Horn R&D

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For the CERN Horn working group

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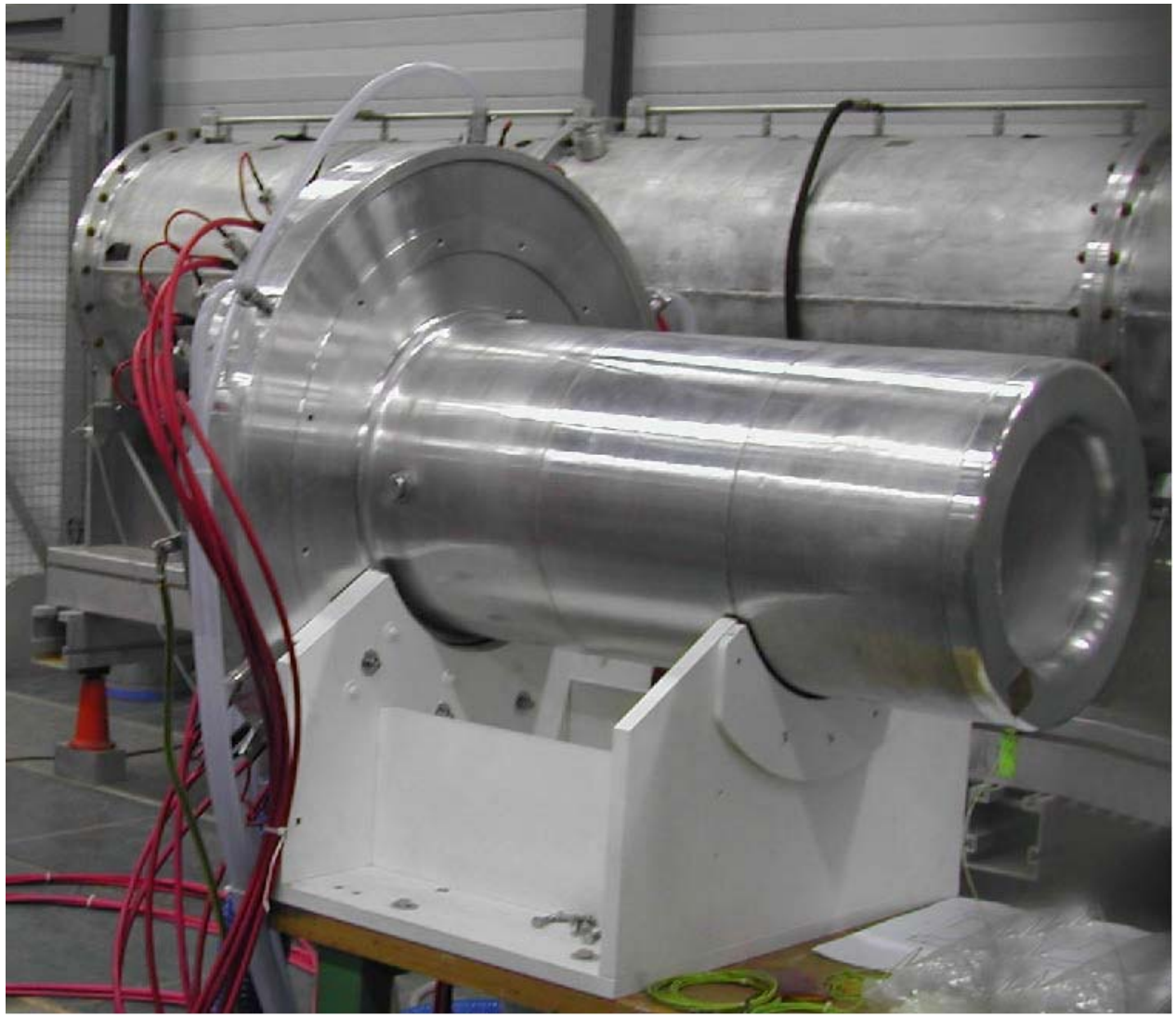
*** Dottore**

Program for 2004

- New simulation of particle production and tracking (LAL)
  - comparison FLUKA vs MARS
  - calculation of energy deposition in conductors
- Mechanical tests
  - determination of mechanical eigenfrequencies
- Electrical tests of power supply
  - determination of weak point in the present design
- Life time review
  - Verification of the life-time limit
  - six weeks as minimum requirement

