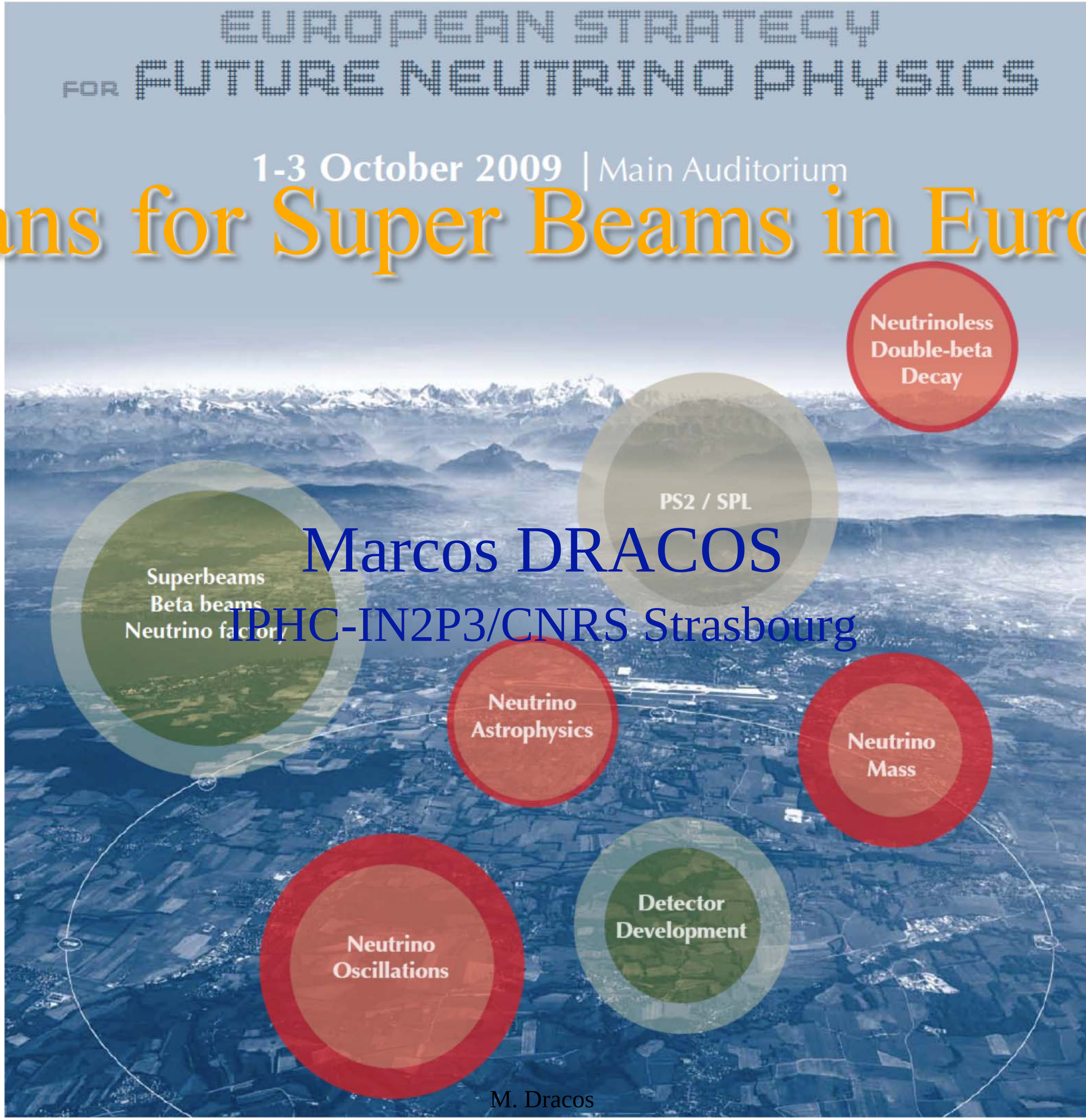
Plans for Super Beams in Europe

Marcos DRACOS
IPHC-IN2P3/CNRS Strasbourg



Super-Beam Studies in Europe

- New possibilities from LHC upgrades
- Anything more to do with the CNGS?
- Relating European Projects
- Super Proton Driver at CERN (SPL)
- Super Beam from SPL
- Physics Performance

Neutrino Oscillations and θ_{13}

$$U = \underbrace{\begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix}}_{\text{rotation around x-axis with angle } \theta_{23}} \underbrace{\begin{pmatrix} c_{13} & 0 & s_{13}e^{-i\delta_{CP}} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta_{CP}} & 0 & c_{13} \end{pmatrix}}_{\text{rotation around y-axis with angle } \theta_{13}} \underbrace{\begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}}_{\text{rotation around z-axis with angle } \theta_{12}}$$

atmospheric, accelerators

θ_{23}~45°

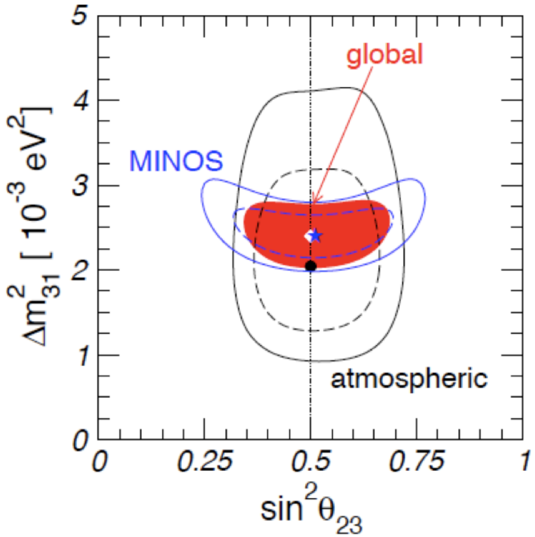
CP violation can be observed if

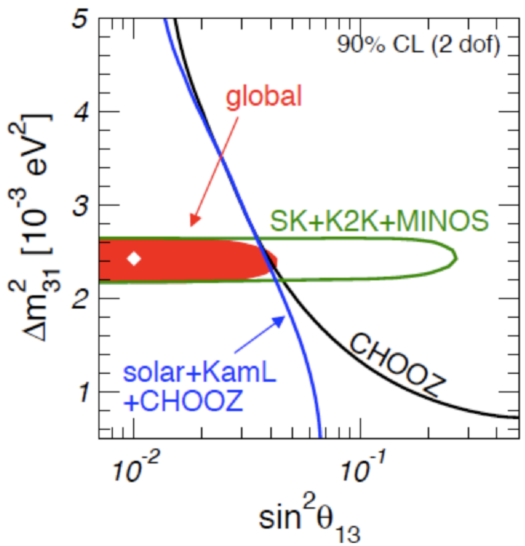
θ_{13}>0

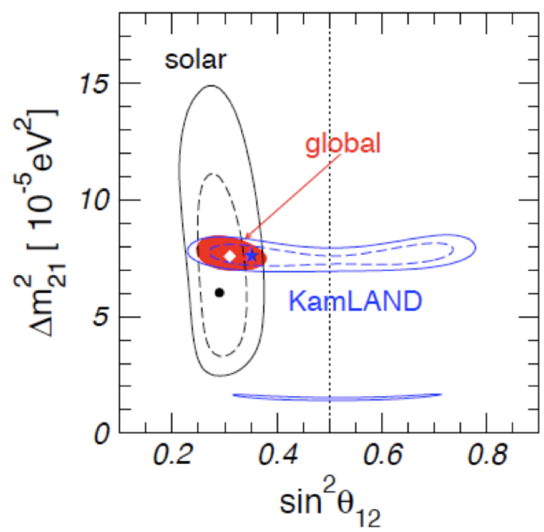
solar, reactors

θ_{12}~34°

arXiv:0808.2016v2







$\sin^2\theta_{23} = 0.50^{+0.07}_{-0.06}$

$\Delta m^2_{21} = 2.40^{+0.12}_{-0.11} \times 10^{-3}\ \text{eV}^2$

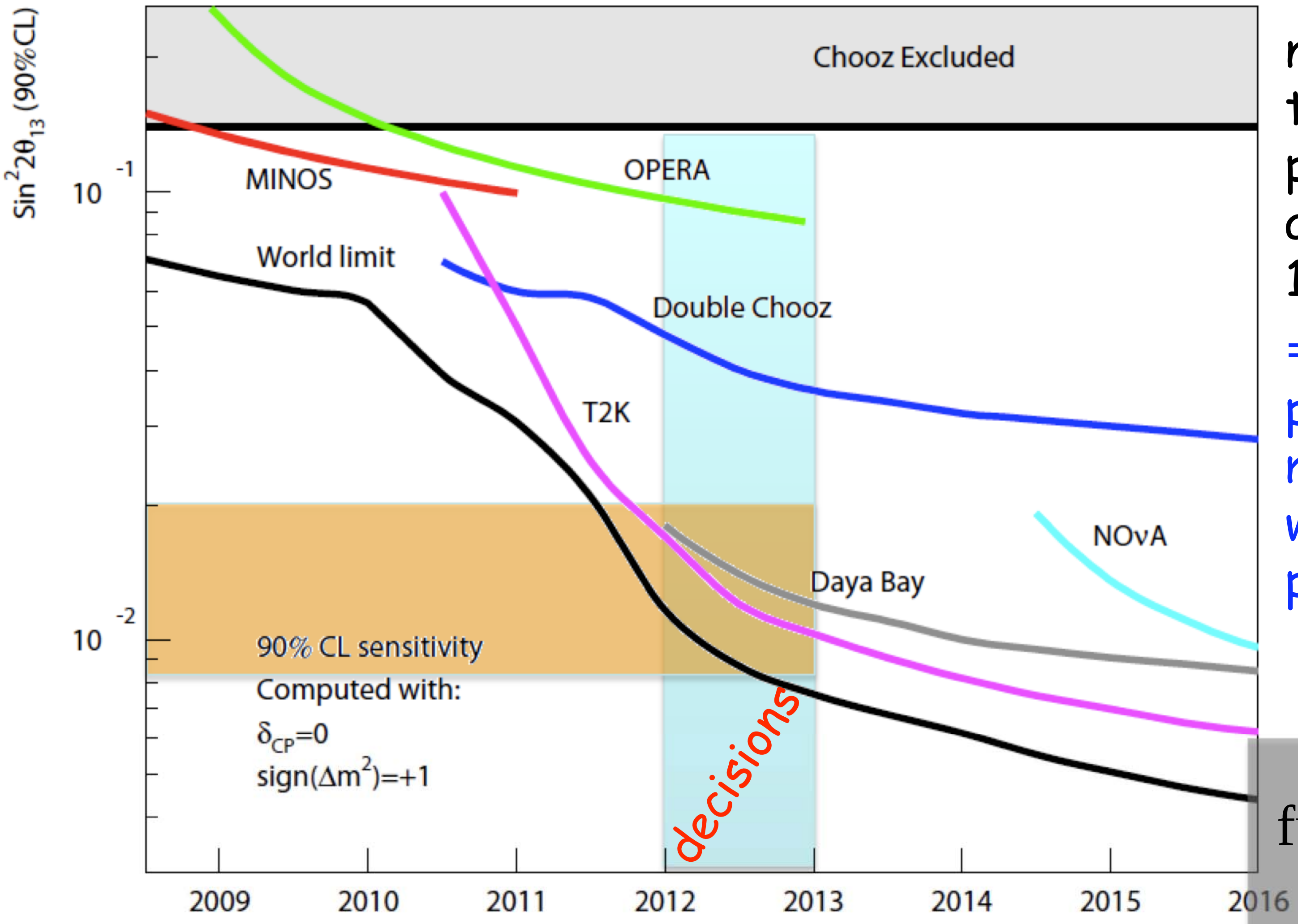
$\sin^2\theta_{13} < 0.035,\ 90\%\ \text{CL}$

$< 0.056,\ 3\sigma$

$\sin^2\theta_{12} = 0.304^{+0.022}_{-0.016}$

$\Delta m^2_{21} = 7.65^{+0.23}_{-0.20} \times 10^{-5}\ \text{eV}^2$

θ_{13} limit expectations up to 2016



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

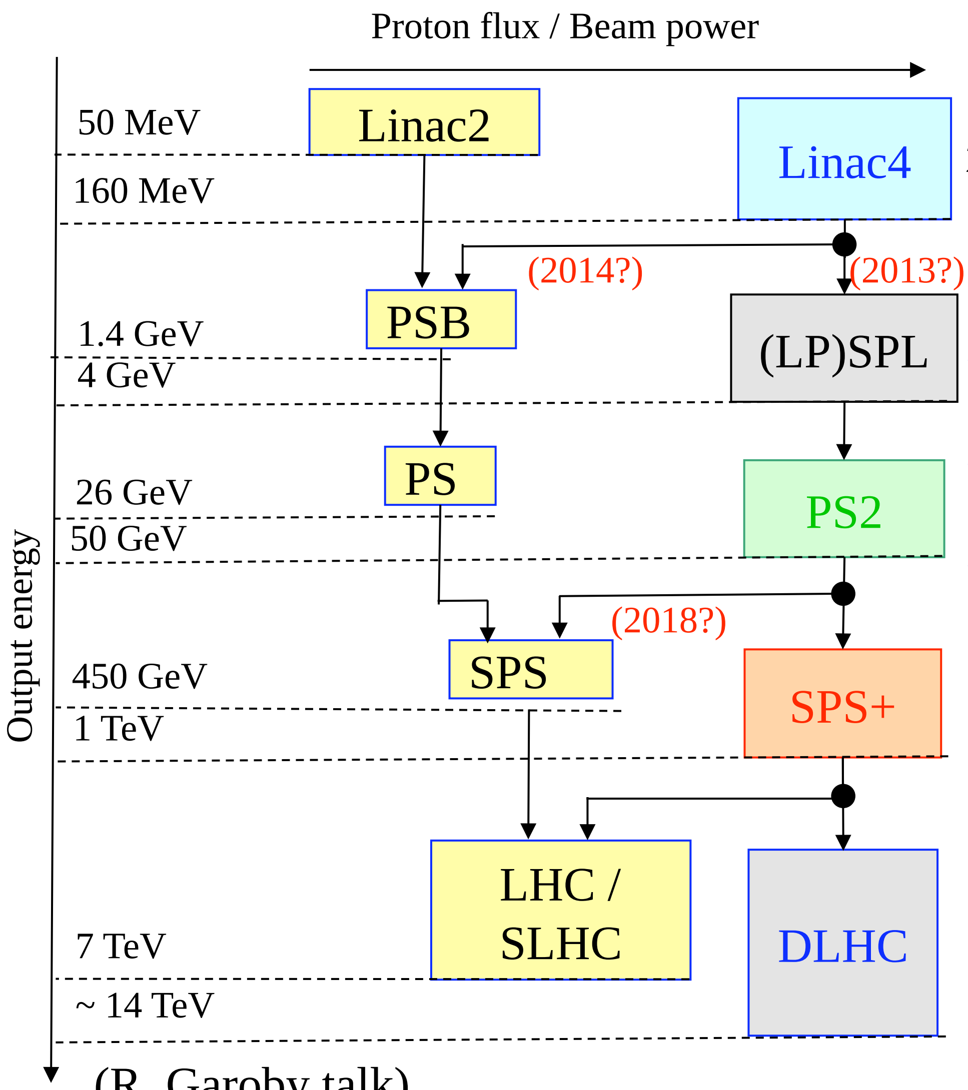
⇒ in this case precision measurements with next projects

future facilities

Can we profit from high priority facilities likely to exist at CERN before 2020

a good way to go further…

Take profit of an upgrade of CERN accelerator complex



(R. Garoby talk)

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

- Increase injection energy in the PSB from 50 to 160 MeV
- Increase injection energy in the SPS from 25 to 50 GeV
- Design the PS2 with an acceptable space charge effect for the maximum beam envisaged for sLHC => injection energy of 4 GeV.

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)

Maximum potential proton flux to CNGS

Protons on target per year [$\times 10^{19}$] for 200 days of operation with 80% machine availability

	SPS cycle length	6 s		4.8 s	
	Injection momentum	14 GeV/c		26 GeV/c	
	Beam sharing / Max SPS intensity @ 400GeV [$\times 10^{13}$]	0.45	**0.85**	0.45	**0.85**
Present injectors + machines' improvement	4.8 "nominalCNGS"	5	9.4		
	5.7 "maximum SPS"	5.9	**11.1**		
Future injectors + SPS RF upgrade	7 "ultimate CNGS"			9	17.1
Future injectors + new SPS RF system + CNGS new equipment design	10 "Maximum PS2"			12.9	**24.5**

CERN-AB-2007-013

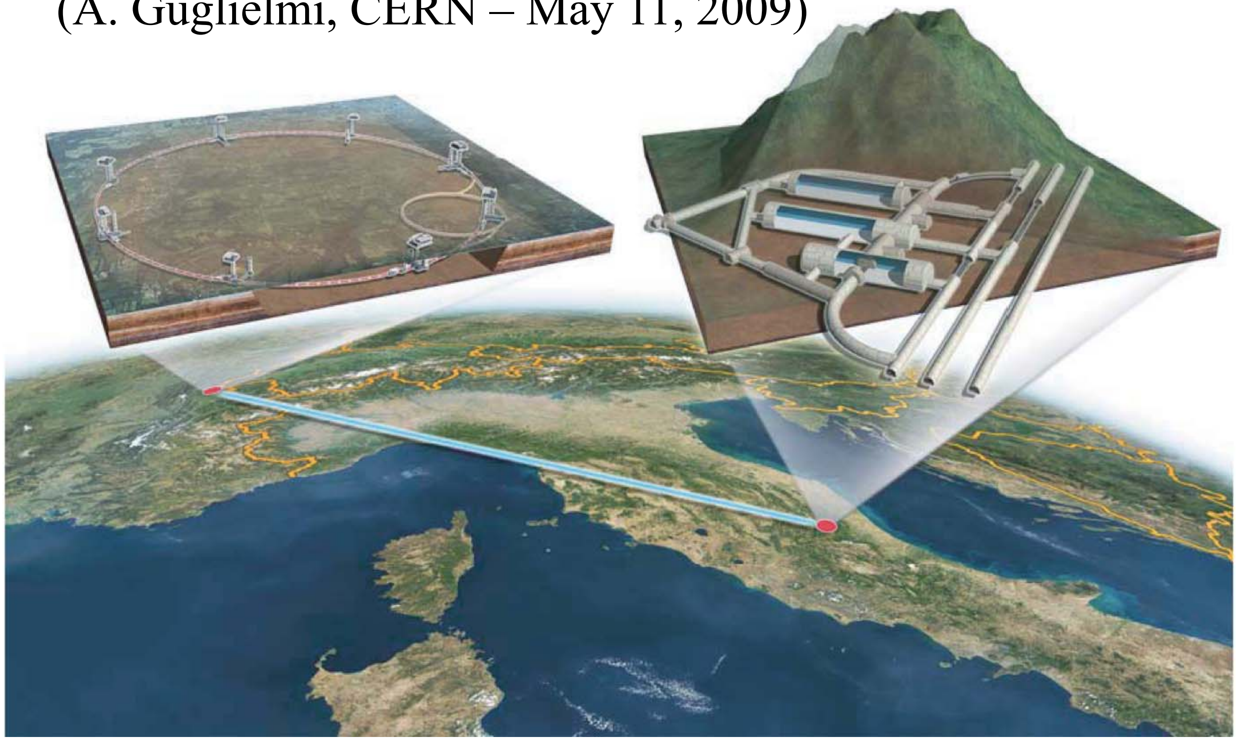
"…It must however be underlined that, after the planned 5 years run for CNGS, the target chamber will be so activated that the replacement of the present target and its shielding by a new assembly will be extremely challenging if not impossible."

