.10^{-13} /pot

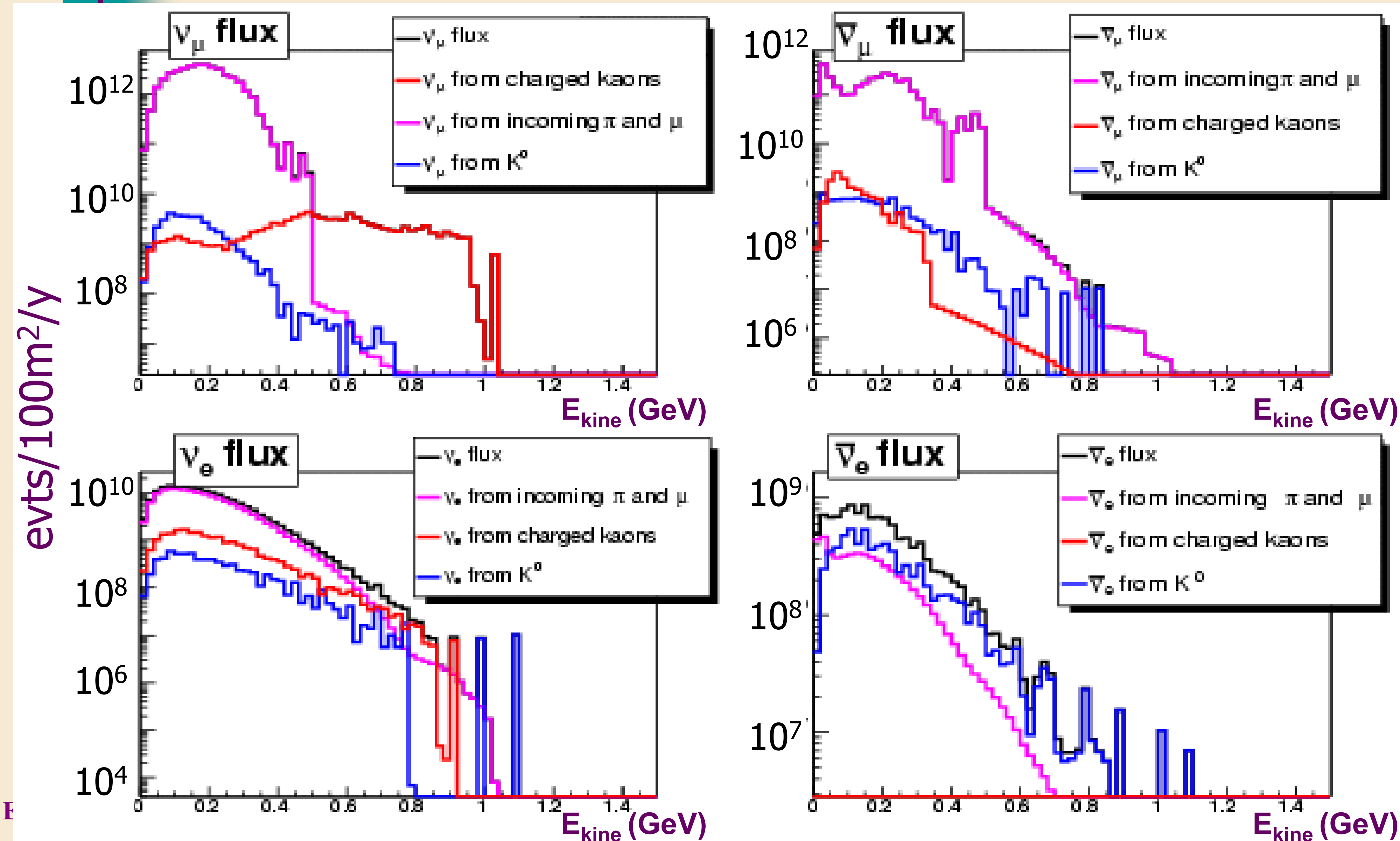
(•2.2GeV proton beam
•20m long decay tunnel
•horn focussing π^+)

➢ Need ~10^{15} evts…

➢ Need to find computational tricks!