Horn prototype ready for tests

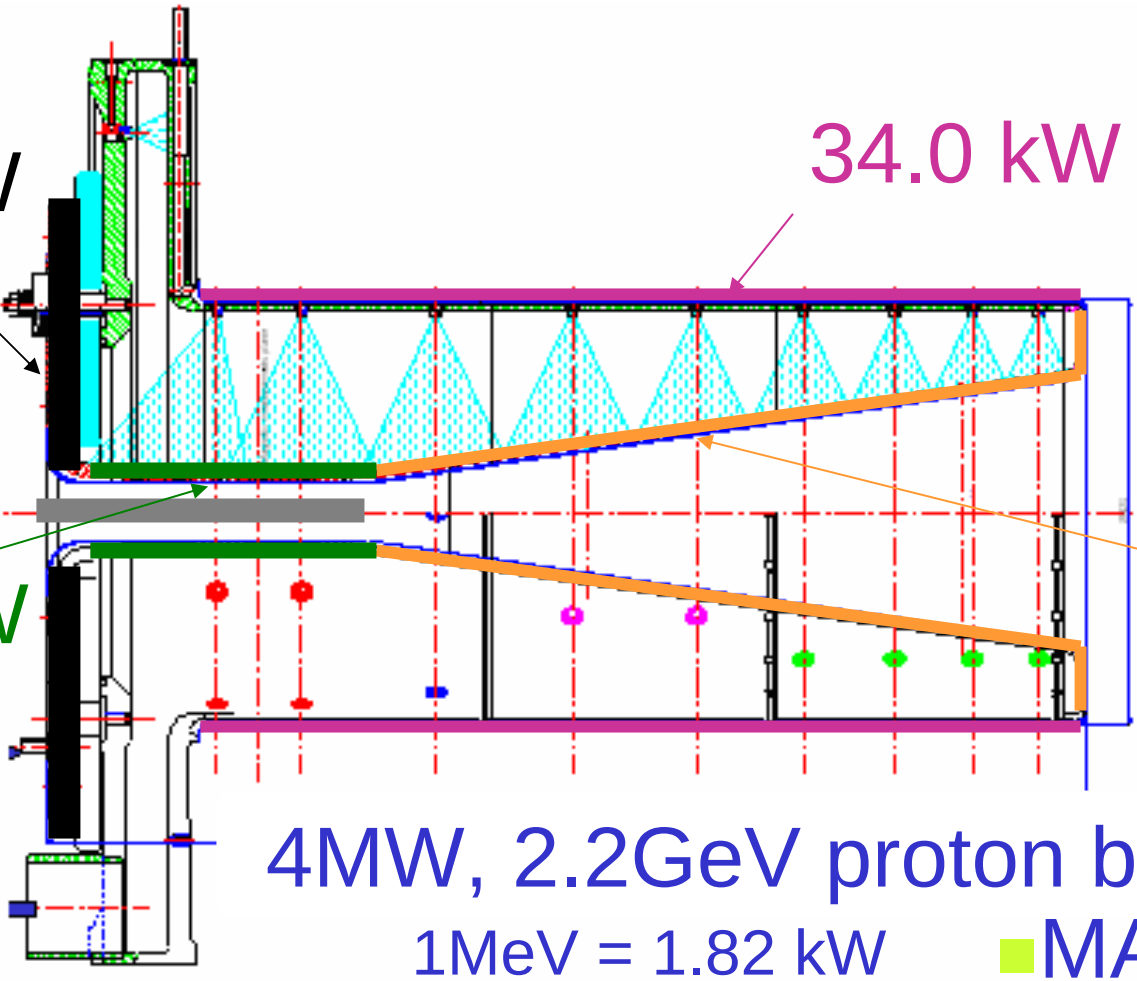


Horn simulation at LAL

J.E. Campagne, A. Cazes

- Target simulation (FLUKA)
- Horn simulation (Geant 3.2.1)
  - CERN design tested, optimization under study.
  - tracking through magnetic fields and materials
  - Energy deposition computed
- Decay tunnel
  - different geometry tested:
    - length = 10m, 20m and 40m ; R = 1m and 1.5m
  - decay simulation
    - using probability method
    - including kaon decays
- Fluxes computed at Fréjus for the SuperBeam

Energy deposition in the horn



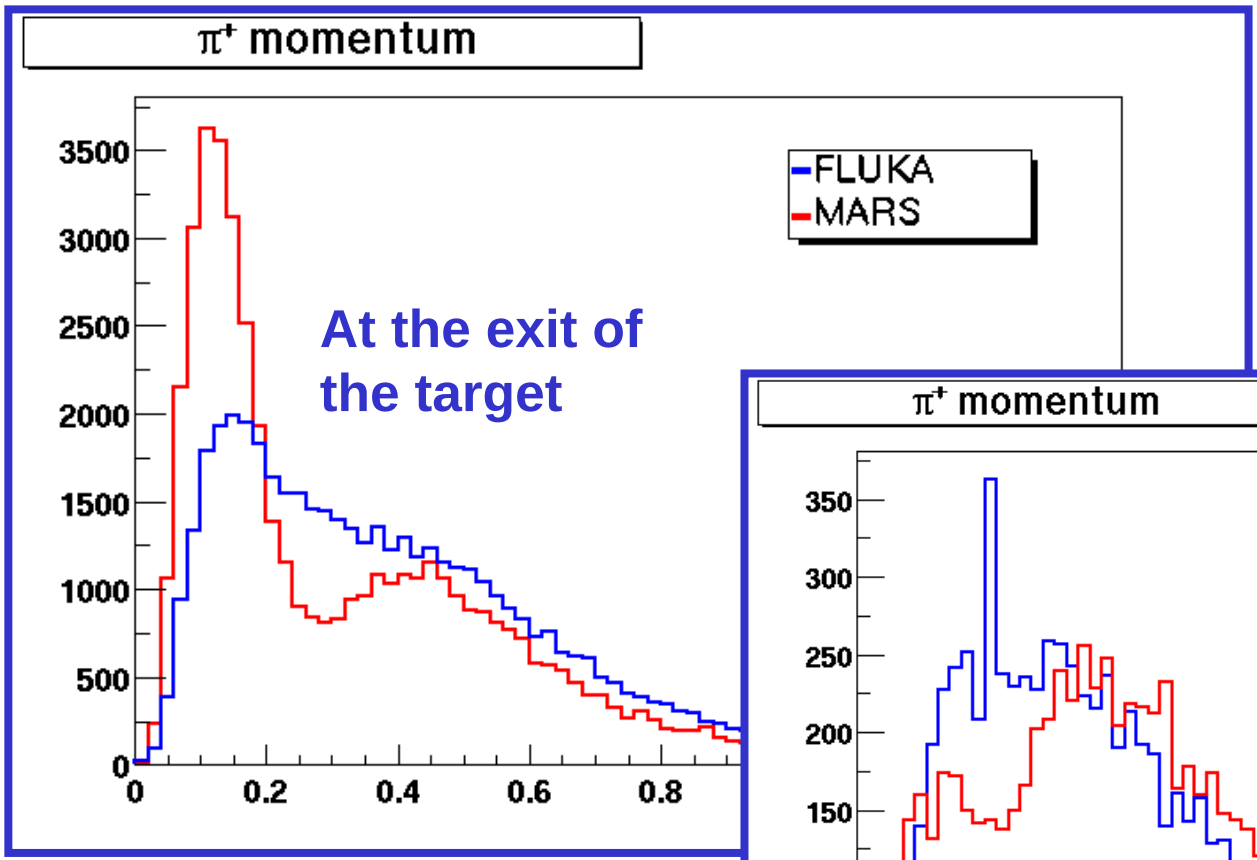
4MW, 2.2GeV proton beam

1MeV = 1.82 kW ■MARS

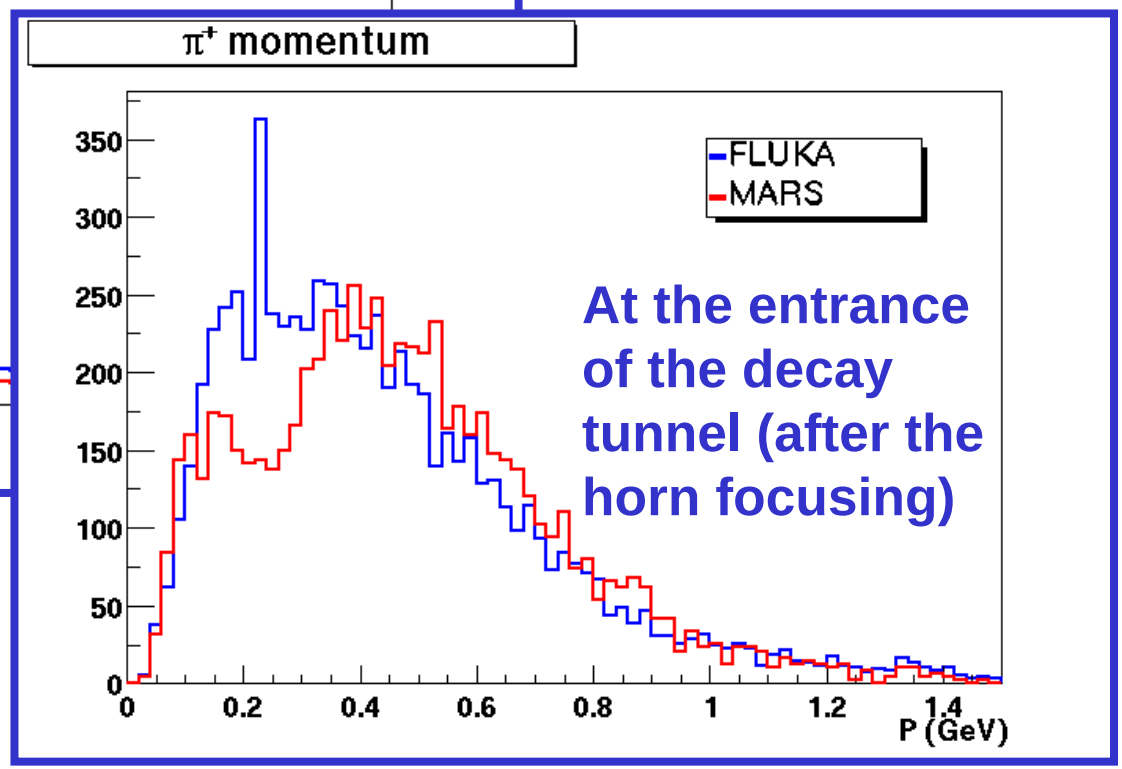
Solution under investigation :