"…As for the target, it must be underlined that, after the planned 5 years run for CNGS, the target chamber will be so activated that the removal of the horn of the first generation and its replacement with a newly designed device will be extremely challenging if not impossible."

MODULAr

$\nu_\mu \rightarrow \nu_e$

(A. Guglielmi, CERN – May 11, 2009)

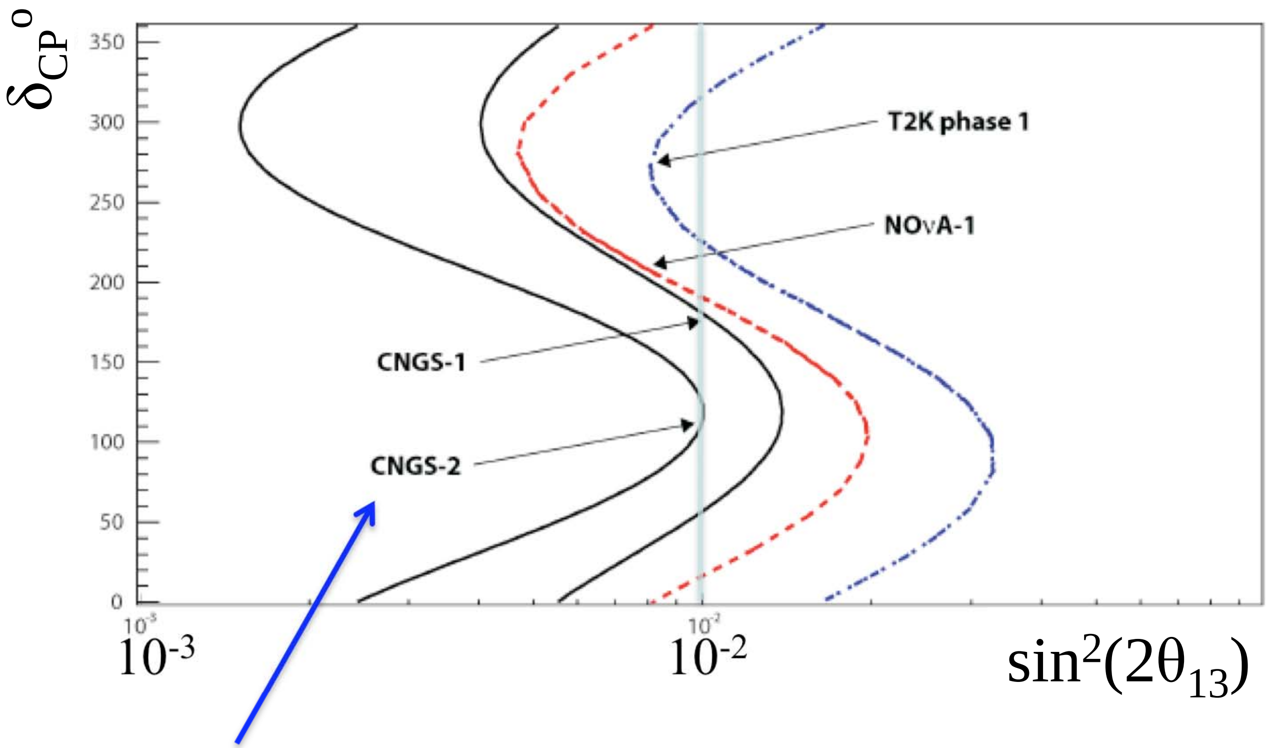


Very massive modular Liquid Argon Imaging Chamber to detect low energy off-axis neutrinos from the CNGS beam

- LAr-TPC Imaging underground detector made of several identical units 5 kt fid. mass each, 20 kt LAr-TPC detector as a first step.
- New experimental area LNGS-B, 10 km Off-Axis the main lab.
- ~1200 mwe depth for p-decay and cosmic ν searches
- Neutrino beam derived from the existing CNGS facility with an increased intensity.
- Nearly optimal ν_μ beam in few GeV energy range.

MODULAr

3σ MODULAr sensitivity to θ_{13} and δ_{CP}



CNGS-1: 1.2×10^{20} pot/y
CNGS-2: 4.3×10^{20} pot/y
$\Delta m_{23}{}^2 = 2.5 \times 10^{-3} eV^2$
normal mass hierarchy

GLoBES calculation:
5 % beam systematics
$\Delta E/E = 15$ %

needs PS2
but lim. @ 2.4 10^{20} pot/y

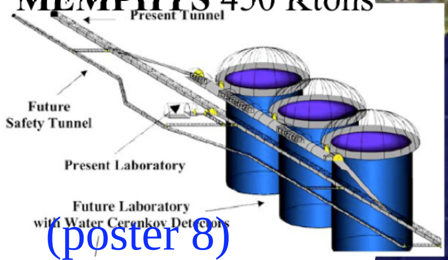
Neutrino Related European Projects

Two FP7 projects:

- **EUROν** (http://www.euronu.org/)
  - Design Study for new neutrino facilities in Europe
  - Project started: 1^{st} September 2008
  - Duration: 4 years – completion in 2012
  - Budget allocated by EU: 4.0M€, total cost 13.5M€
- **LAGUNA** (Large Apparatus for Grand Unification and Neutrino Astrophysics, http://laguna.ethz.ch:8080/Plone)
  - Design Study for large underground laboratories for astroparticle and neutrino studies
  - Project started: 1^{st} August 2008 (poster 11)
  - Duration: 2 years – completion in 2010
  - Budget allocated by EU: 1.7M€

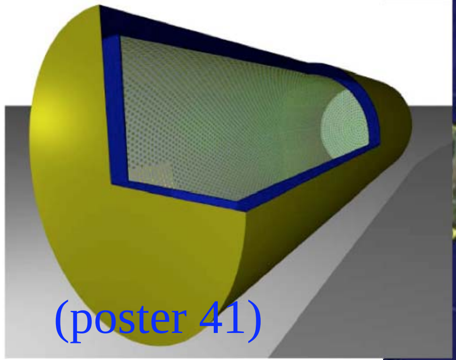
All sites and detection techniques under consideration by LAGUNA and possible neutrino beams from CERN

MEMPHYS 450 Ktons



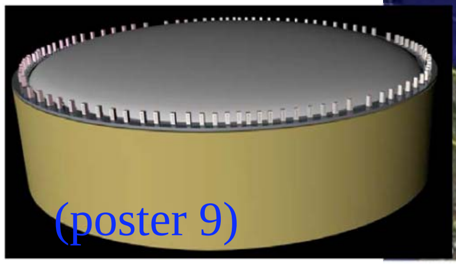
(poster 8)

LENA 50 ktons



(poster 41)

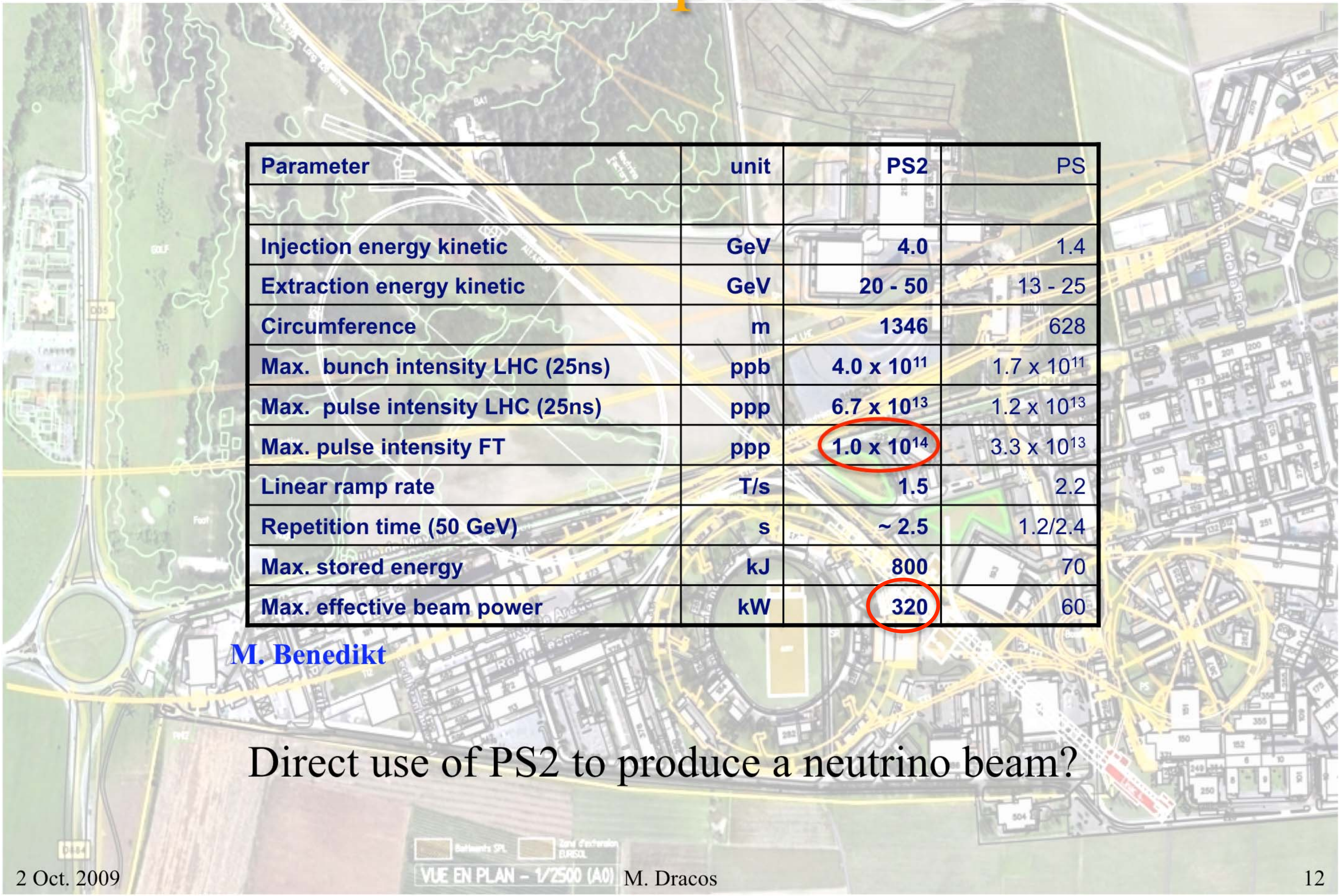
GLACIER 100 ktons



(poster 9)

Distance (km)	1st osc. max (GeV)
130	0.26
630	1.27
665	1.34
950	1.92
1050	2.12
1570	3.18
2300	4.65

PS2 main parameters



Parameter	unit	PS2	PS
Injection energy kinetic	GeV	4.0	1.4
Extraction energy kinetic	GeV	20 - 50	13 - 25
Circumference	m	1346	628
Max. bunch intensity LHC (25ns)	ppb	4.0×10^{11}	1.7×10^{11}
Max. pulse intensity LHC (25ns)	ppp	6.7×10^{13}	1.2×10^{13}
Max. pulse intensity FT	ppp	1.0×10^{14}	3.3×10^{13}
Linear ramp rate	T/s	1.5	2.2
Repetition time (50 GeV)	s	~ 2.5	1.2/2.4
Max. stored energy	kJ	800	70
Max. effective beam power	kW	320	60

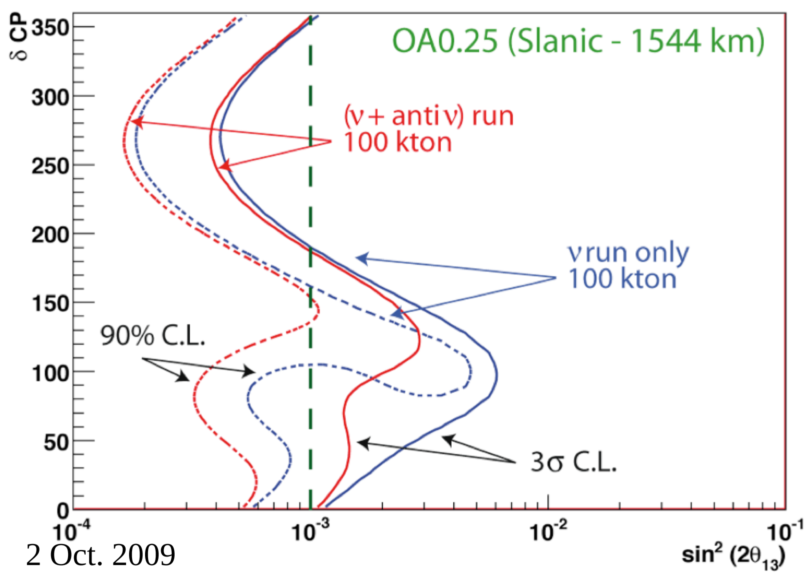
M. Benedikt

Direct use of PS2 to produce a neutrino beam?

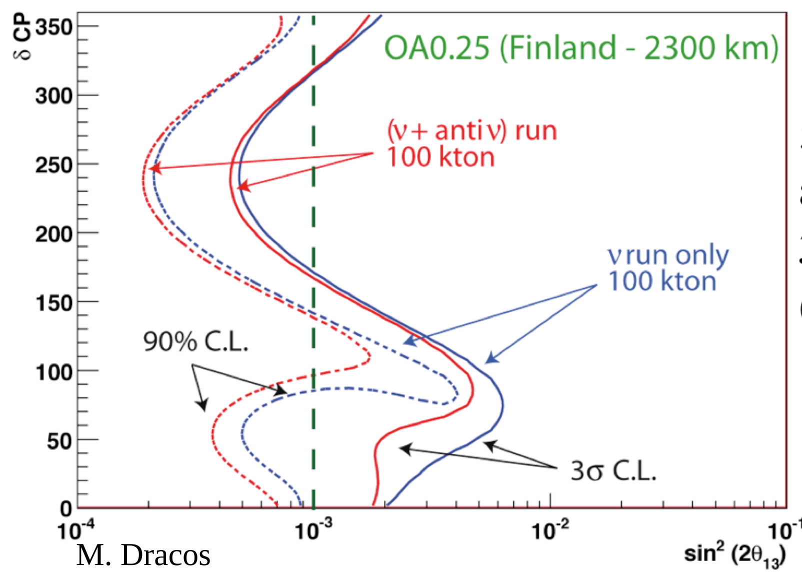
LBL using PS2

(A. Rubbia WIN09)	J-PARC design [2]	J-PARC upgrade [72]	J-PARC ultimate [2]	CERN SpS CNGS dedicated	CERN SpS + [61]	CERN SpS 1 [73]	CERN SpS 2 [73]	CERN PS2 SLHC	CERN PS2 ν?
Proton energy E_p	30 GeV/c		40 GeV/c	400 GeV/c				50 GeV/c	
$ppp(\times 10^{13})$	33	67	> 67	4.8	14	4.8	15	12.5	25
T_c (s)	3.64	2	< 2	6	6	6	6	2.4	1.2
Efficiency	1.0	1.0	1.0	0.55	0.83	0.8	0.8	1.0	1.0
Running (d/y)	130	130	130	220	220	240	280	200	200
N_{pot} / yr $(\times 10^{19})$	**100**	**380**	**$\simeq$ 700**	**7.6**	**33**	**12**	**43.3**	**90**	**360**
Beam power (MW)	0.6	1.6	4	0.5	1.5	0.5	1.6	0.4	1.6
$E_p \times N_{pot}$ $(\times 10^{22}$ GeV·pot/yr)	4	11.5	28	3	13.2	4.7	17.3	4.5	18
Relative increase		$\times 3$	$\times 7$	$\times 2$	$\times 7$	$\times 3$	$\times 10$	–	$\times 4$
Timescale	$\simeq$ 2014	>2014?	?	> 2008	>2016 ?			>2018 ?	>2020 ?

θ13 Sensitivity - CNXX NOvA Horns - 50 GeV protons



θ13 Sensitivity - CNXX NOvA Horns - 50 GeV protons



100 kton LAr
5 yrs ν (+5 yrs anti-ν)
3×10^{21} pots/yr @ 50 GeV

preliminary, work ongoing

SPL for Neutrino Beams

Parameters	LP-SPL (SLHC)	HP-SPL	
		Option 1	Option 2
Kinetic Energy (GeV)	4	2.5 or 5	2.5 and 5
Beam power (MW)	0.12 (at 4 GeV)	>2 MW (2.5 GeV) or >4 MW (5 GeV)	4 MW (2.5 GeV) and 4 MW (5 GeV)
Rep. frequency (Hz)	0.6	50	50
Protons/pulse (x 10^{14})	1.1	1.1	2 (2.5 GeV) + 1 (5 GeV)
Av. Pulse current (mA)	20	20	40
Pulse duration (ms)	0.9	0.9	0.8 (2.5 GeV) + 0.4 (5 GeV)

(poster 26)

for neutrinos and radioactive beams (including Beta Beams), could be ready by 2020.

- The study of LP-SPL has already started at CERN,
- CDR for 2.2 and 3.5 GeV HP-SPL already done (CERN 2000-012, CERN 2006-006),
- decision and beginning of construction of LP-SPL by 2012/2013,
- at that time the design must take into account the possibility to go to HP-SPL, impossible to do it afterwards,
- **LINAC4 shielding already designed to go to high power.**

CERN LHC injector upgrade

Stage 3: upgrade to HP-SPL

- 4 ➔ 5 GeV, 2 ➔ 50 Hz, 20 ➔ 40 mA, 0.2 ➔ 4 MW,
- replace all klystron modulators and power supplies,
- double the number of klystrons,
- new infrastructure for electricity, water, cryogenics, surface buildings.

Applications:

- PS2/SPS/LHC,
- neutrino beta beam,
- EURISOL, ISOLDE upgrade.

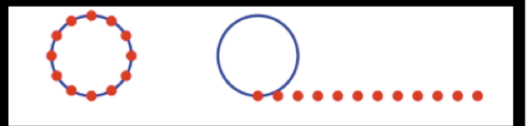
"Future high-intensity proton accelerators", SRF'07, 15-19 October 2007, F. Gerigk

LP-SPL ➔ HP-SPL

Stage 4/5: accumulator/compressor

Accumulator ring

- neutrino superbeam,



Compressor ring:

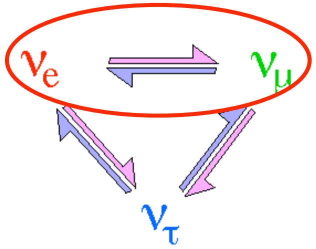
- neutrino factory.