Neutrino Spectra, 2.2GeV, π^+ focusing

- Decay tunnel: 20m



Flux summary, 2.2 GeV

		positive focusing		negative focusing	
		Flux ($/100m^2/y$)	Majoritary composition	Flux ($/100m^2/y$)	Majoritary composition
Decay tunnel :20m	ν_μ	$3.89\ 10^{13}$	π^+ (99%)	$5.08\ 10^{12}$	π^+(99%)
	$\bar{\nu}_\mu$	$3.19\ 10^{12}$	π^- (99%)	$2.93\ 10^{13}$	π^- (99%)
	ν_e	$1.77\ 10^{11}$	$\pi^+\rightarrow\mu^+$(80%)	$2.85\ 10^{10}$	$\pi^+\rightarrow\mu^+$(38%); K^+ (37%) ;K^0 (25%)
	$\bar{\nu}_e$	$1.24\ 10^{10}$	K^0 (55%); $\pi^-\rightarrow\mu^-$(45%)	$8.14\ 10^{10}$	$\pi^-\rightarrow\mu^-$(90%)
Decay tunnel :80m	ν_μ	$4.21\ 10^{13}$ (+8%)	π^+ (99%)	$5.06\ 10^{12}$ (-0.4%)	π^- (99%)
	$\bar{\nu}_\mu$	$3.38\ 10^{12}$ (+6%)	π^- (99%)	$3.18\ 10^{13}$ (+8.5%)	π^+ (100%)
	ν_e	$2.66\ 10^{11}$ (+50%)	$\pi^+\rightarrow\mu^+$(90%)	$3.09\ 10^{10}$ (+8.5%)	$\pi^+\rightarrow\mu^+$(40.%) K^+ (35%) ;K^0 (25%)
	$\bar{\nu}_e$	$1.42\ 10^{10}$ (+14.5%)	K^0 (50%) $\pi^-\rightarrow\mu^-$(50%)	$1.14\ 10^{11}$ (+40%)	$\pi^-\rightarrow\mu^-$(95%)