reduced Al thickness + strength ring

Comparison MARS - FLUKA



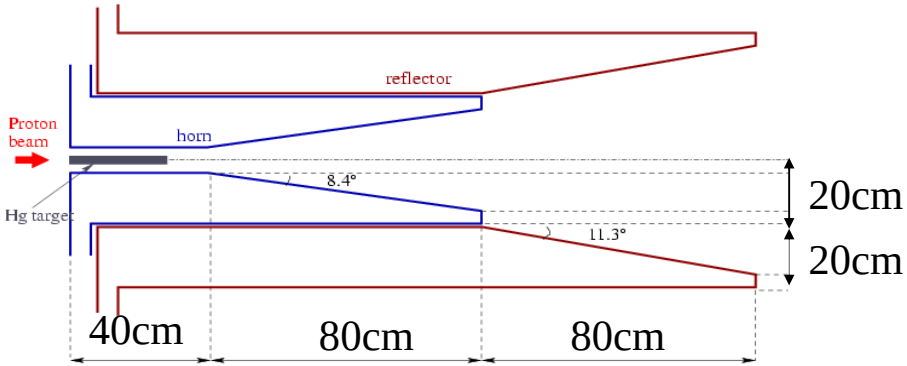
200 000 pot.
target is
- 30cm long,
- 0.75cm radius



Discrepancies reduced in the beam line

SPL energy optimisation

Horn design optimized for 600MeV π

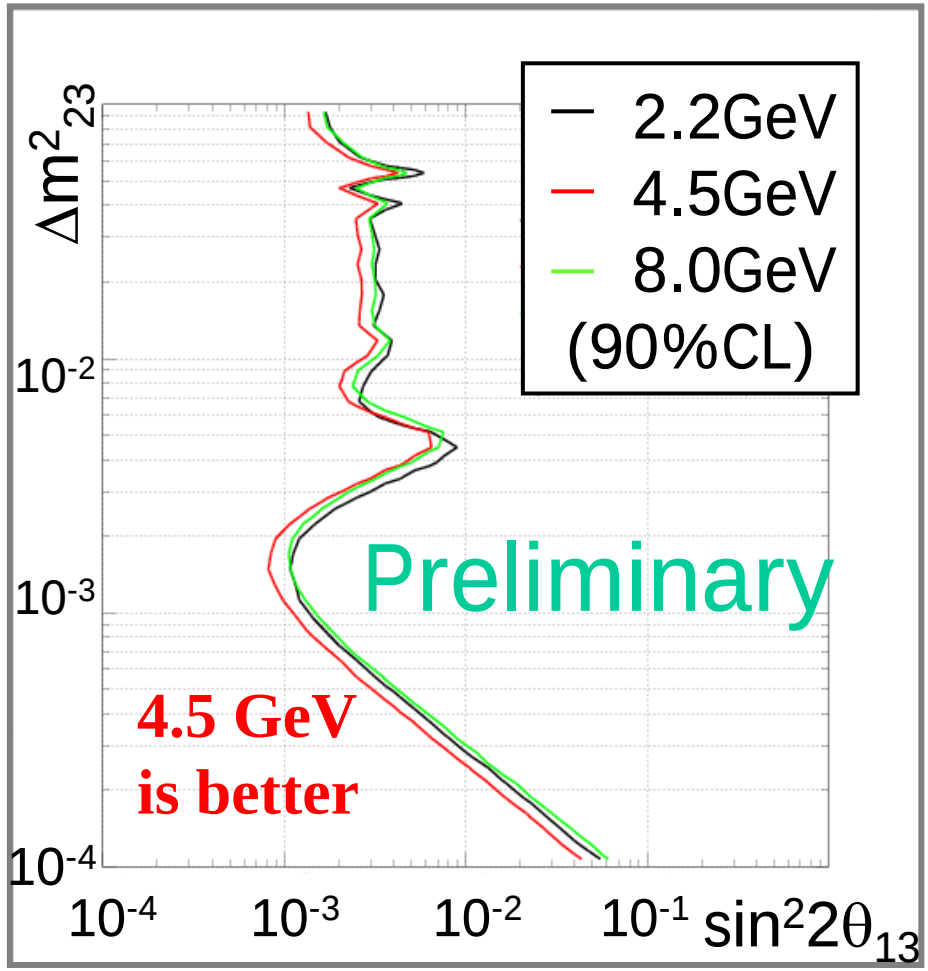


- Proton kinetic energy: 2.2GeV, 4.5GeV and 8GeV
- θ_{13} sensitivity computed thanks to Mauro Mezzetto's code.

5 years running π^+	
tunnel : 20m long 1m radius	440 kT, ε_{syst} = 2% 130km from CERN

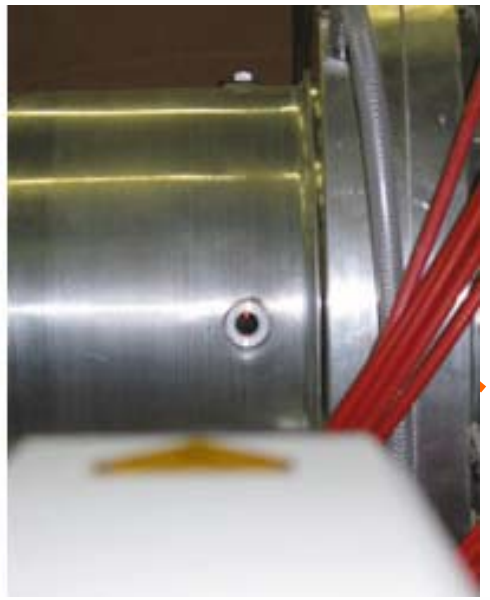
$\Delta m^2_{12} = 7.1\ 10^{-5}\ eV^2$, $\theta_{12} = 32°$

$\Delta m^2_{23} = 2.5\ 10^{-3}\ eV^2$, $\theta_{23} = 45°$



Long write up coming soon

Laser Measurement of horn Eigenfrequencies



Laser vibrometer measurements:

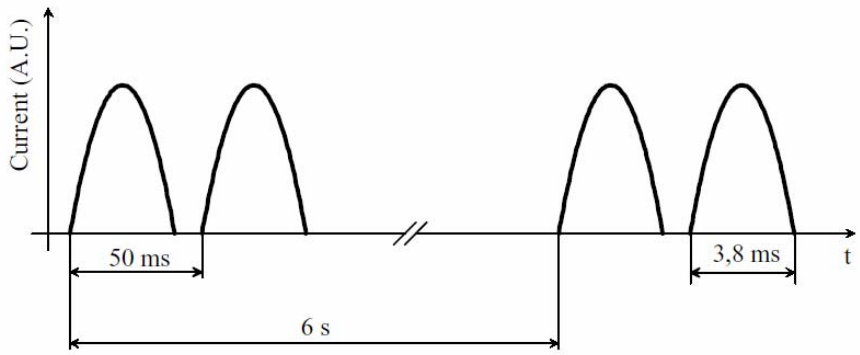
- displacements via phase difference
- velocity via Doppler shift

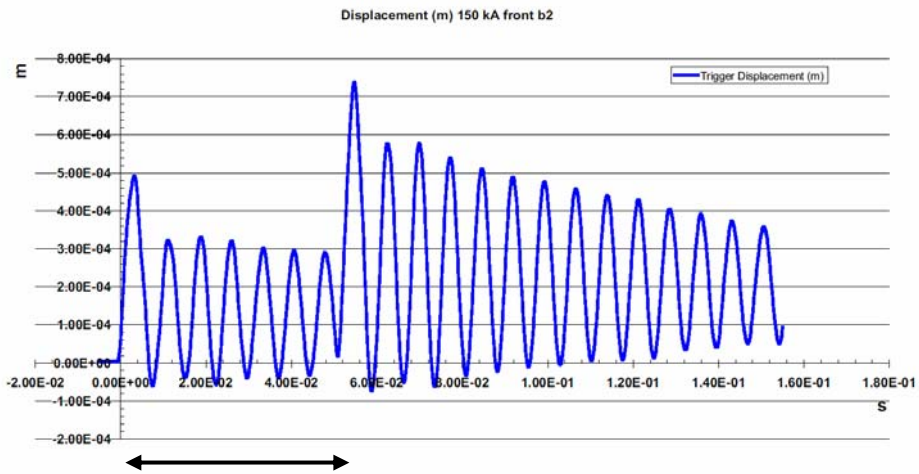
Laser Vibrometer	OFV-3001-22/303
Laser Type	He-Ne
Laser Class	2
Light wavelength	632.8 nm
Power	1 mW
Frequency range	1 Hz - 1.5 MHz
Min. displacement	1 nm

Validation of the method: CNGS horn

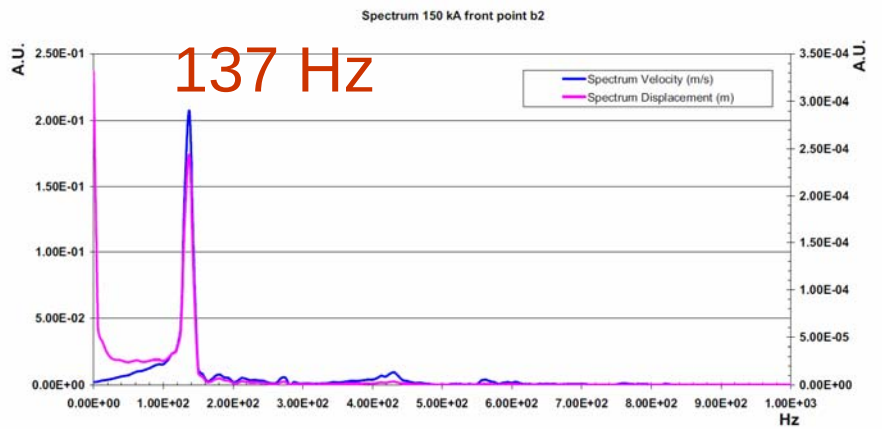
CNGS horn:
two 150 kA pulses separated
by 50 ms and repeated every 6s