Only at this stage one has to fix the time structure of the beam:
circumference = pulse length
harmonic number = number of bunches
bunch length = RF gymnastics

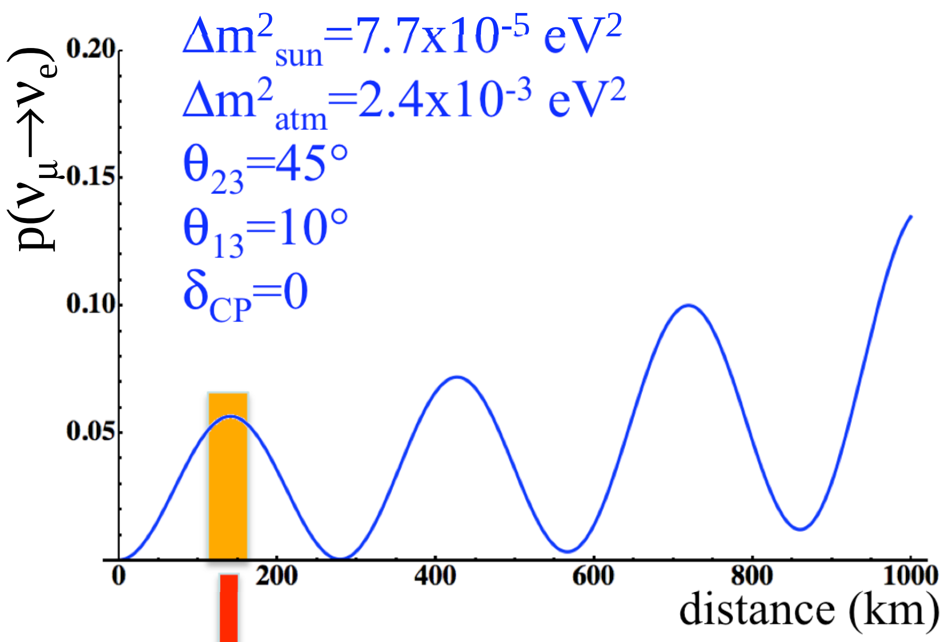
"Future high-intensity proton accelerators", SRF'07, 15-19 October 2007, F. Gerigk 29

Neutrino Super Beam from SPL

SPL proton kinetic energy: ~4 GeV



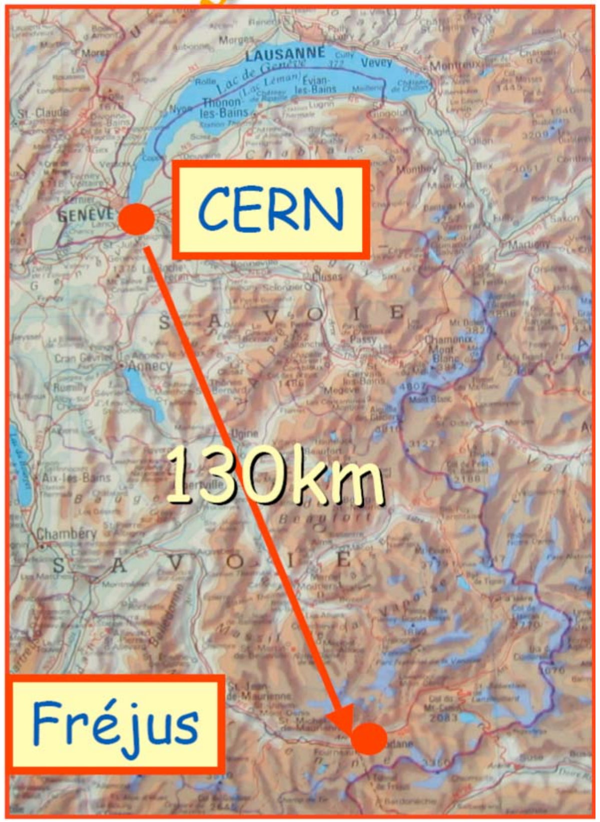
Neutrino energy: ~300 MeV



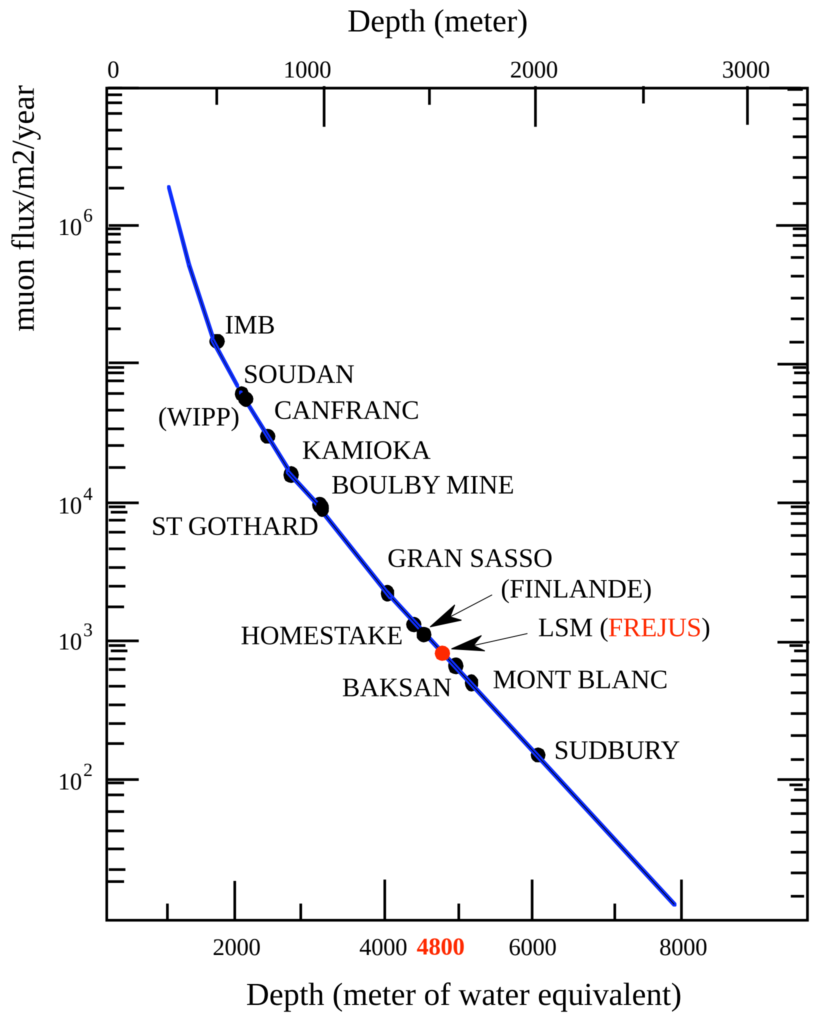
~130 km

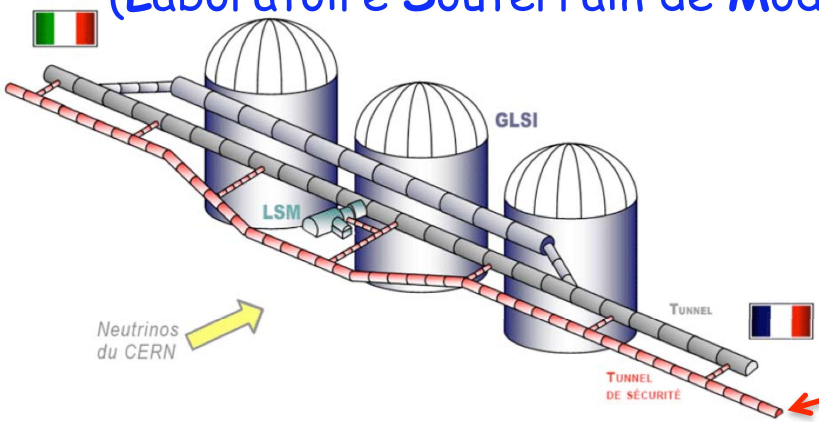
Fréjus tunnel

Fréjus underground laboratory



(Laboratoire Souterrain de Modane)

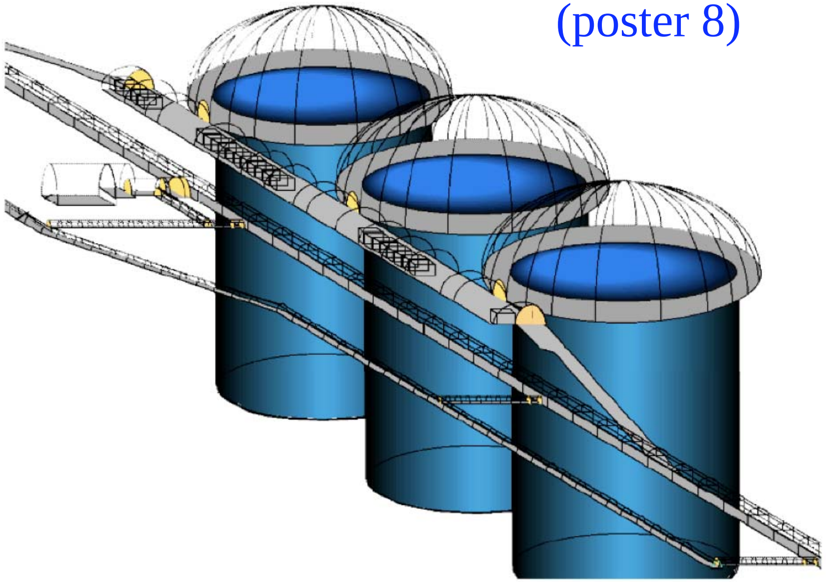




new safety gallery to be dug, profit of this opportunity to enlarge LSM

The MEMPHYS Project
(within FP7 LAGUNA DS)

(poster 8)



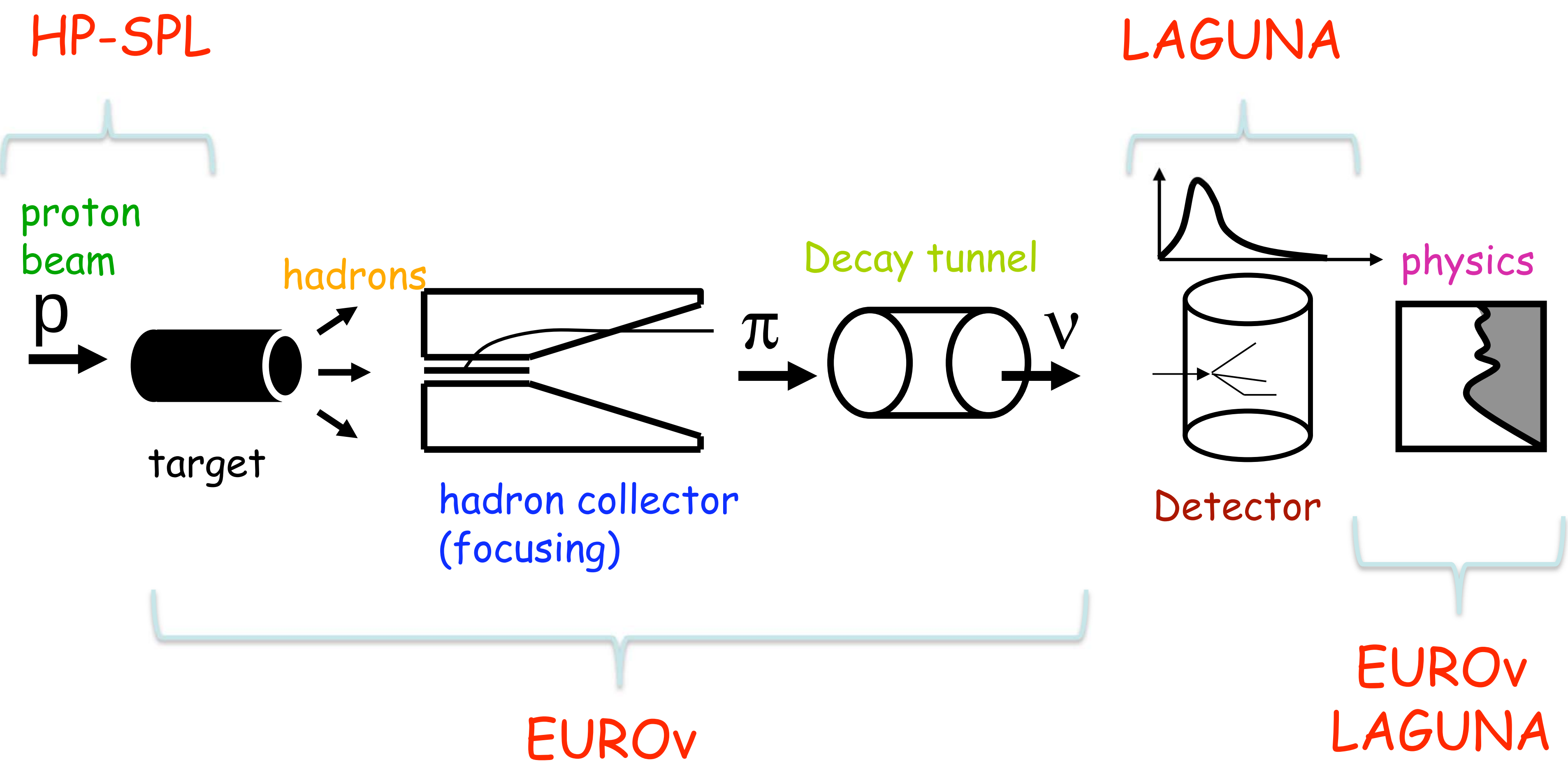
Mainly to study:

- **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)

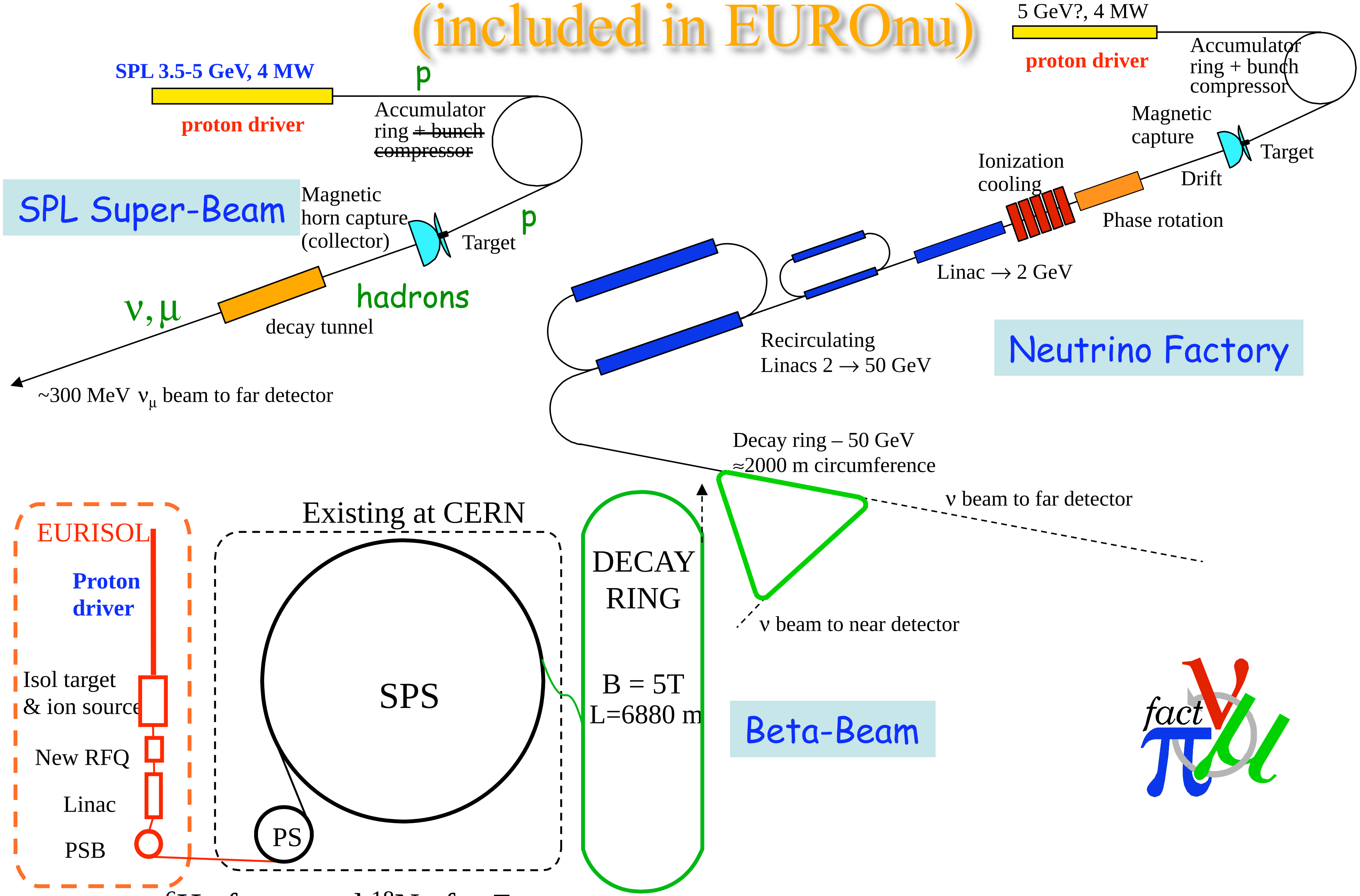
Water Cerenkov Detector with total fiducial mass: 440 kt:
- 3 Cylindrical modules 65x65 m
- Readout: 3x81k 12” PMTs, 30% geom. cover. (#PEs =40% cov. with 20” PMTs).