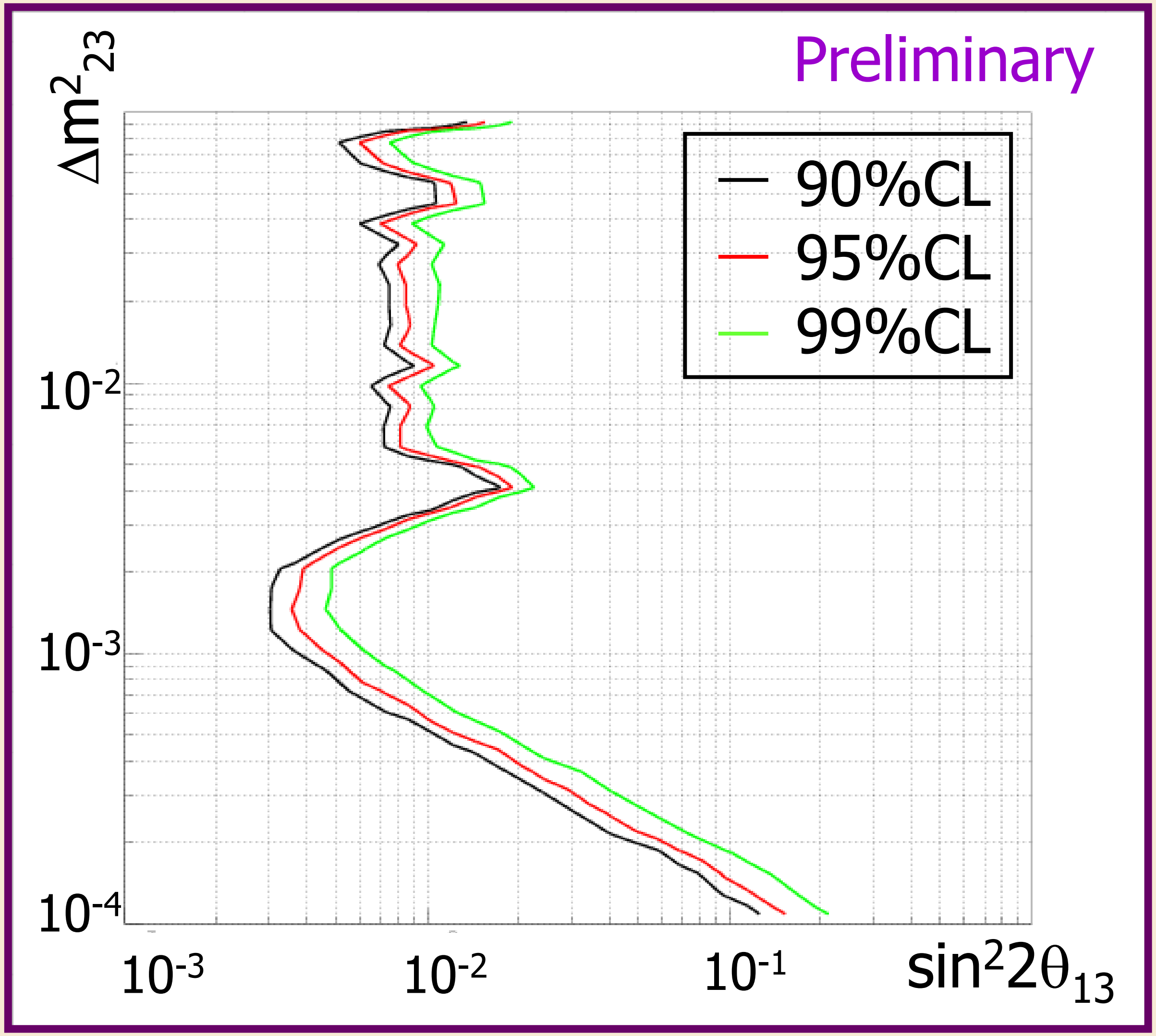
Flux summary, 3.5 GeV

		positive focusing		negative focusing	
		Flux (/100m2/y)	Majoritary composition	Flux (/100m2/y)	Majoritary composition
Decay tunnel :20m	ν_μ	$7.82\ 10^{13}$	π^+ (100%)	$1.42\ 10^{13}$	π^- (98%)
	$\bar{\nu}_\mu$	$1.10\ 10^{13}$	π^- (99%)	$6.65\ 10^{13}$	π^+ (99.5%)
	ν_e	$4.07\ 10^{11}$	$\pi^+ \rightarrow \mu^+$(84%)	$1.19\ 10^{11}$	K^+ (50%);K^0 (30%) $\pi^+ \rightarrow \mu^+$(20%)
	$\bar{\nu}_e$	$5.34\ 10^{10}$	K^0 (70%) $\pi^- \rightarrow \mu^-$(30%)	$1.87\ 10^{11}$	$\pi^- \rightarrow \mu^-$(80%)
Decay tunnel :80m	ν_μ	$8.32\ 10^{13}$ (+6%)	π^+ (99%)	$1.56\ 10^{13}$ (+10%)	π^- (98%)
	$\bar{\nu}_\mu$	$1.19\ 10^{13}$ (+8%)	π^- (98%)	$7.03\ 10^{13}$ (+6%)	π^+ (100%)
	ν_e	$5.60\ 10^{11}$ (+38%)	$\pi^+ \rightarrow \mu^+$(89%)	$1.30\ 10^{11}$ (+9%)	K^+ (45%);K^0 (30%) $\pi^+ \rightarrow \mu^+$(25%)
	$\bar{\nu}_e$	$5.93\ 10^{10}$ (+11%)	K^0 (60%) $\pi^- \rightarrow \mu^-$(40%)	$2.59\ 10^{11}$ (+38.5%)	$\pi^- \rightarrow \mu^-$(85%)