Ref. Frequency: ~ 130 Hz

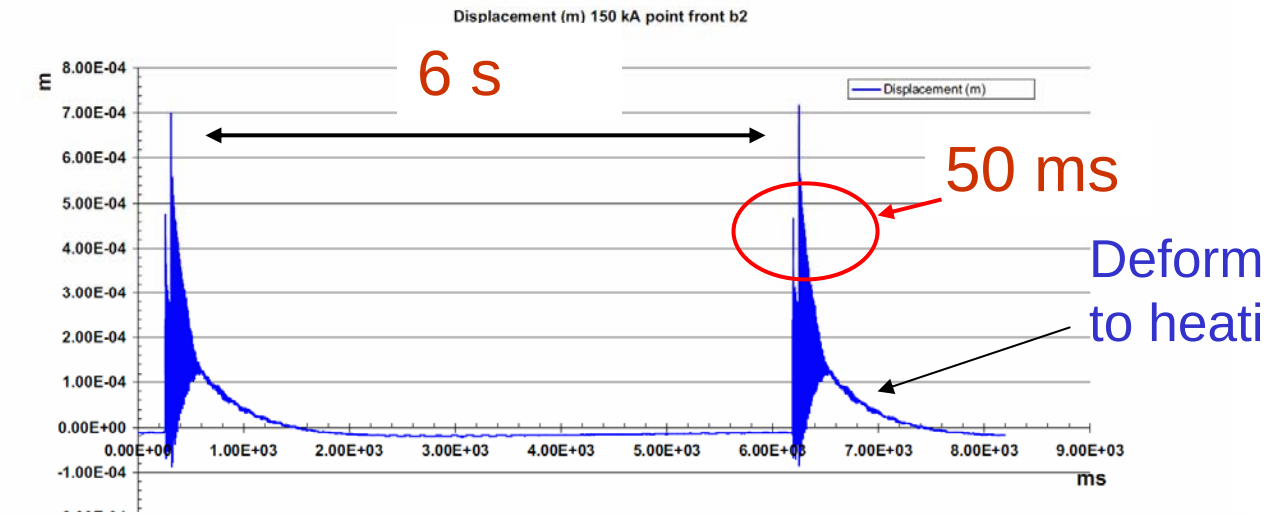


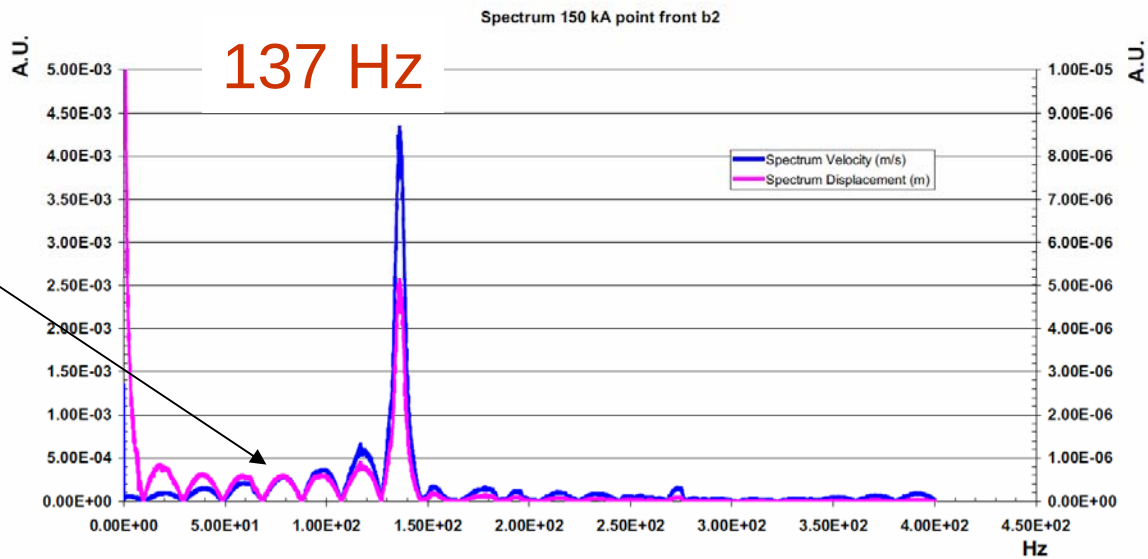


50 ms

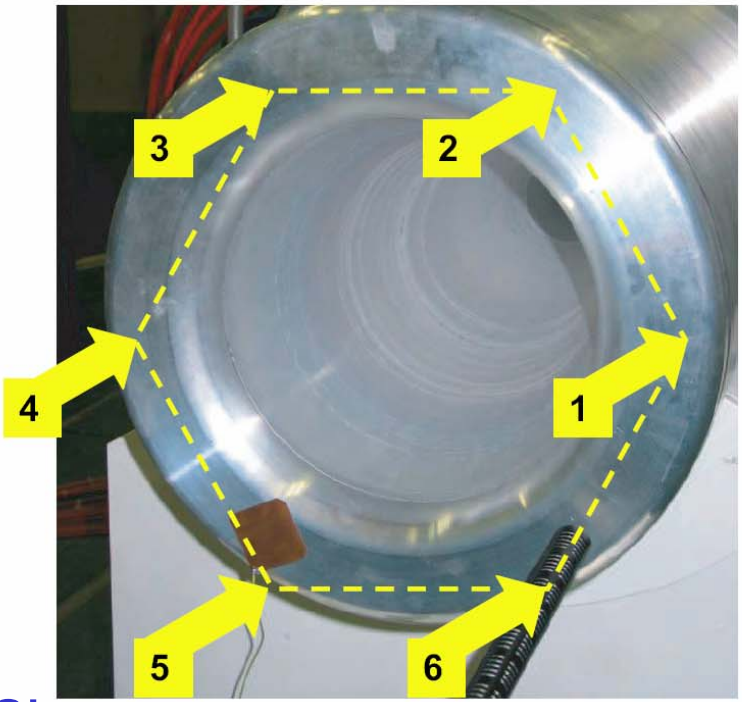


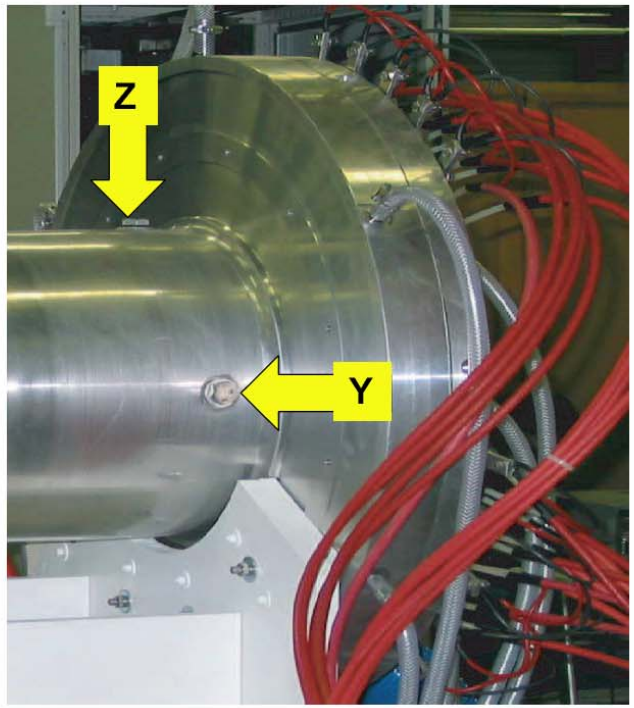
Longer time scale





Nufact horn measuring points





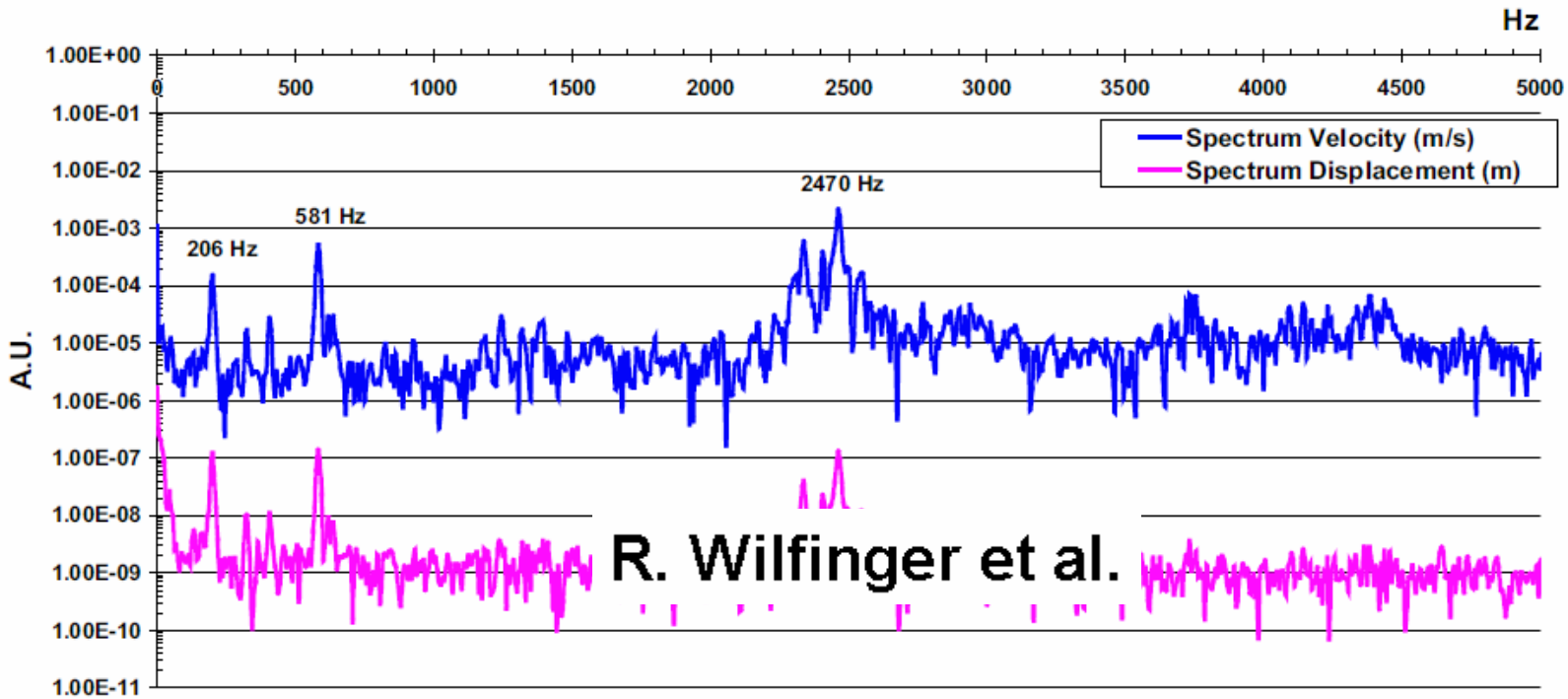
Results:

1. freq.s found with acoustic method confirmed
2. new frequency found... but ...