(arXiv: hep-ex/0607026)

Conventional Neutrino Beams

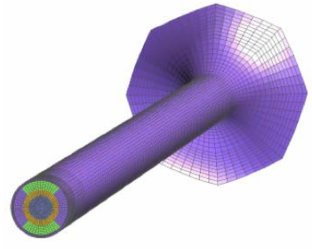


Present European Projects
(included in EUROnu)



Technological Challenges

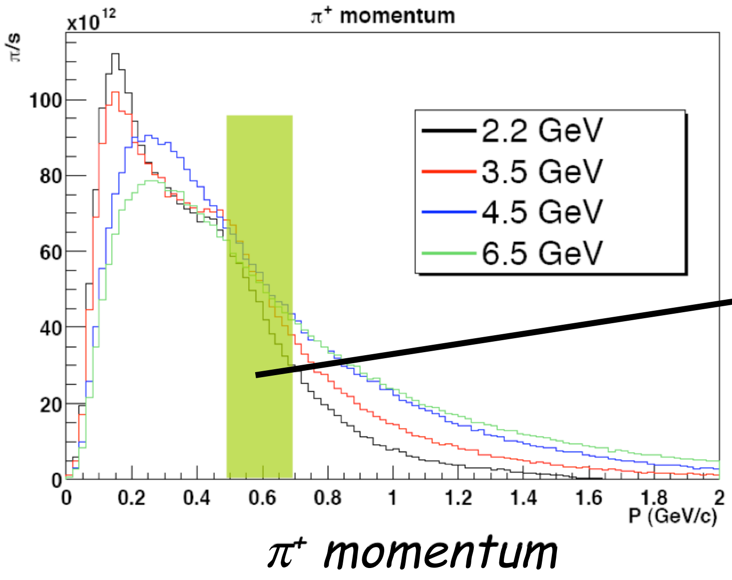
Target

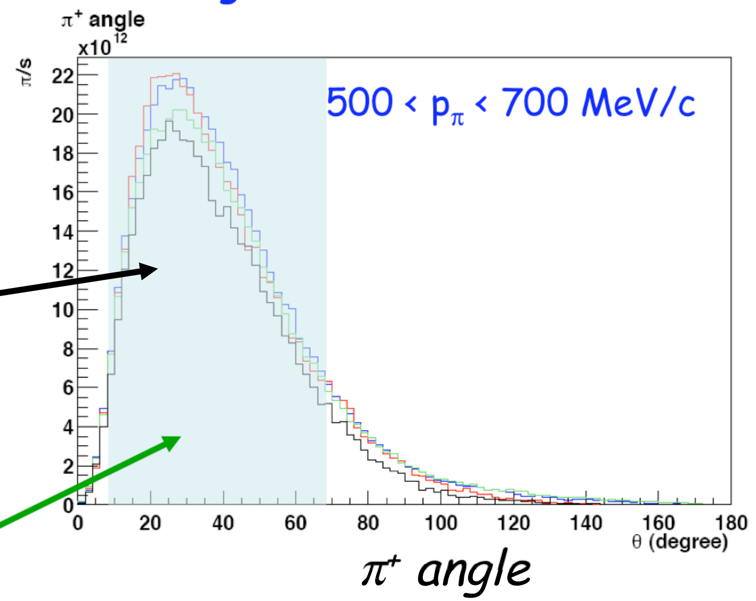


- 300-1000 J cm^{-3}/pulse
- Severe problems from : sudden heating, stress, activation
- Safety issues (profit of installations to exist by then like T2K, ESS, SNS)!
- Solid versus liquid targets:
  - Extremely difficult problem : need to pursue two approaches :
    - Liquid metal target (mercury, Merit experiment)
    - Solid target (extensive R/D program at STFC and BNL)
- Envisage alternative solutions

Proposed design for SPL

for pions coming out of the target





for a Hg target, 30 cm length, ∅15 mm

horn region

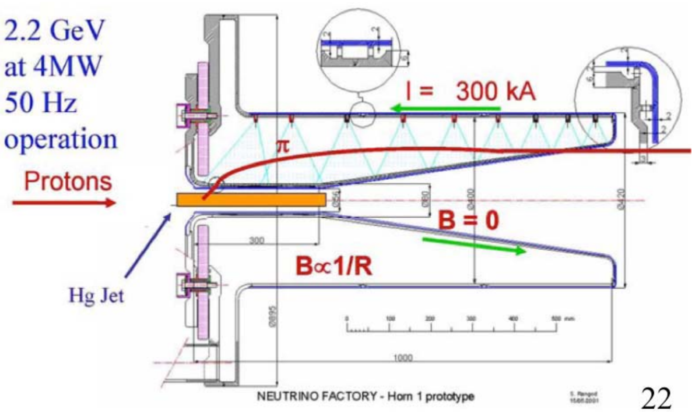
⇒

relatively better collection when p_{proton} ↗

⇒

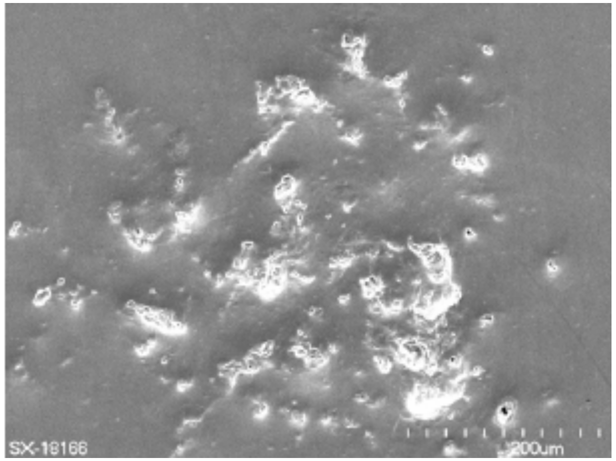
the target must be inside the horn!

2.2 GeV
at 4MW
50 Hz
operation



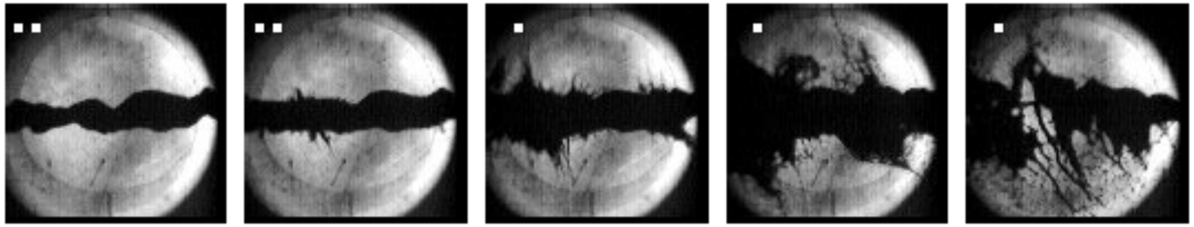
Studies on Hg targets

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 (talk by H. Kirk)



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

•Damping of splashes due to magnetic field observed as predicted

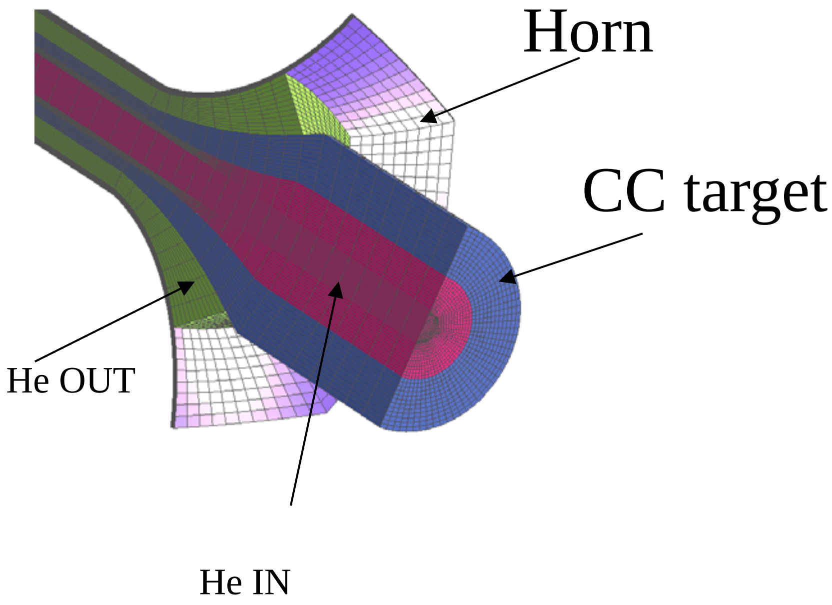
•More studies ongoing (poster 28)

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? If so, would the jet be 'open' or 'contained'?
- 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.

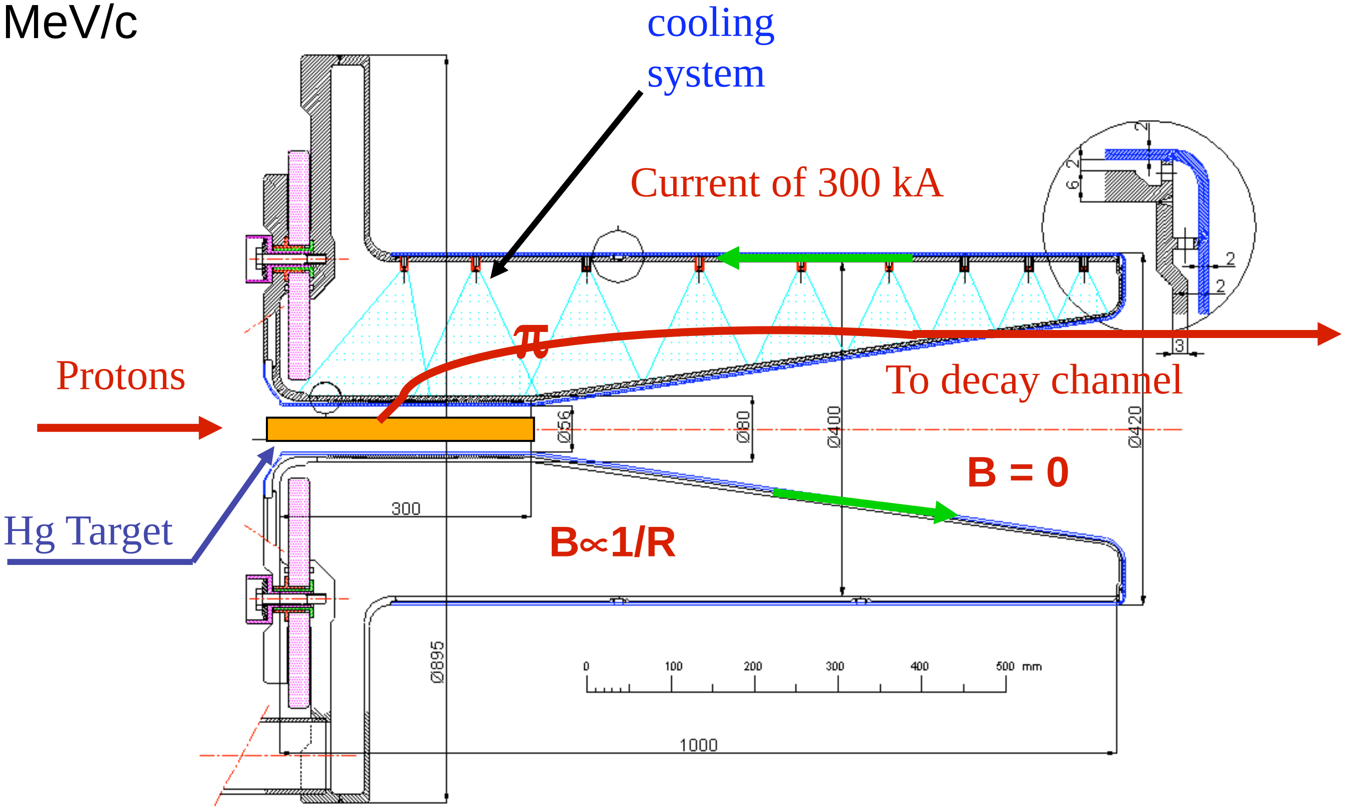


cooling is a main issue…

Hadronic Collector (Horn) geometry

First studies with old SPL characteristics

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

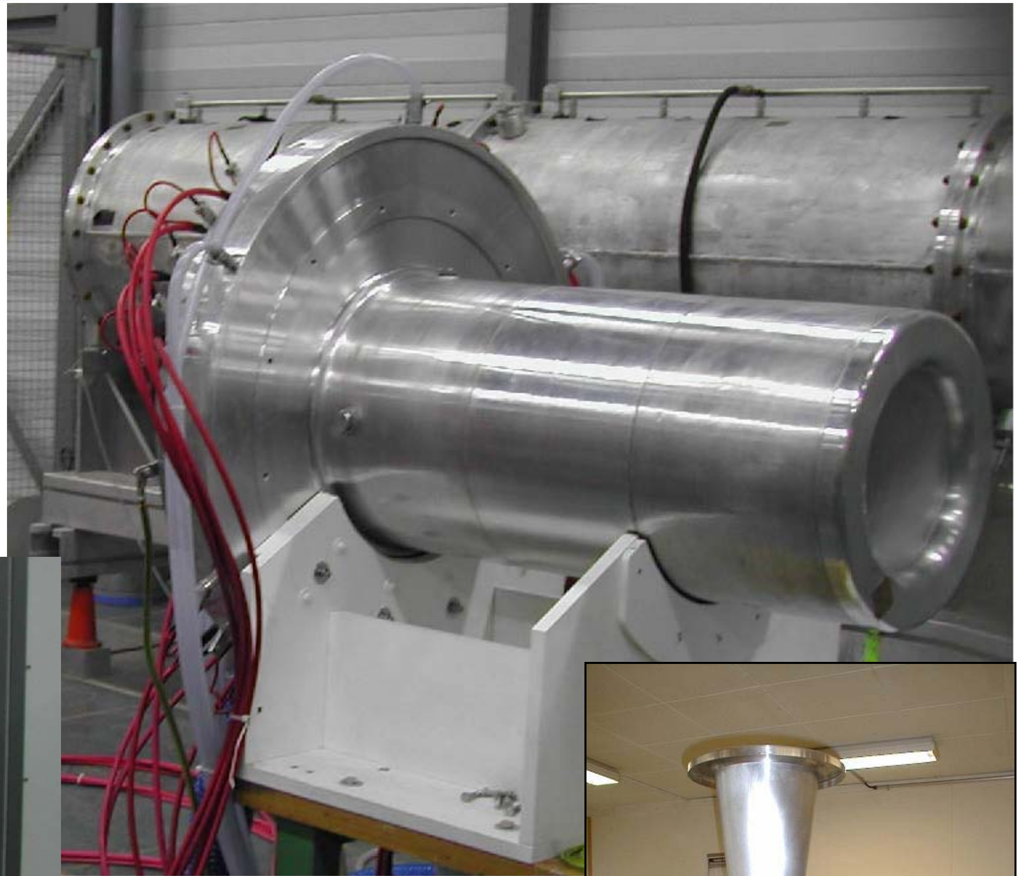


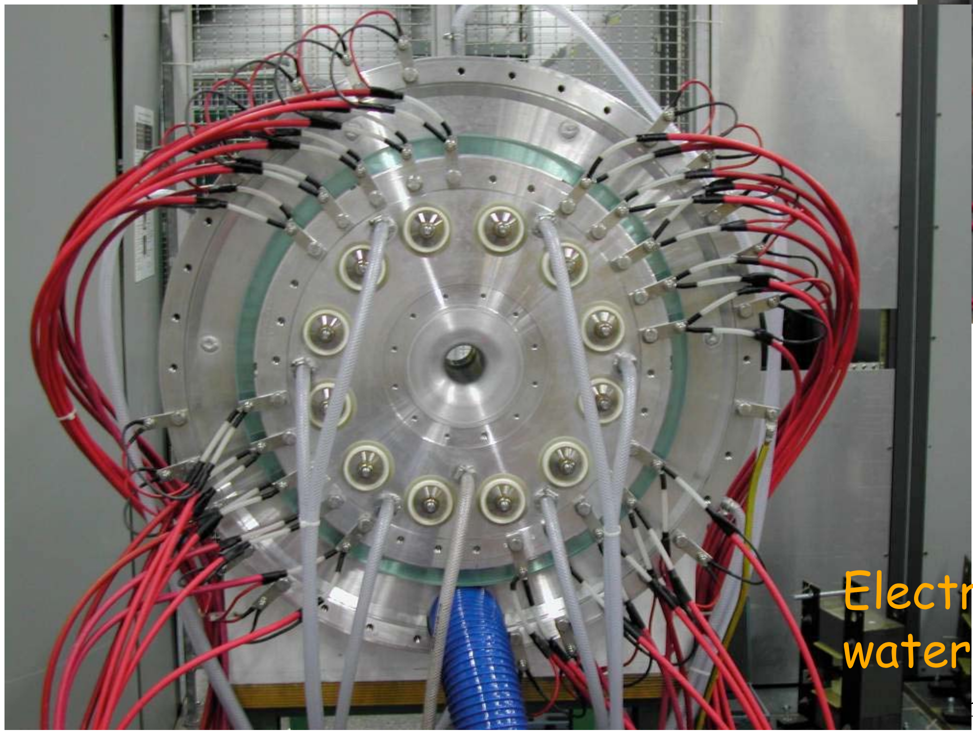
initial design satisfying both, Neutrino Factory and Super-Beam

- http://doc.cern.ch/archive/electronic/cern/preprints/thesis/thesis-2004-046.pdf
- http://newbeams.in2p3.fr/talks/gilardoni.ppt

CERN Horn prototype

- **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

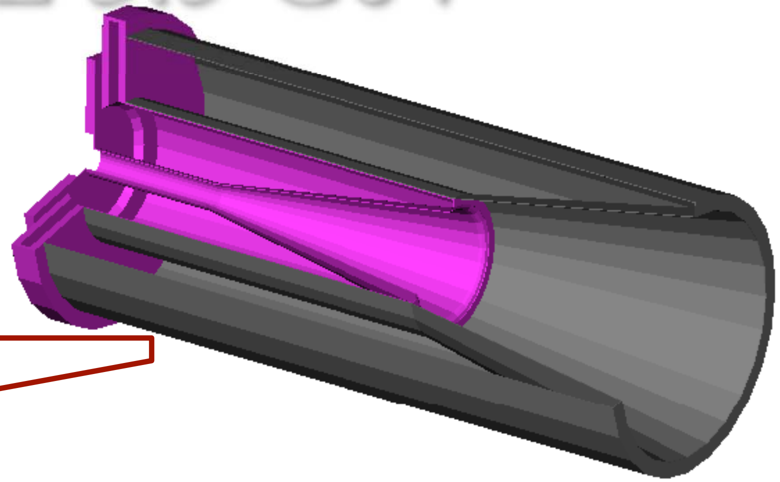


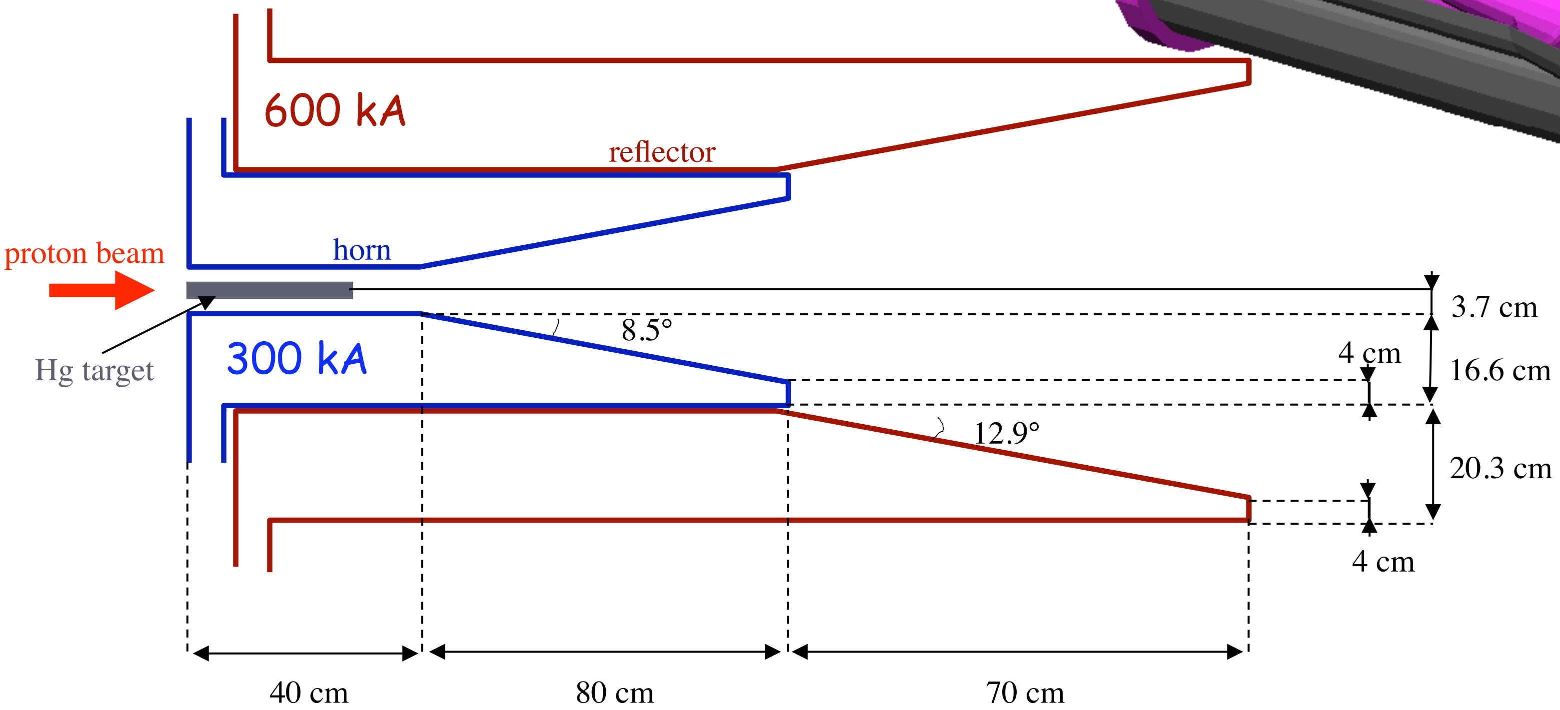


Electrical and water connections

…but Al not compatible with Mercury!