θ_{13} Sensitivity

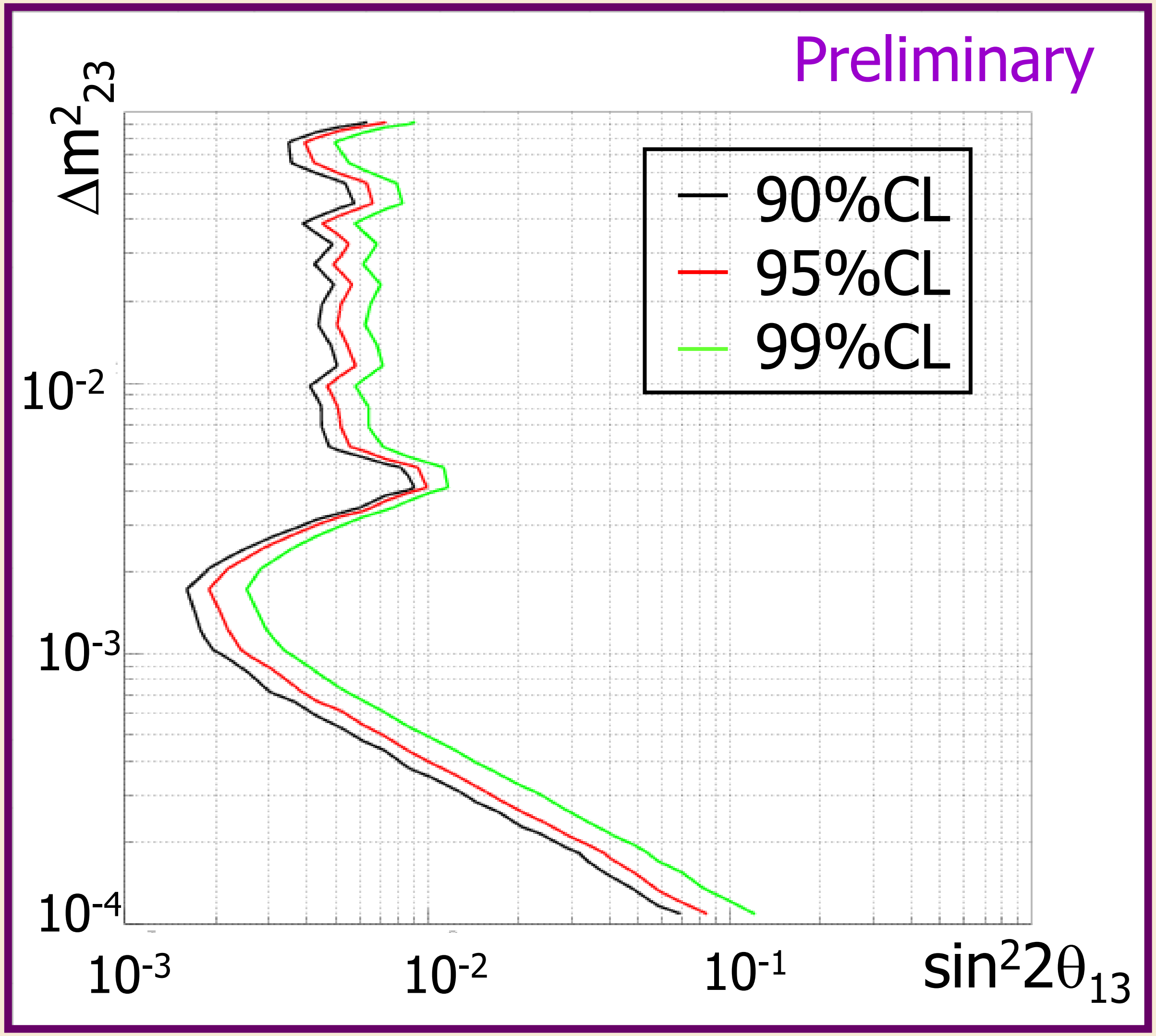
- Use Mauro Mezzetto code.
- detector:
  - Water Cerenkov
  - 440 kt
  - at Fréjus (130 km from CERN)
- Run:
  - 2 years with positive focussing.
  - 8 years with negative focussing.
- Computed with δ_{CP}=0 (standard benchmark) and θ_{13} = 0
- parameter…
  - Δm_{23} = 2.5 $10^{-3} eV^2$
  - Δm_{12} = 7.1 $10^{-5} eV^2$
  - $\sin^2(2\theta_{23})$ =1
  - $\sin^2(2\theta_{12})$ =0.8

Sensitivity 2.2GeV



Minimum:
$\theta_{13} = 1.6°$
(90%CL)