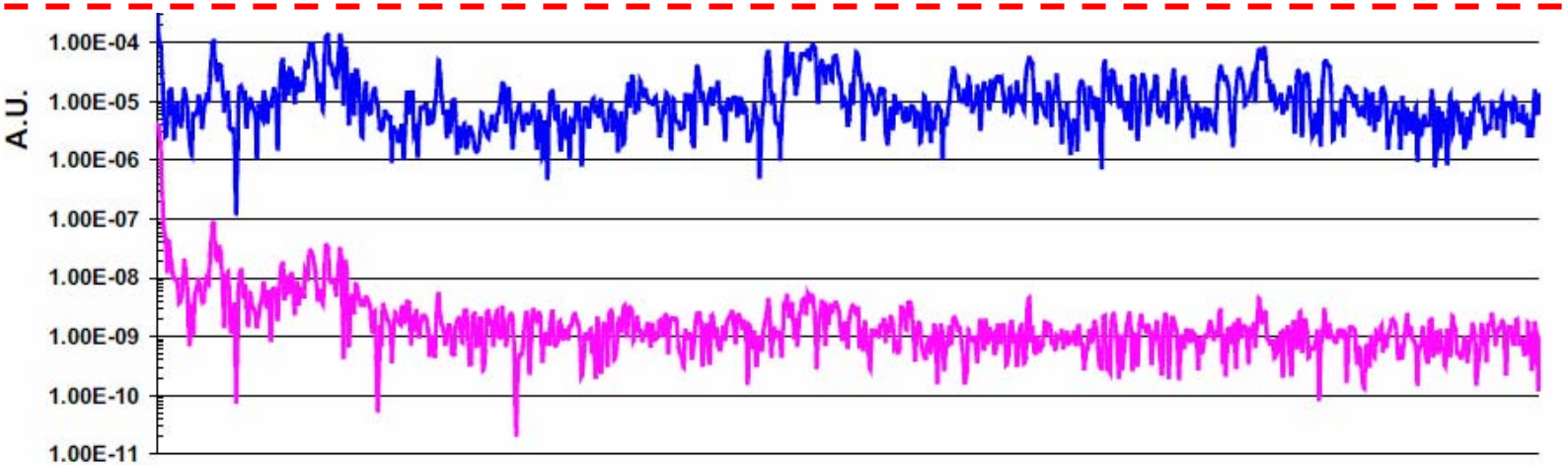
Mode	Acoustic freq. (Hz)	Laser freq. (Hz)
1	193.7	206
2	549.1	581
3	-	2470
Costs	~ 3 $ US	~ 3000 $ US