New design for SPL 3.5 GeV





⇨ very high current in reflector inducing severe problems

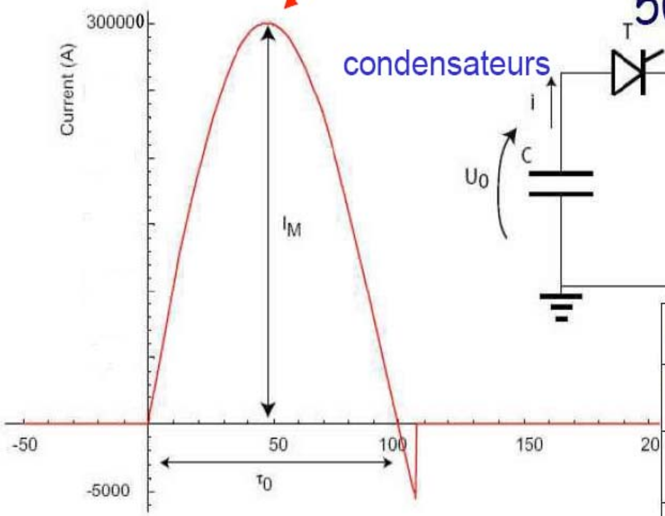
- http://tel.ccsd.cnrs.fr/tel-00008775/en/
- http://slap.web.cern.ch/slap/NuFact/NuFact/nf142.pdf
- http://slap.web.cern.ch/slap/NuFact/NuFact/nf-138.pdf

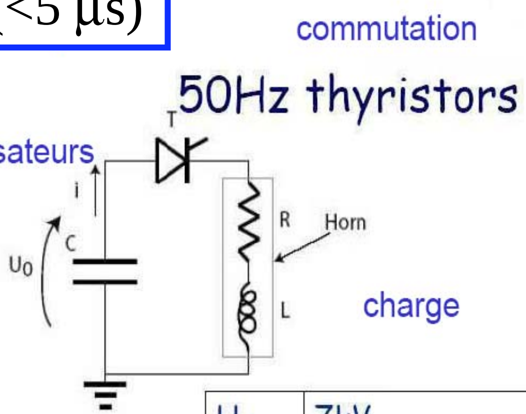
Main Collector Challenges

- 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 (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.

Power Supply for horn pulsing
(major issue)

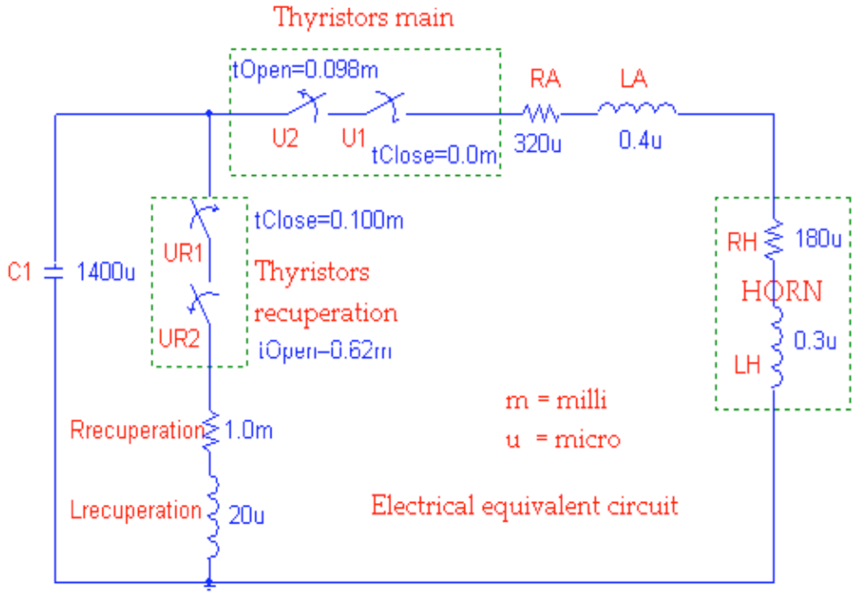
focusing done during this "plateau"
proton pulse duration must be limited (<5 μs)





CNRS/IN2P3 March 2006

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



energy recuperation (>60%) and reinjection

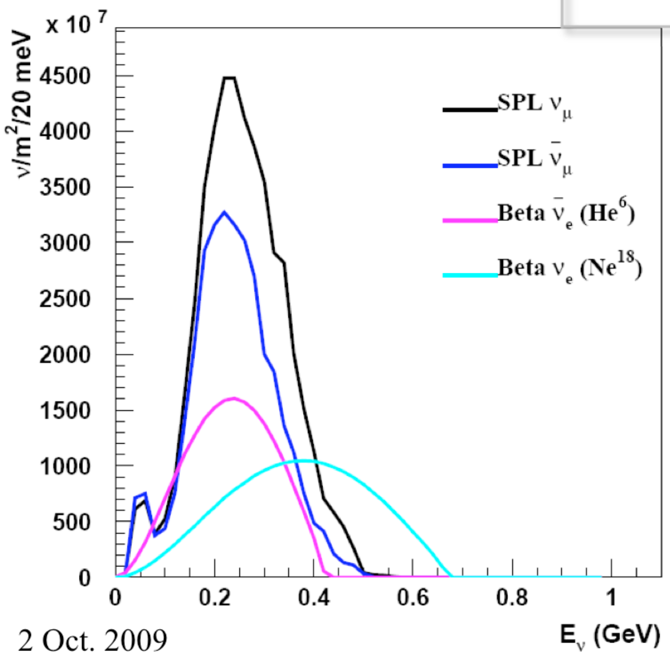
Combination of Super-Beam with Beta-Beam

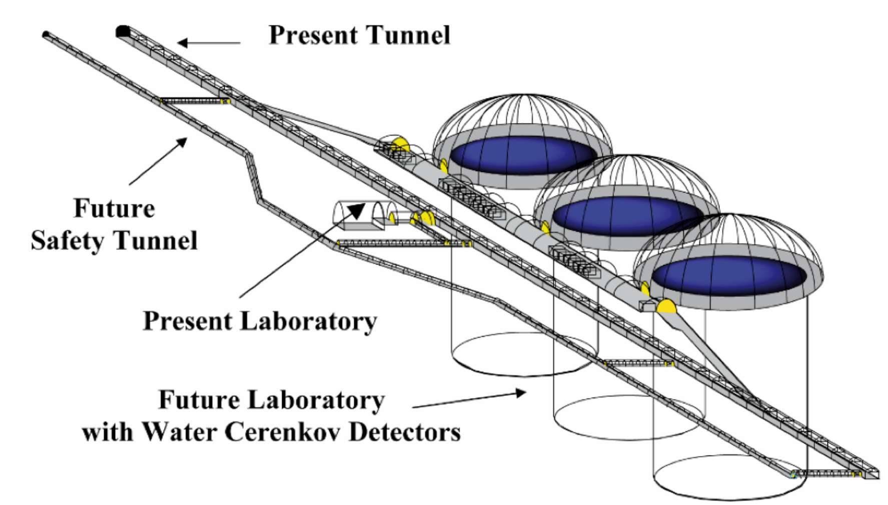
combines CP and T violation tests

2 beams

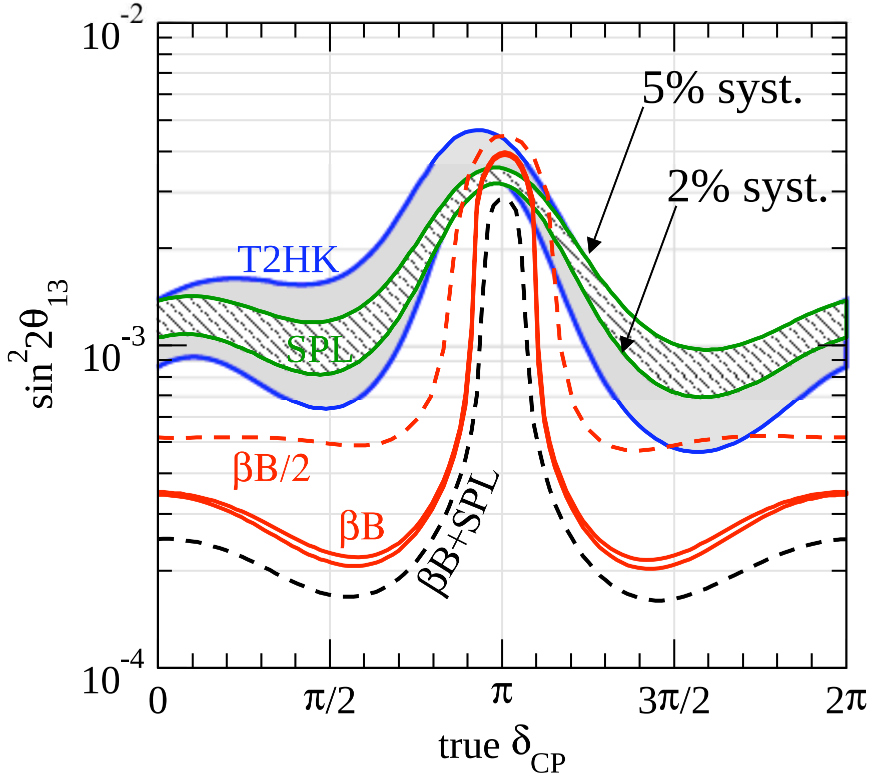
1 detector

Beta-Beam		Super-Beam
$\nu_e \rightarrow \nu_\mu$ ($\beta+$)	(T)	$\nu_\mu \rightarrow \nu_e$ (π^+)
(CP)	(CPT)	(CP)
$\bar{\nu}_e \rightarrow \bar{\nu}_\mu$ ($\beta-$)	(T)	$\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ (π^-)



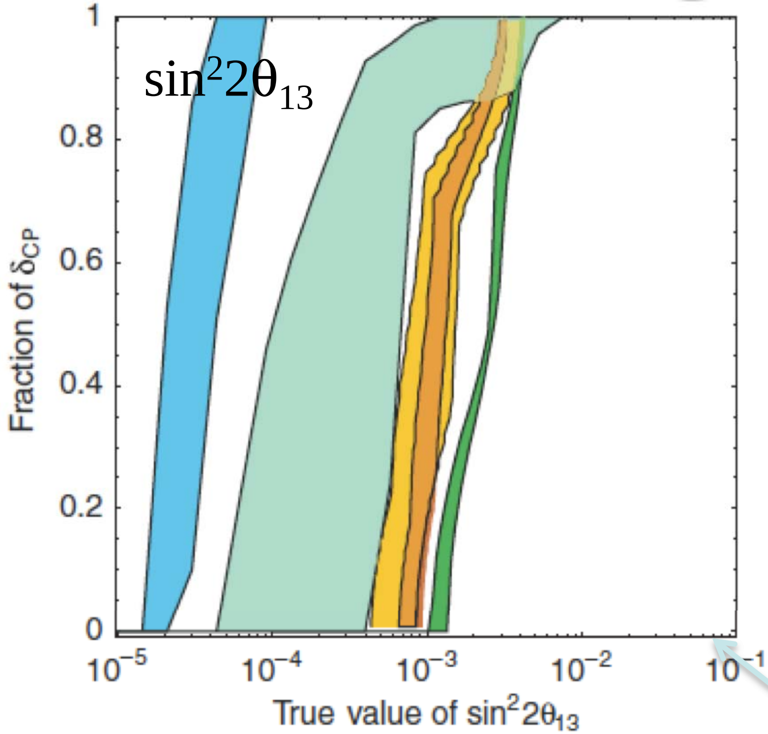


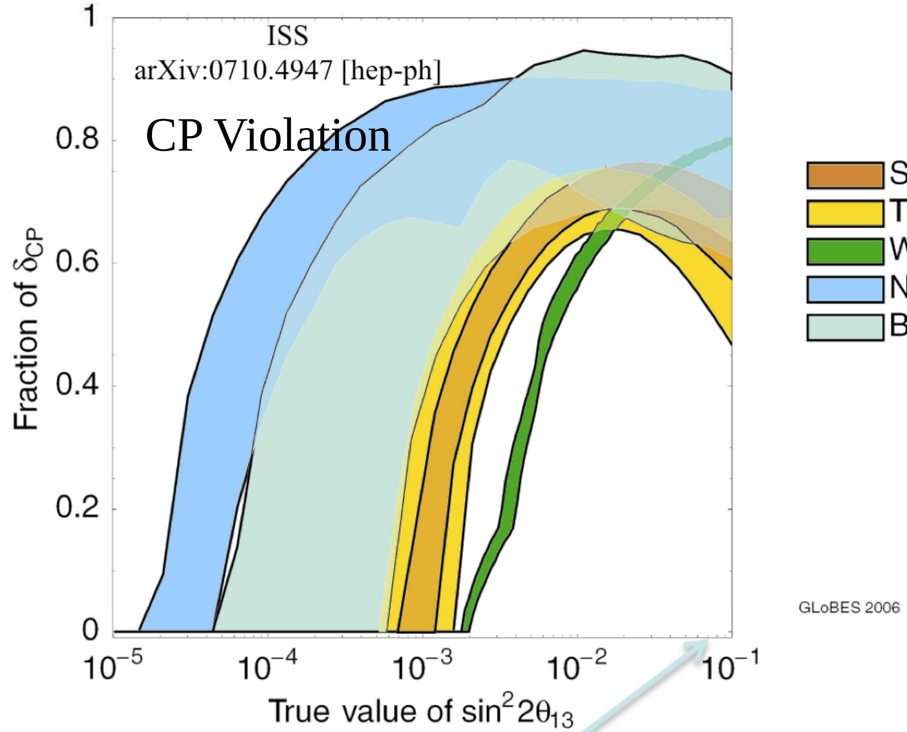
Performance and Comparisons



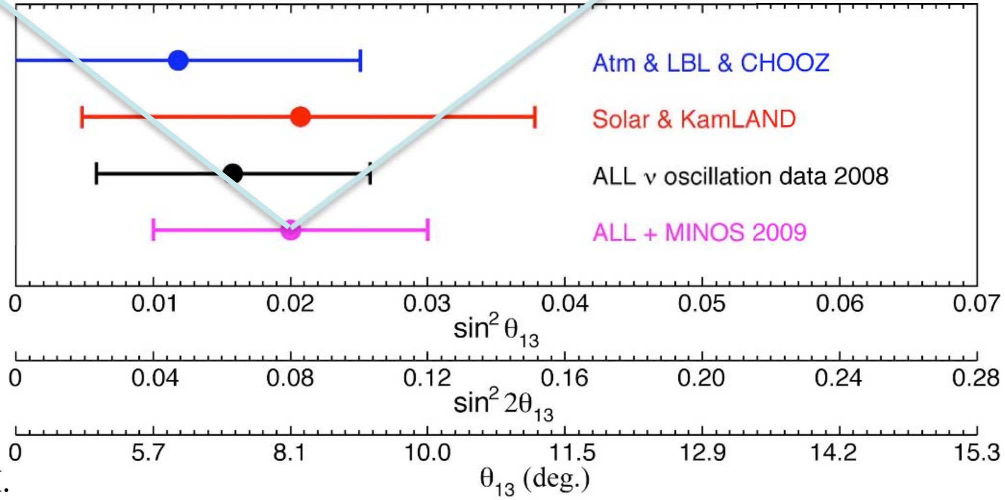
	βB	SPL	T2HK
Detector mass	440 kt	440 kt	440 kt
Baseline	130 km	130 km	295 km
Running time ($\nu + \bar{\nu}$)	5 + 5 yr	2 + 8 yr	2 + 8 yr
Beam intensity	$5.8\,(2.2) \cdot 10^{18}$ He (Ne) dcys/yr	4 MW	4 MW
Systematics on signal	2%	2%	2%
Systematics on backgr.	2%	2%	2%

Sensitivity of future projects





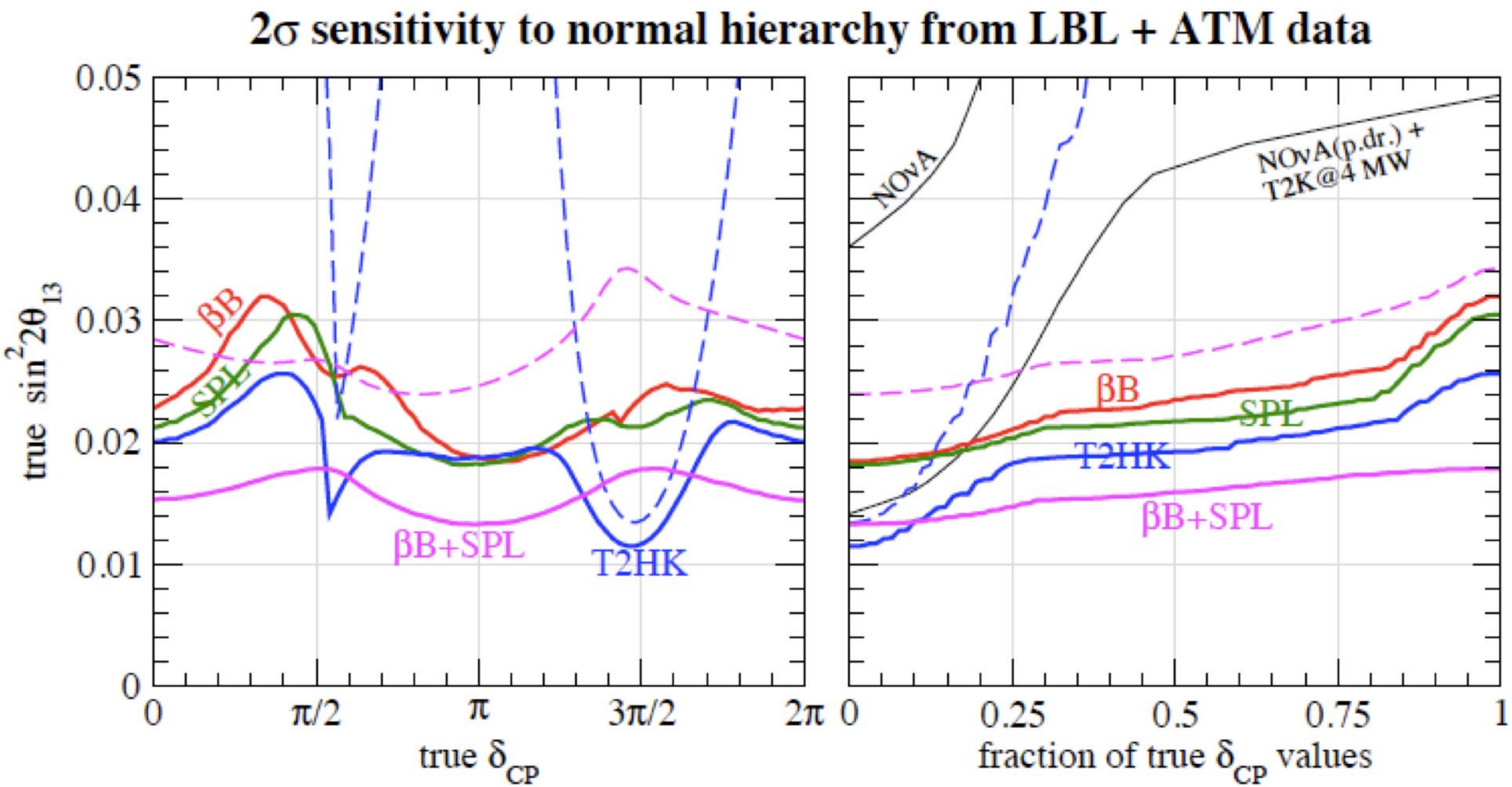
http://www.iop.org/EJ/toc/0034-4885/72/10



Hints (~1σ) for relatively large θ_{13} by combining all results

G. Fogli et al., [*http://arxiv.org/abs/0905.3549*](http://arxiv.org/abs/0905.3549)

Sensitivity to mass Hierarchy?