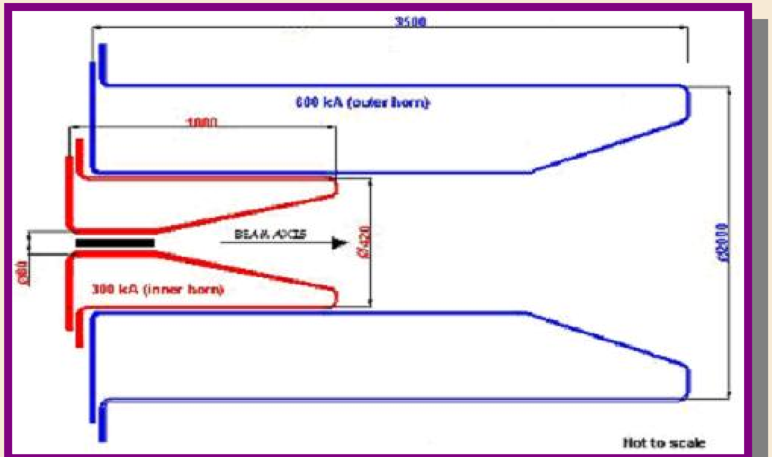
Sensitivity 3.5GeV

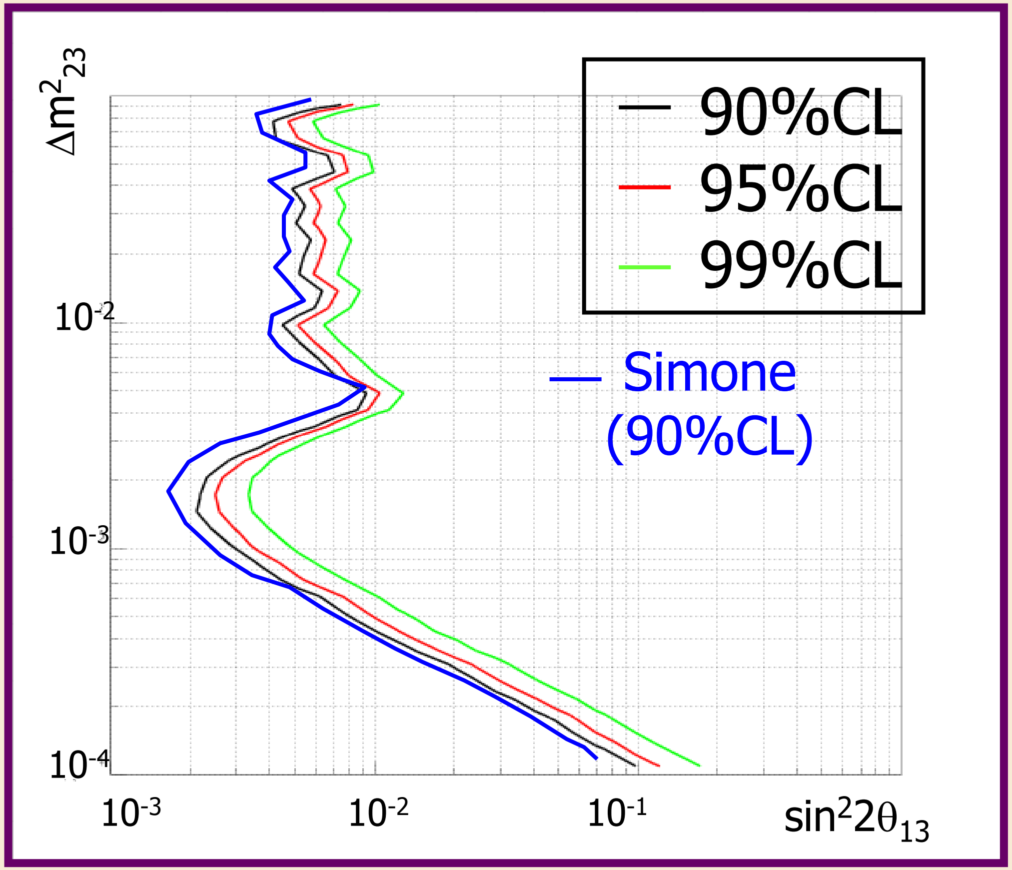


Minimum:
$\theta_{13} = 1.2°$
(90%CL)

Other reflector design (S. Gilardoni Thesis)

- Relfector length 3.5m
- Reflector inner conductor cylindrical length : 2.5m
- Proton Beam 2.2GeV





Minimum:
θ_{13}= 1.3° (90%CL)