Advantages of the laser

Vibration reduction by water

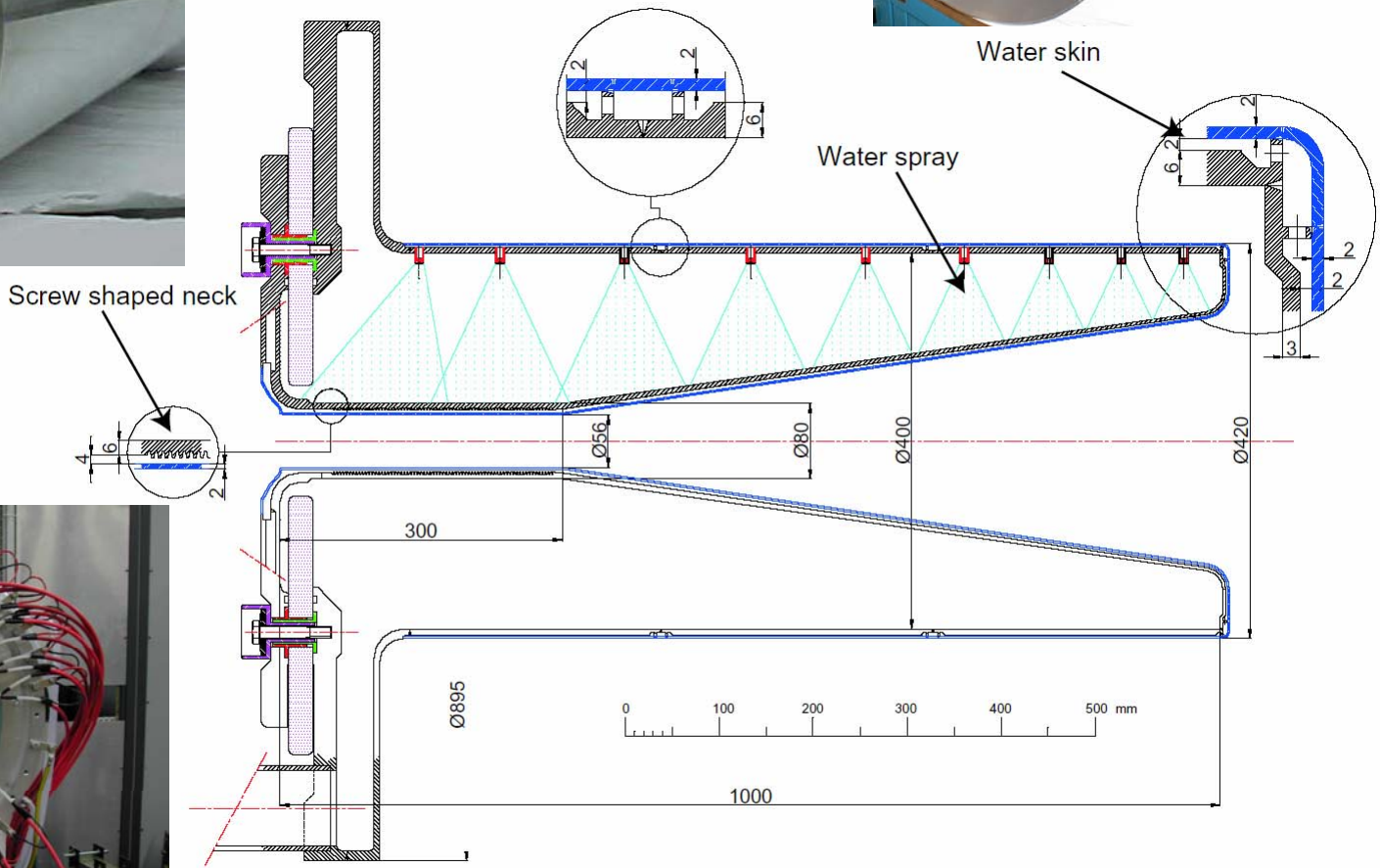


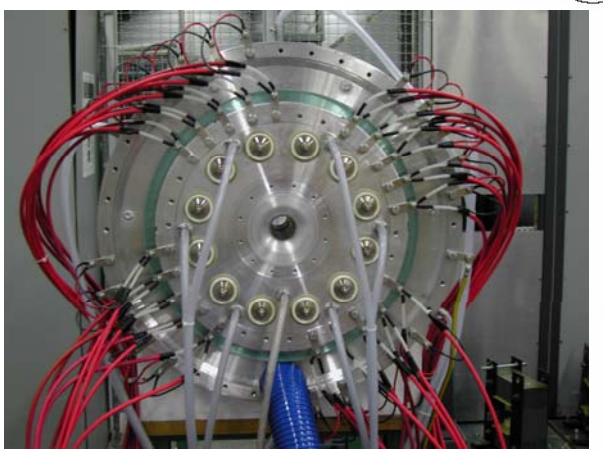
Without water cooling



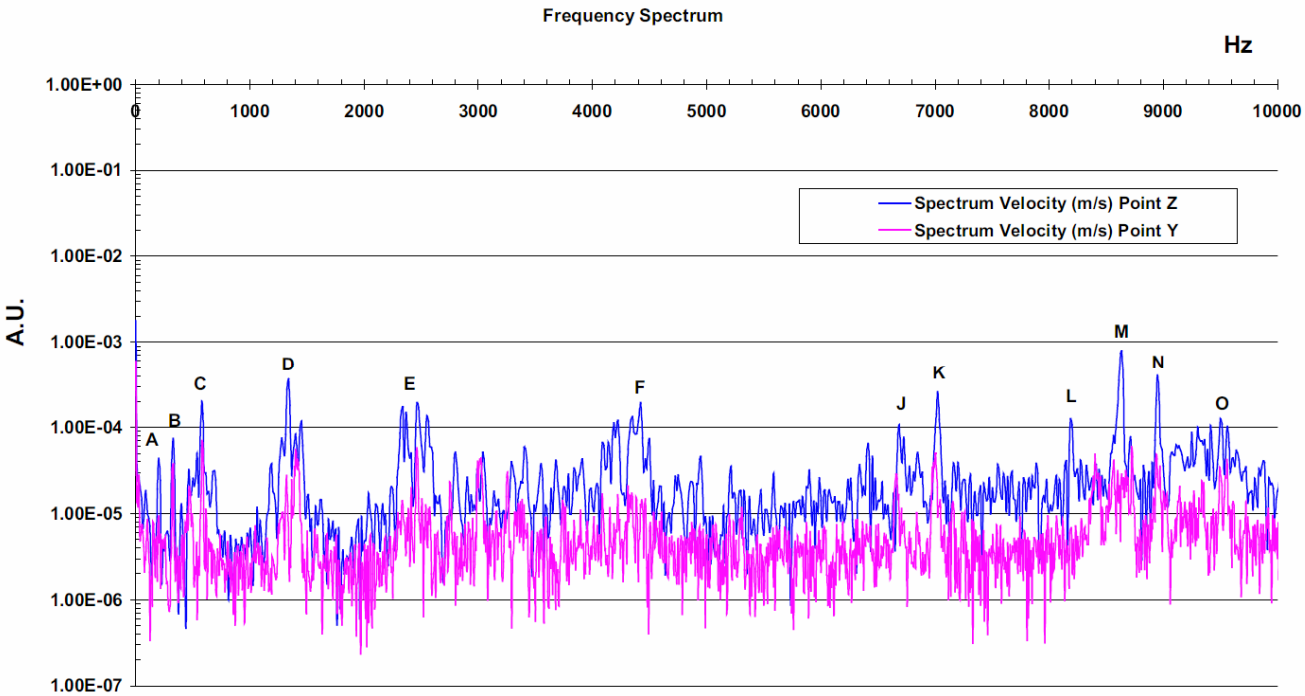
With water cooling

Horn cooling scheme





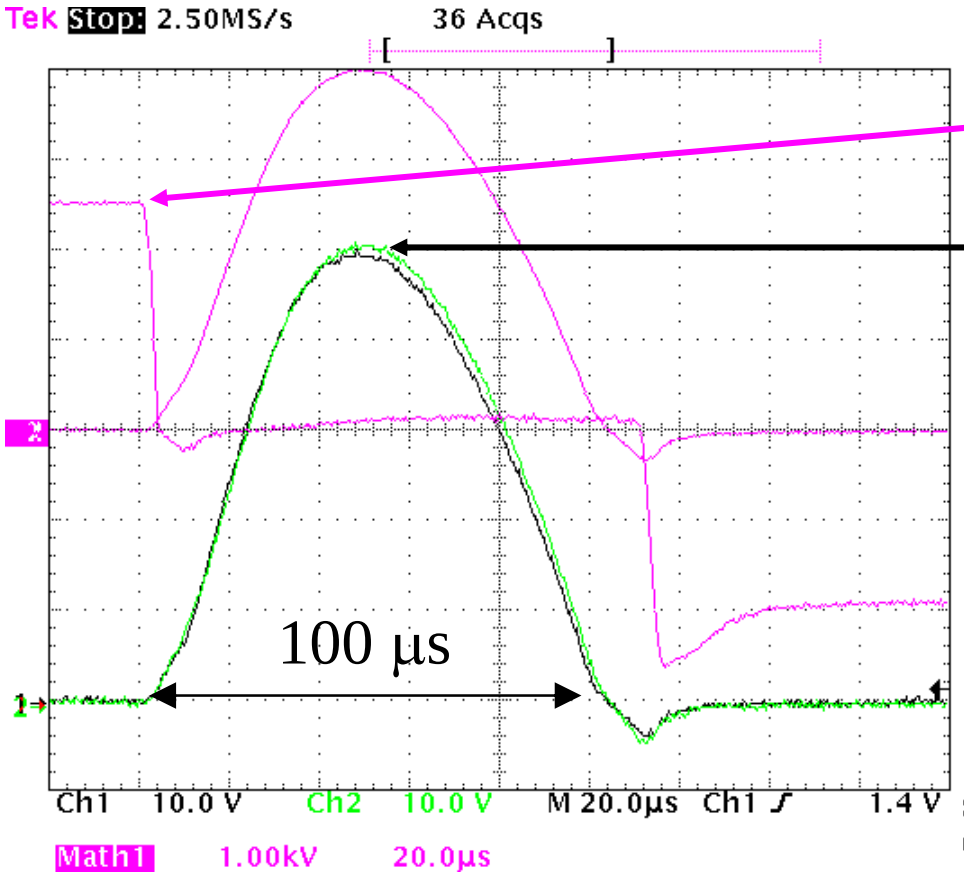
Neck Measurements



Mode	Frequency (Hz)
A	200
B	325
C	575
D	1330
E	2460
F	4410
J	6690
K	7030
L	8200
M	8640
N	8990
O	9860