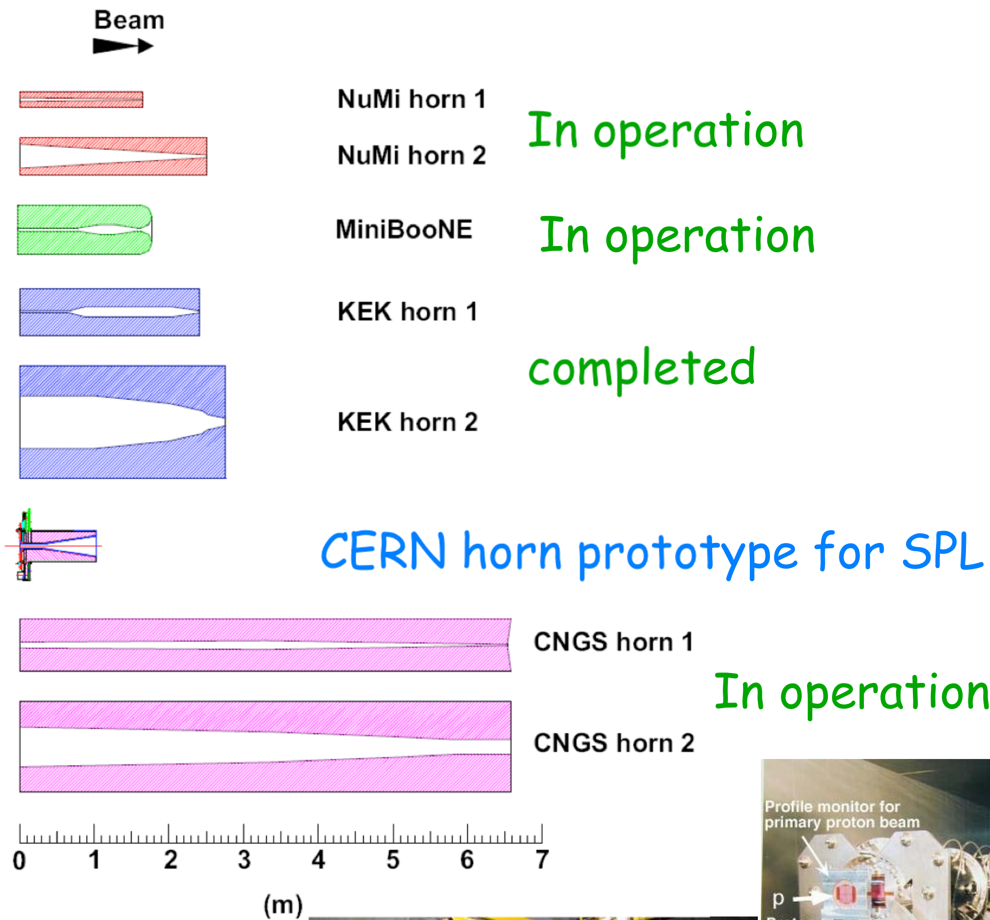
- solid line: LBL+**atm**.
- dashed line: LBL
- BB: 5 ν+5 anti-ν years
- SB: 2 ν+8 anti-ν years

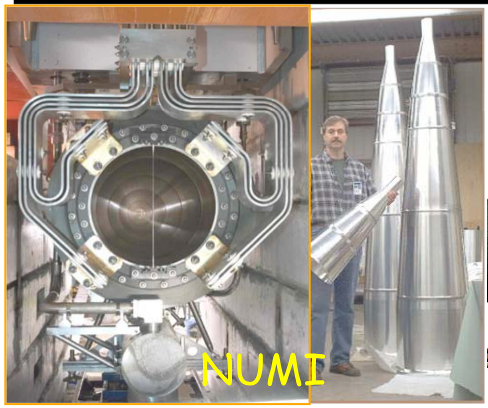
arXiv:hep-ph/0603172v3

(T. Schwetz talk)

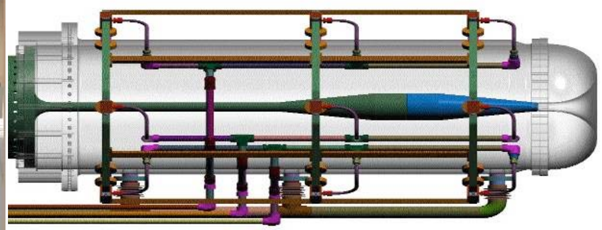
Present Collectors

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





MiniBooNE

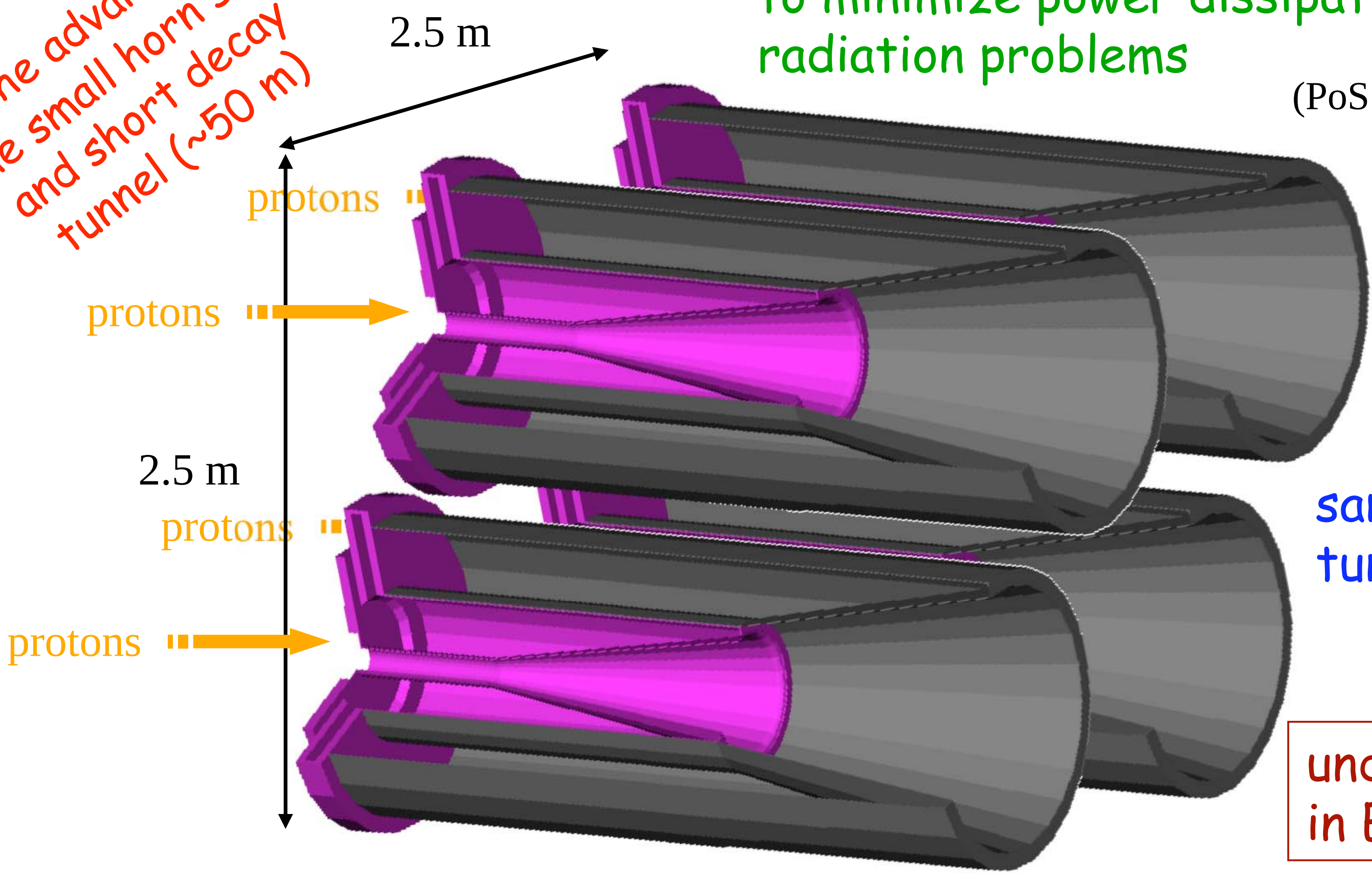


New ideas and studies

use the advantage of the small horn size and short decay tunnel (~50 m)

to minimize power dissipation and radiation problems

(PoS (NuFact08) 076)



same decay tunnel Ø 4 m

under study in EUROν

3 options (only one pulser):

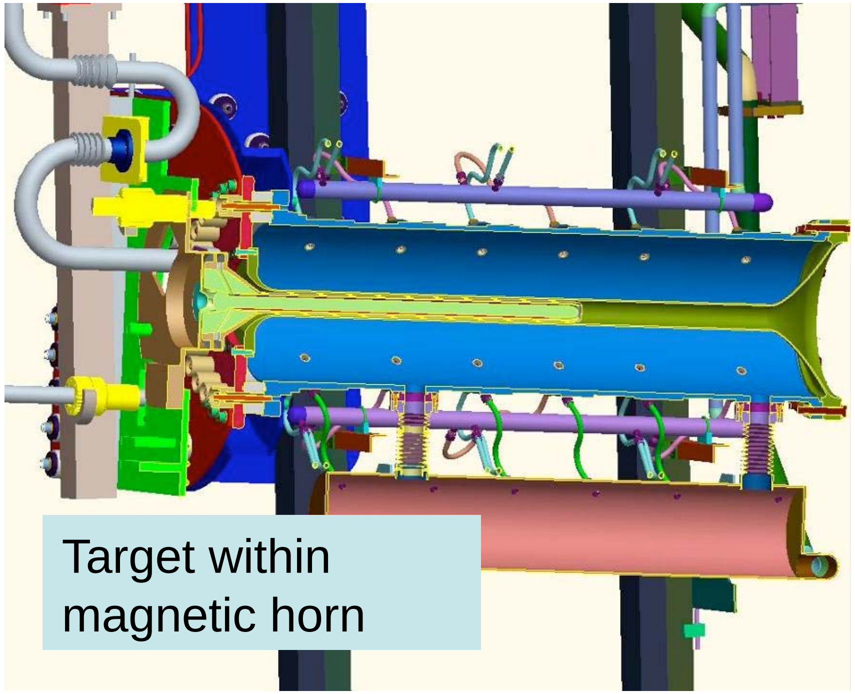
- send at the same time 1 MW per target/horn system
- send 4 MW/system every 50/4 Hz
- change target/horn every Δt (min.?)

→ possibility to use solid target

Solid target studies (experience from T2K)

Work at RAL on T2K target (750 kW) ->
Beam dump designed for 3-4 MW operation
-> Continue studies for 3-4 MW operation e.g. beam window, target limits

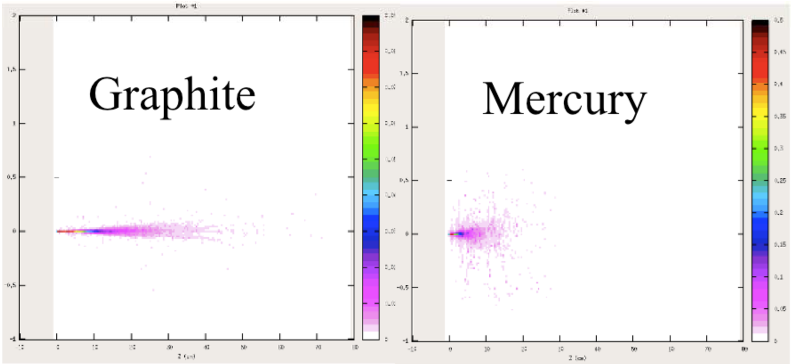
For T2K the Target Station, Decay Volume and Beam Dump are designed and constructed for 4 MW as these cannot be replaced after activation.

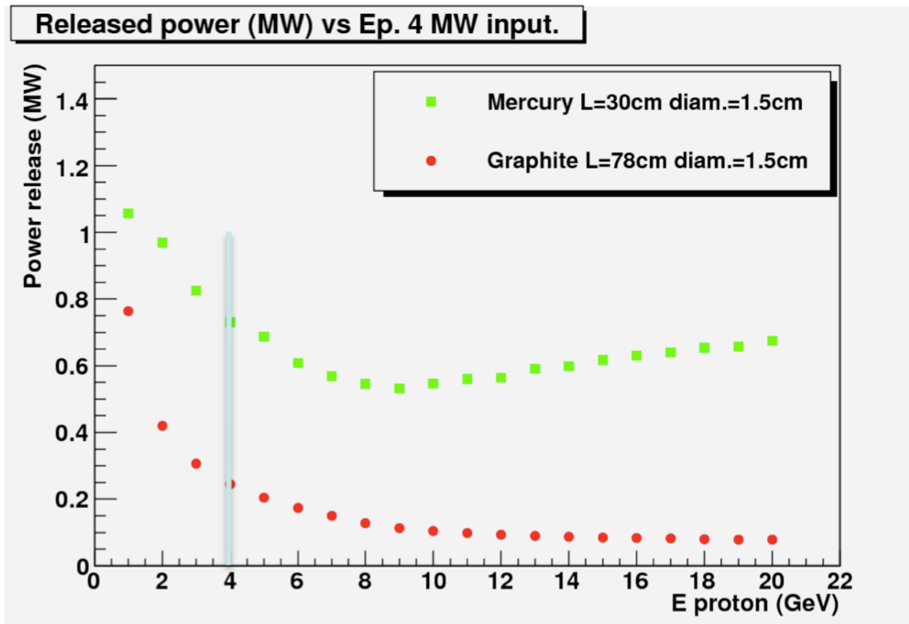


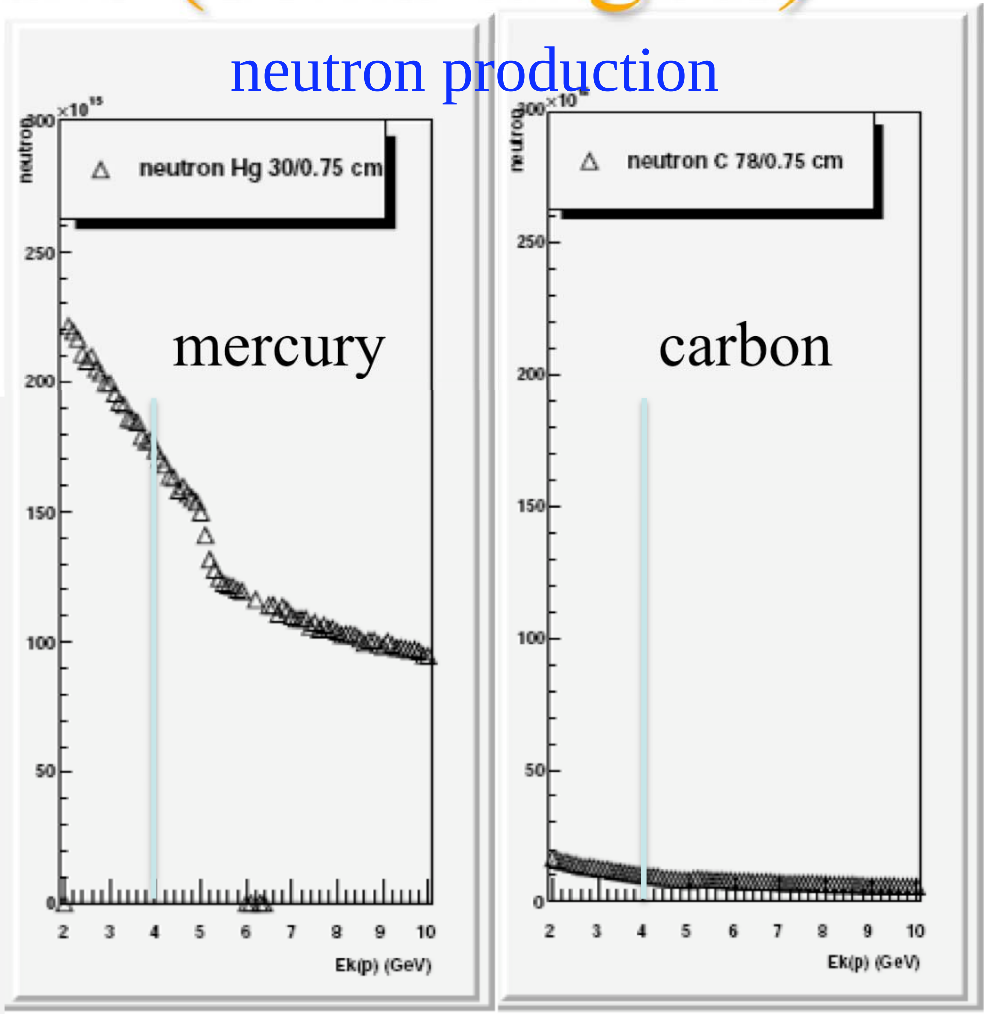
New ideas: Fluidised jet of tungsten or tantalum particles in He

(O. Caretta and Ch. Densham, EUROnu annual meeting CERN March 2009)

Back to the Future (solid targets)



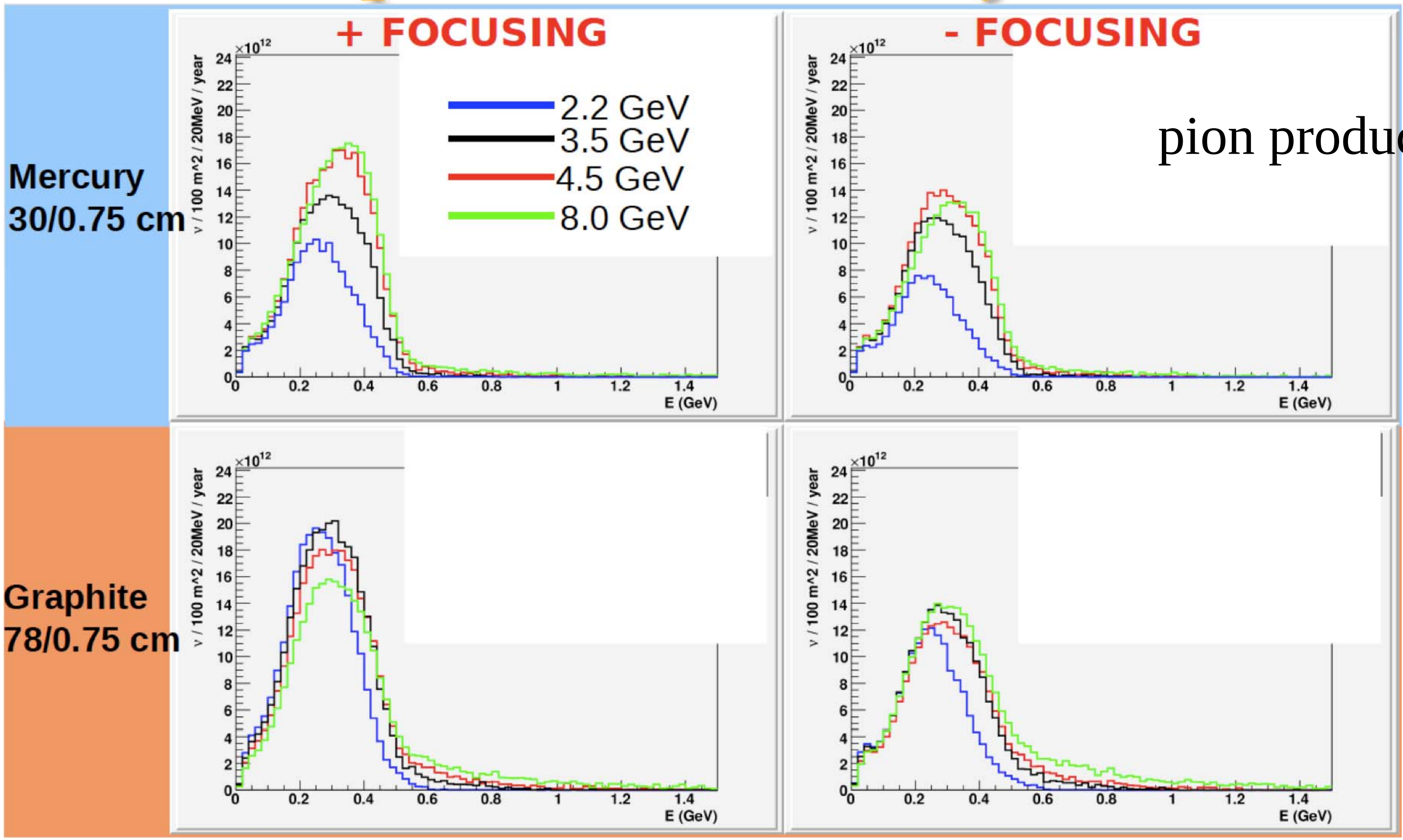




Hg: ~ 1 - 0.6 MW
C : ~ 0.8 - 0.1 MW
considerably lower for Carbon !

n flux dramatically reduced wrt Hg! (~ 15 x)
(A. Longhin, NuFact09
see also poster 7)

Comparison Mercury/Carbon



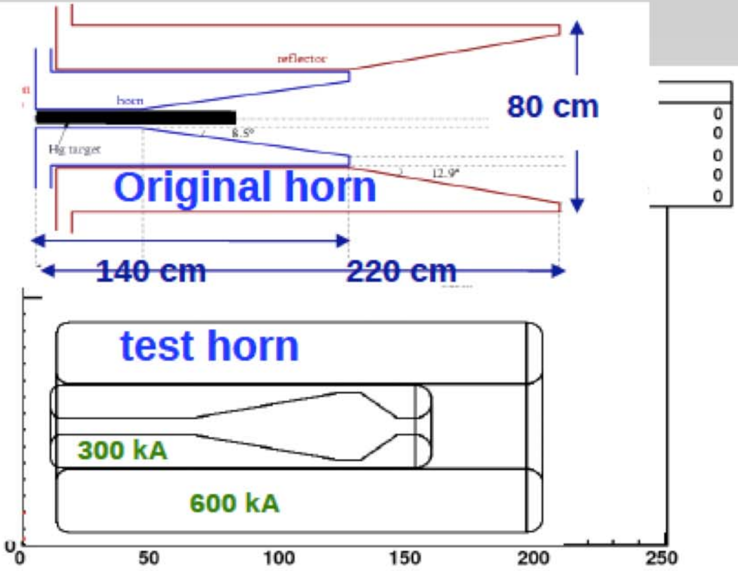
•pion yield trends are reflected in fluxes despite non optimized focusing for long Graphite target
•fluxes intensities are similar
•higher high energy tail for Graphite (not optimized focusing)

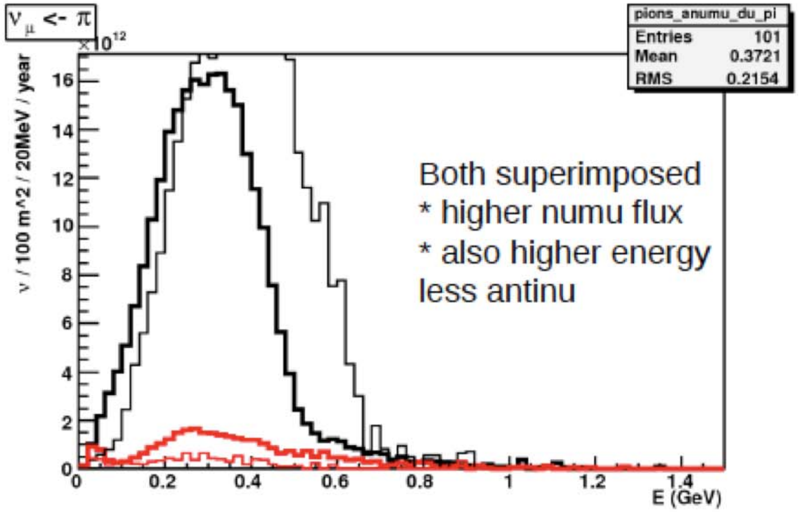
Solid targets and new Horn design

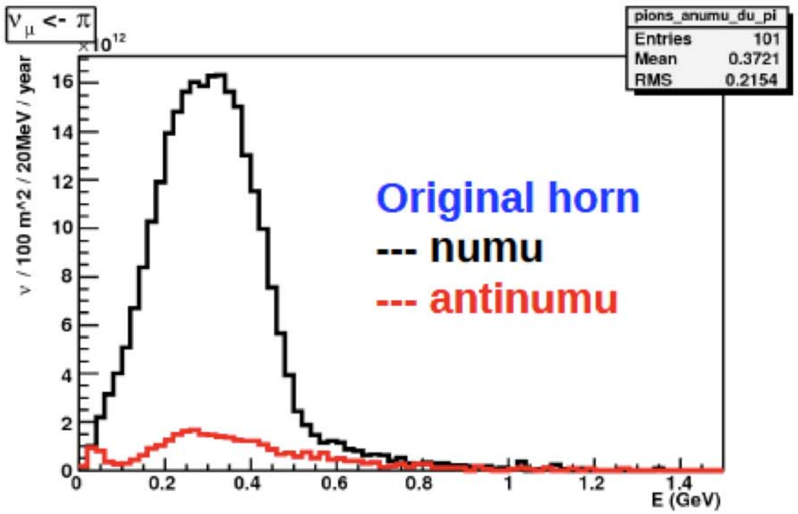
A “promising” configuration

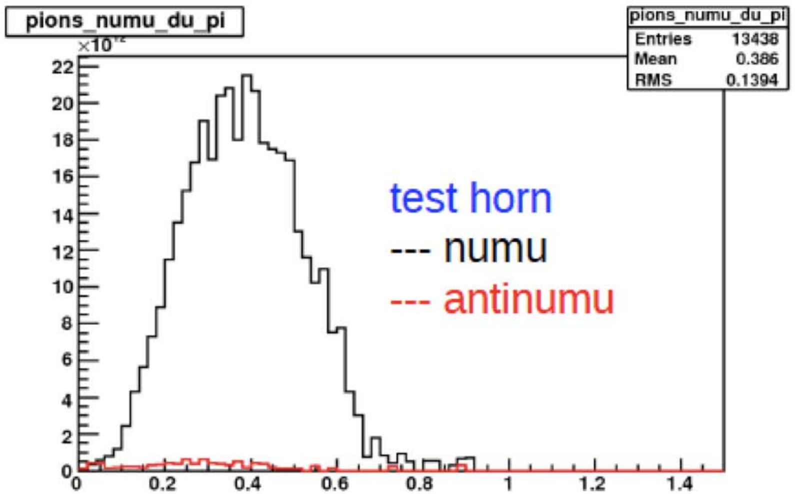
No fine tuning tried
* much less antinumu! -> CPV :)
* higher flux (+10cm for reflector, forward “plug”)
* to be studied at level of sensitivity (in progress)

MiniBoone like horn

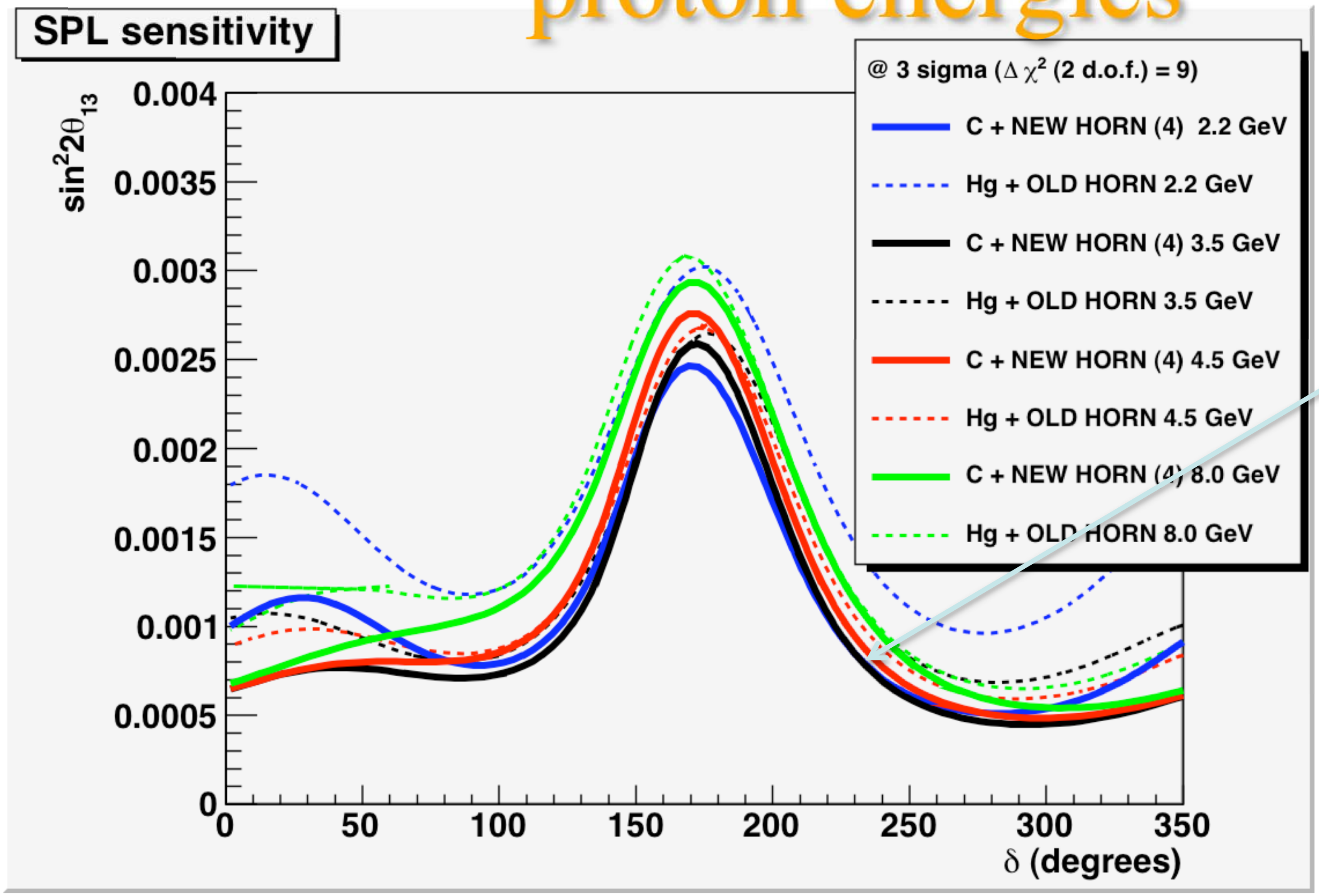








Comparison Hg/C for different proton energies



Carbon, 3.5 GeV seems to be the best (black)

betters results with the new horn geometry

➡ **very promising (work ongoing)**

Conclusions

- Future neutrino beams could greatly profit of installations likely to exist at CERN by 2020.
- The SPL design must include the High Power option.
- HP-SPL can be used as Proton Driver for a CERN Super-Beam.
- The SPL to Fréjus project is under study in FP7 EUROnu:
  - Conventional technology
  - "Short" schedule
  - Cost effective
  - Many synergies with other projects
  - Competitive CP sensitivity down to $\sin^2(2\theta_{13}) \sim 10^{-3}$
- The physics potential of this project is very high (also for astrophysics) especially in case of SB/BB combination.

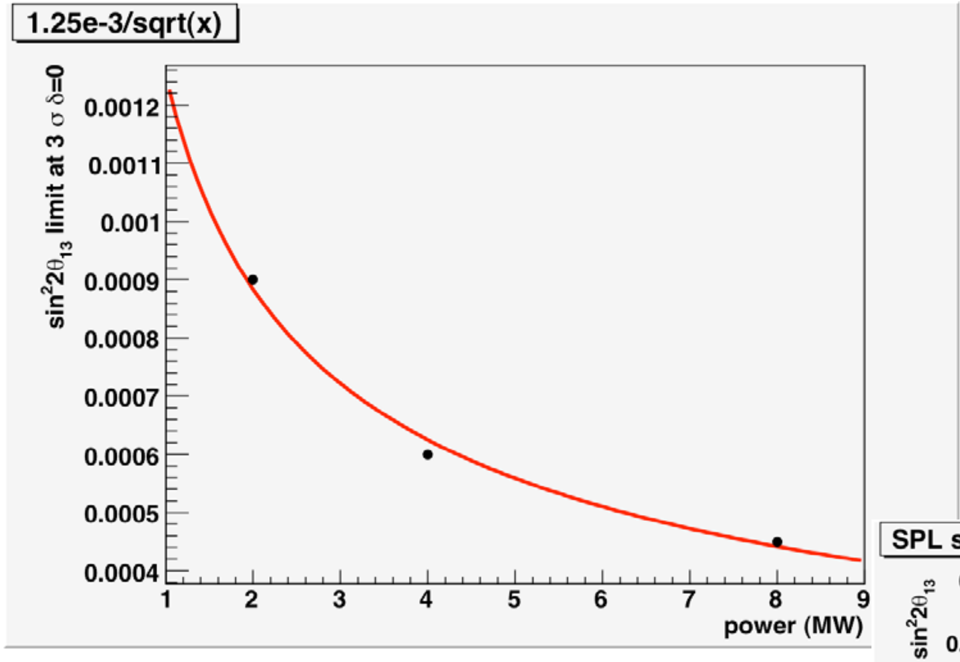
END

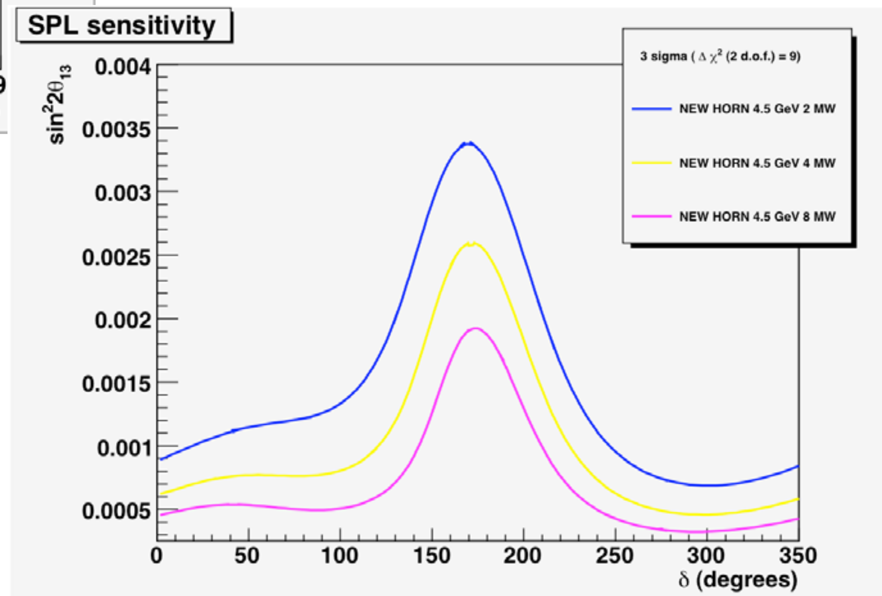
END

What to do:
push (or shout) in the same direction

…and what to avoid

Proton beam power and performance





Flux summary for 2.2/3.5 GeV

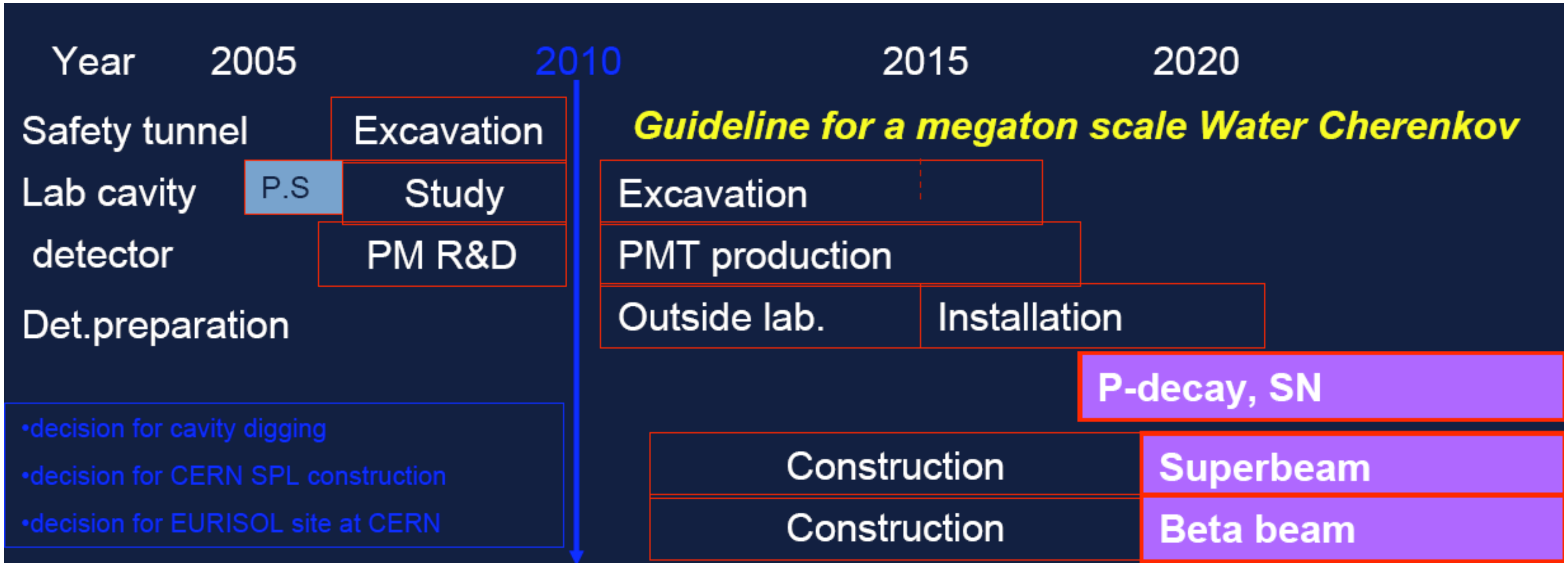
Decay tunnel :20m

	positive focusing		negative focusing	
	Flux ($/100m^2/y$)	Main source	Flux ($/100m^2/y$)	Main source
ν_μ	3.89/7.82 10^{13}	π^+ (99/100%)	0.51/1.42 10^{13}	π^+(99/98%)
$\bar{\nu}_\mu$	3.2/1.10 10^{12}	π^- (99/99%)	2.93/6.65 10^{13}	π^- (99/99.5%)
ν_e	1.77/4.07 10^{11}	$\pi^+ \to \mu^+$(80/84%)	0.29/1.19 10^{11}	$\pi^+ \to \mu^+$(38/20%); K^+ (37/50%) ;K^0 (25/30%)
$\bar{\nu}_e$	1.24/5.34 10^{10}	K^0 (55/70%); $\pi^- \to \mu^-$ (45/30%)	0.81/1.87 10^{11}	$\pi^- \to \mu^-$(90/80%)