Radial vibration of the inner conductor measured through the magnetic probe without water cooling

Power supply last prototype: 100 kA – 0.5 Hz



Voltage on horn/thyristor:
2.5 kV
Current first/second unit
50 kA

This is the Limit for the existing equipment:

– Max voltage on thyristor

– Max rep rate for resistors

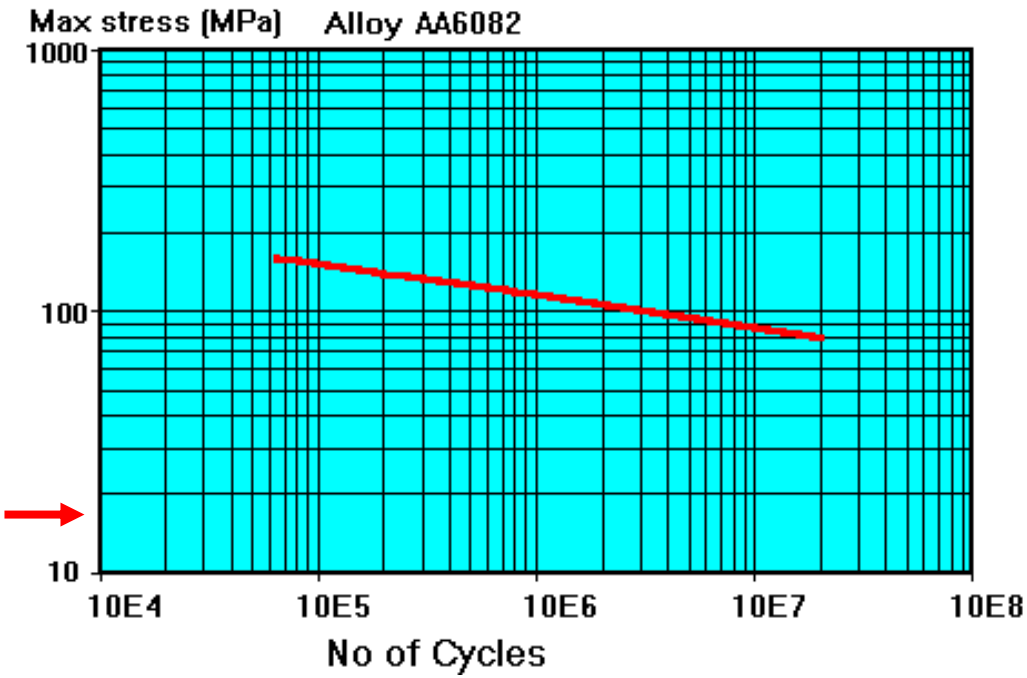
–Major breaking due to refurbished equipments

Ch1: Current of unit one measured with current transformer. (10kA/div)
Ch2: Current of unit two measured with current transformer. (10kA/div)
M1: Voltage across thyristor. (1kV/div)
M2: Sum of both currents. (25kA/div)

Material choices

- **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

Max. allowed stress →



Not compatible with Mercury

Mechanical study Goal

- Verify the reliability of a **300kA-50Hz** horn built according the conventional technique of pulsed horns and providing a minimum lifetime of a minimum of six weeks and a maximum up to one year.
- Best solution: take the horn, power it at the final freq. and current until breaking under irradiation... but of course this is not possible....
  - Verify the construction technique chosen
    - good experience from CNGS
  - Verify the mechanical characteristics of the material
  - Check the limit reached by the Miniboone horn

Material lifetime extrapolation

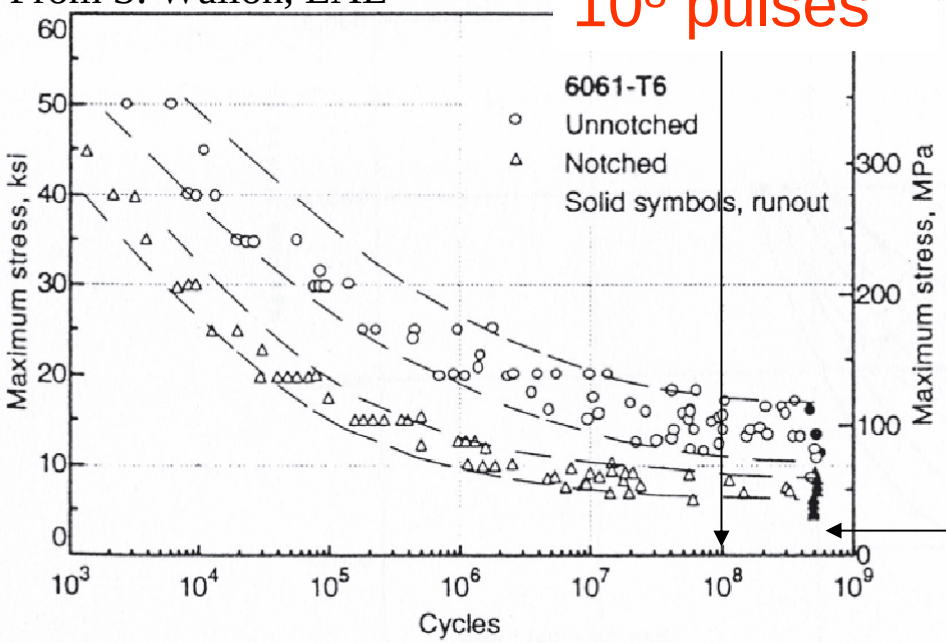
NuFact – CNGS horn

Miniboone horn

AD horn

Al 6082-T6									
%	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
Min	0.7	0.0	0.0	0.4	0.6	0.0	0.0	0.0	Bal
Max	1.3	0.5	0.1	1.0	1.2	0.25	0.2	0.1	Bal
Al 6061-T6									
%	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
Min	0.4	0.0	0.04	0.0	0.8	0.04	0.0	0.0	Bal
Max	0.8	0.7	0.15	0.15	1.2	0.35	0.25	0.15	Bal
Al 7075-T6									
	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
%	0.40	0.50	1.60	0.30	2.50	0.23	5.60	-	Bal

From S. Wallon, LAL



10^8 pulses

Unirradiated material chosen can stand more than 10^8 pulses

And even irradiated: see MiniBoone horn

14 MPa (Max horn stresses)

Horn conclusions

- The first prototype has been tested with the last upgrade of the prototype power supply
  - power supply failures identified and due to the reuse of old refurbished electric elements to reduce the costs
- The life time of the horn has been estimated between a minimum of 6 weeks and a maximum of one year
- The measurements of the mechanical vibration frequencies show a non-resonant behaviour for pulses repeated at 50 Hz
- Comparison FLUKA-MARS
  - good agreement for the “useful pions”