Decay tunnel :80m

ν_μ	4.21/8.32 10^{13} (+8/+6%)	π^+ (99/99%)	0.51/1.56 10^{13} (-0.4/+10%)	π^- (99/98%)
$\bar{\nu}_\mu$	3.38/1.19 10^{12} (+6/+8%)	π^- (99/98%)	3.18/7.03 10^{13} (+8.5/+6%)	π^+ (100/100%)
ν_e	2.66/5.60 10^{11} (+50/+38%)	$\pi^+ \to \mu^+$(90/89%)	0.31/1.30 10^{11} (+8.5/+9%)	$\pi^+ \to \mu^+$(40/25%) K^+ (35/45%) ;K^0 (25/30%)
$\bar{\nu}_e$	1.42/5.93 10^{10} (+14.5/+11%)	K^0 (50/60%) $\pi^- \to \mu^-$(50/40%)	1.14/2.59 10^{11} (+40/38.5%)	$\pi^- \to \mu^-$(95/85%)

Far Detector possible schedule



A possible timeline
2010 decisions for cavity excavation, SPL and Eurisol

Far Detector

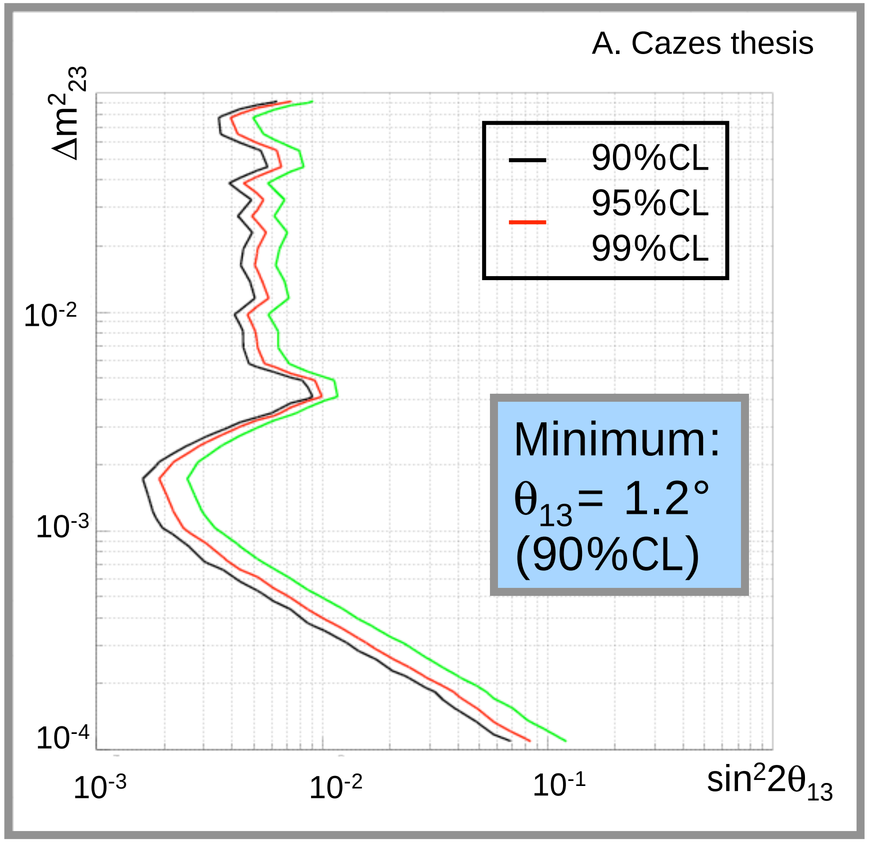
Summary of WC in the world (LAL-06-22)

	UNO (USA)	HK (Japon)	MEMPHYS (EU)
Laboratory			
location	Henderson/Homestake	Tochibora	Fréjus
prof. Mwe	4500/4800	1500	4800
LBL(km)	1480÷2760/1280÷2530	290	130
Dimsensions			
type	3 cubes	2 tunnels de 5 compartments	3 to 5 shafts
dimension	60x60x60m^3	ϕ:43m x L:50m	ϕ:65m x L:65m
M fid. Kt	440	550	440 à 730
Photodetectors			
type	20" PMT	20" H(A)PD	12" PMT
#	38000 (middle) 2 x 9500 (side)	20,000 per compartiment	81,000 per shaft
Couverage	40%/10% (middle/side)	40%	30%
Estimate Cost 50% excavation + 50% Photodetection			
	500M$	500 Oku ¥	161M€ x #shafts +100M€ infra.

θ_{13} Sensitivity (SPL 3.5 GeV)

simulation inputs

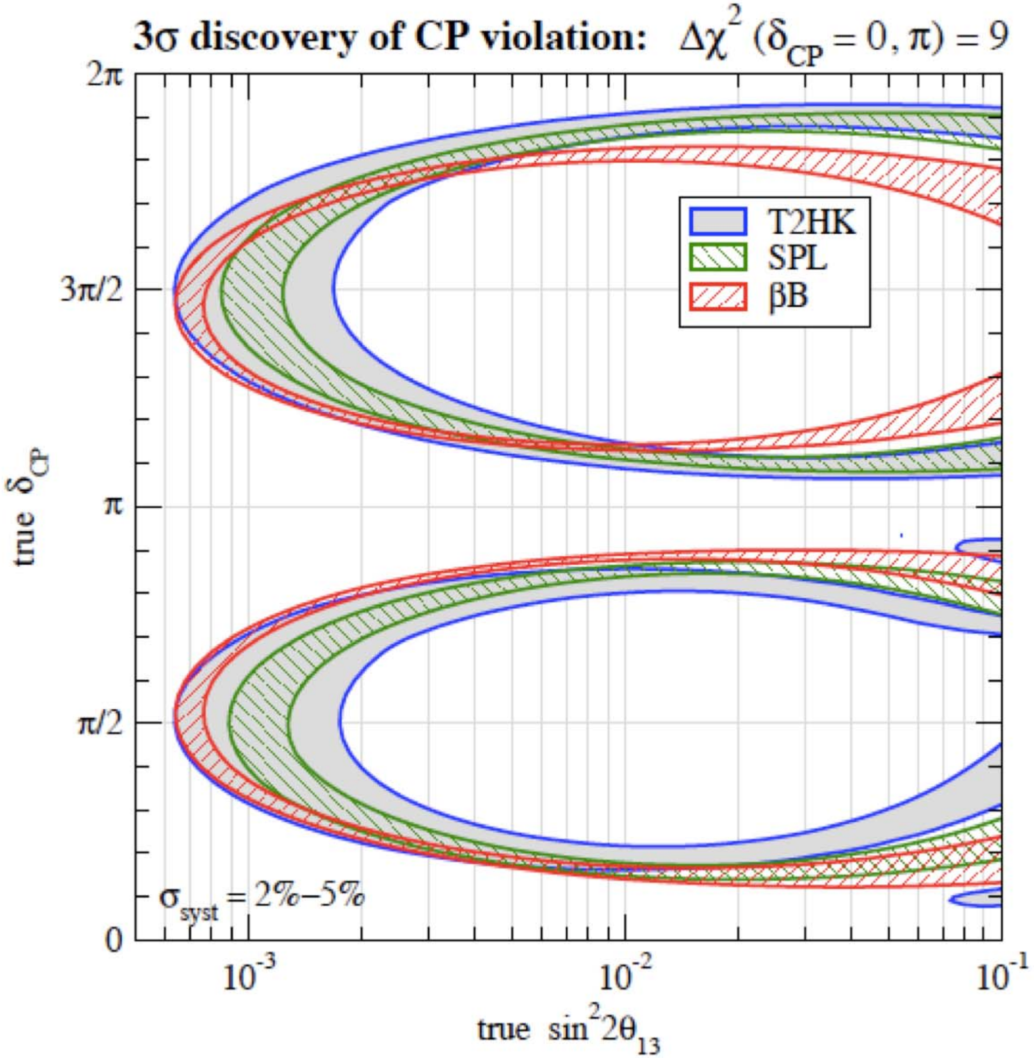
- Detector:
  - Water Cerenkov
  - 440 kt
  - at Fréjus (130 km from CERN)
- Run:
  - 2 years with positive focusing.
  - 8 years with negative focusing.
- Computed with δ_{CP}=0 (standard benchmark) and θ_{13} = 0
- parameter…
  - $\Delta m_{23} = 2.5\ 10^{-3}\ eV^2$
  - $\Delta m_{12} = 7.1\ 10^{-5}\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



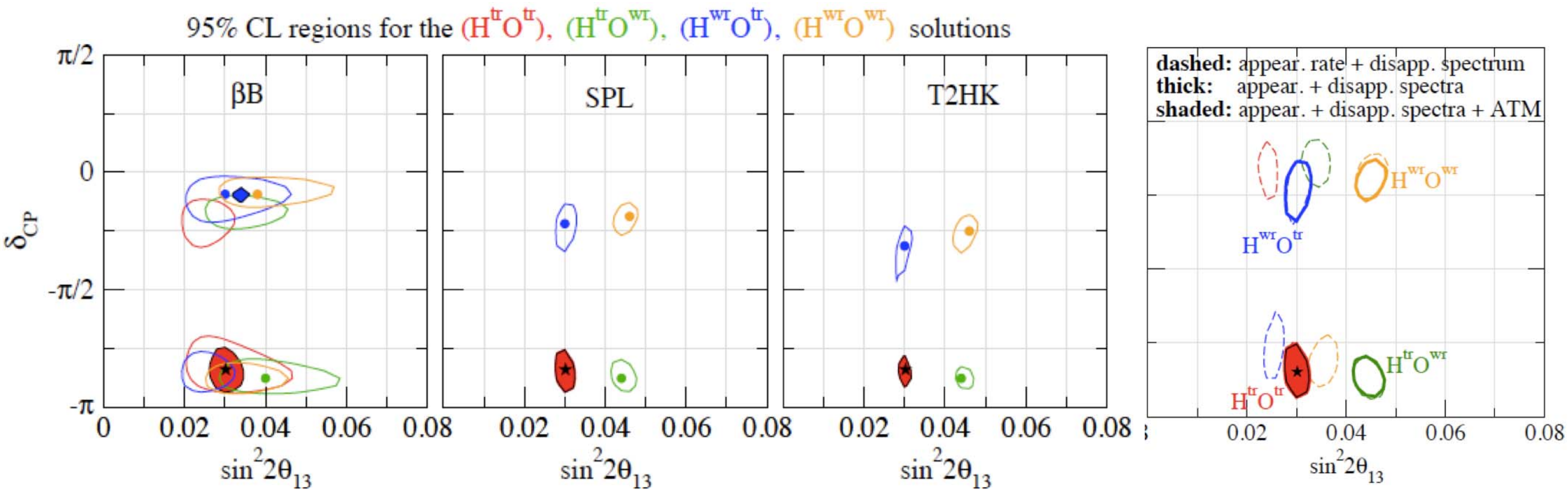
no strong dependence on proton energy for 2.2<p<5 GeV

Sensitivity to LCPV

$(2\nu + 8\bar{\nu})$ yrs for SBs, 5+5 for βB. Curves drawn for 2% and 5% systematic errors.



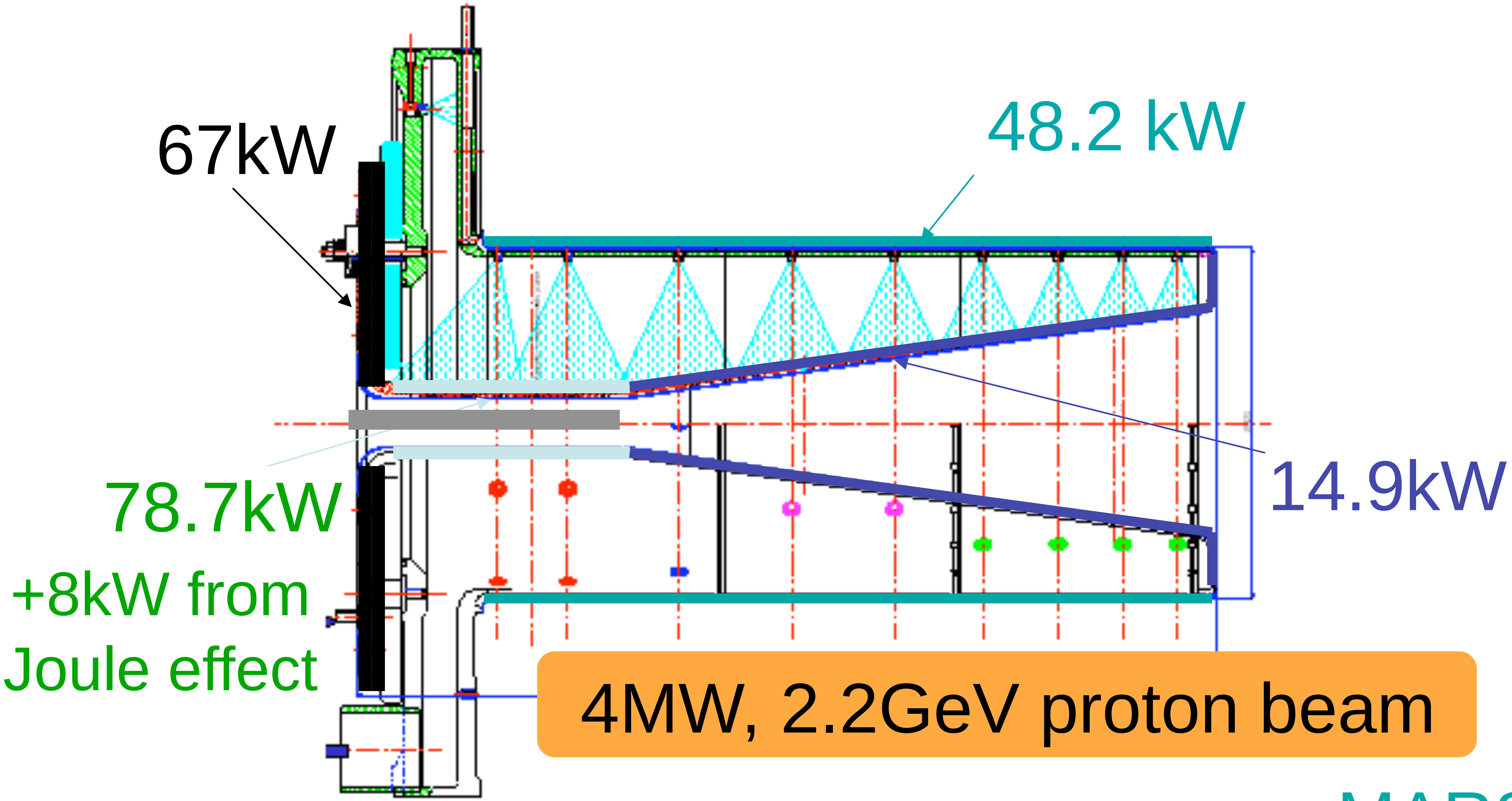
Degeneracies



arXiv:hep-ph/0603172v3

Figure 5: Allowed regions in $\sin^2 2\theta_{13}$ and δ_{CP} for LBL data alone (contour lines) and LBL+ATM data combined (colored regions). $H^{tr/wr}(O^{tr/wr})$ refers to solutions with the true/wrong mass hierarchy (octant of θ_{23}). The true parameter values are $\delta_{CP} = -0.85\pi$, $\sin^2 2\theta_{13} = 0.03$, $\sin^2 \theta_{23} = 0.6$, and the values from Eq. (1) for the other parameters. The running time is $(5\nu + 5\bar{\nu})$ yrs for βB and $(2\nu + 8\bar{\nu})$ yrs for the Super Beams.

Energy deposition in the conductors

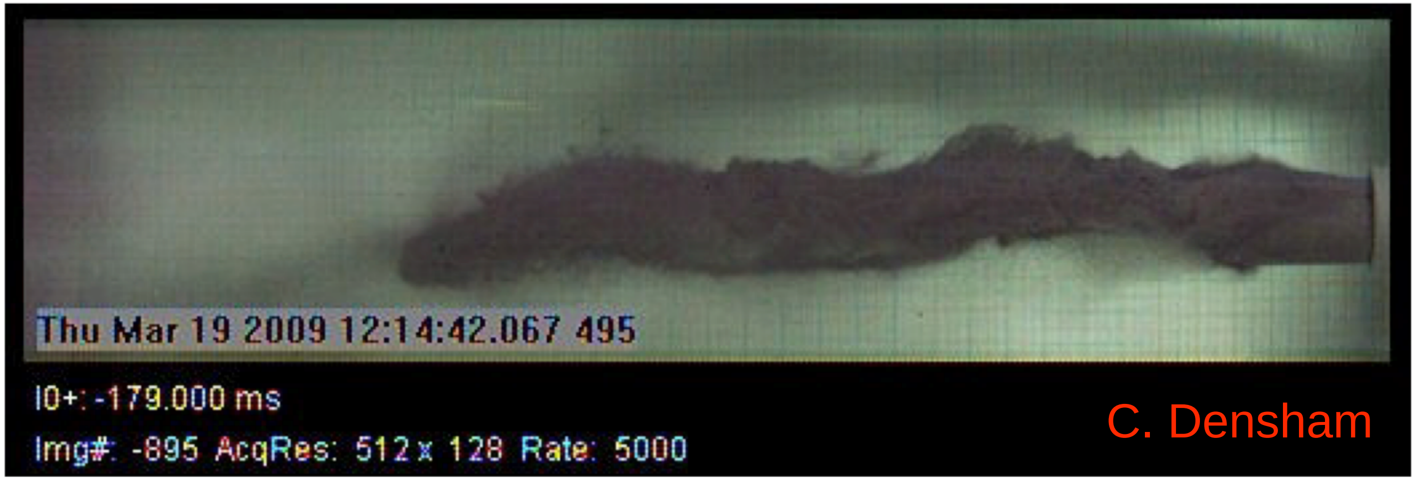


- MARS

Proton Target studies

A new Nufact/Super-Beam target concept being studied at RAL: fluidised jet of particles

(O. Caretta and Ch. Densham, EUROnu annual meeting CERN March 2009)



- Fluidised jet of tungsten or tantalum particles in He could be used as a target
  - Combines the advantages of the solid target with those of the liquid target
  - Shock waves constrained within the material (no cavitation, no splashing)
  - Highly effective cooling of the target material
  - Target easily replenished and reasonably safely contained
    BUT: Is it technically feasible? - Study needed