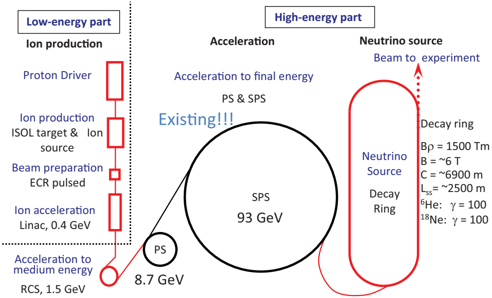
Mauro Mezzetto
Istituto Nazionale di Fisica Nucleare, Sezione di Padova

““Future Experiments (II): Beta Beams"



- General principles of a Beta Beam
- Strategies for a Beta Beam experiment
- Sensitivities
- Future options

Some slides borrowed by E. Wildner (CERN) presentation at Neutrino Telescopes 2011

The Beta Beam Facility Collaborations

FP6 “Research Infrastructure Action - Structuring the European Research Area” EURISOL DS Project Contract no. 515768 RIDS)

Ended 2008

http://beta-beam.web.cern.ch/beta-beam/task/index.asp

FP7 “Design Studies” (Research Infrastructures) EUROnu (Grant agreement no.: 212372)

Ongoing work from 2008

Lasts until 2012

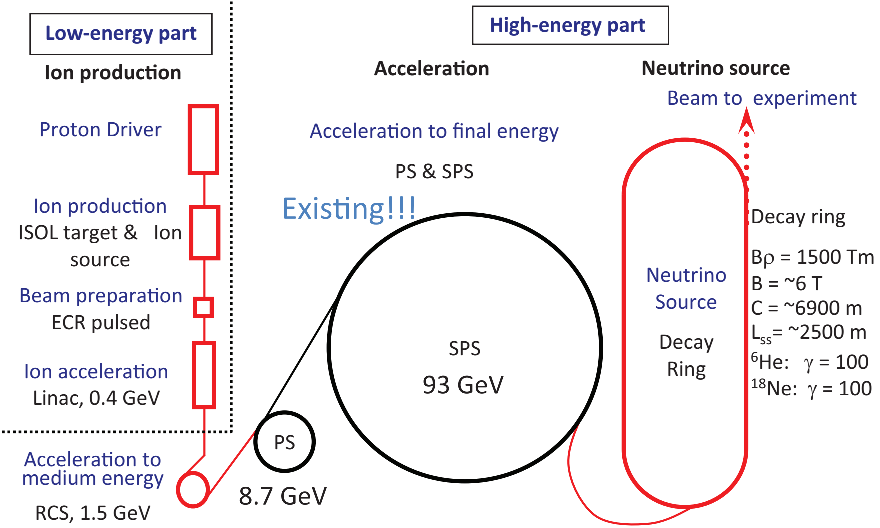
http://heplnv135.pp.rl.ac.uk/joomla/index.php?option=com_content&view=category&id=9&Itemid=12

http://heplnv135.pp.rl.ac.uk/joomla/

Contribution to the development of a beta beam facility is now going on mainly within EUROnu

Beta Beam (P. Zucchelli: Phys. Lett. B532:166, 2002)

M. Lindroos M. Mezzetto, "Beta Beams", Imperial College Press, 2009



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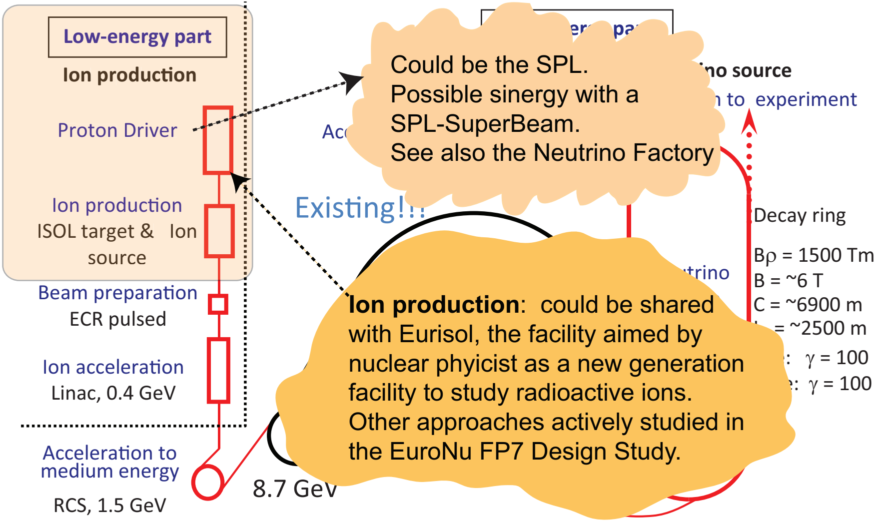

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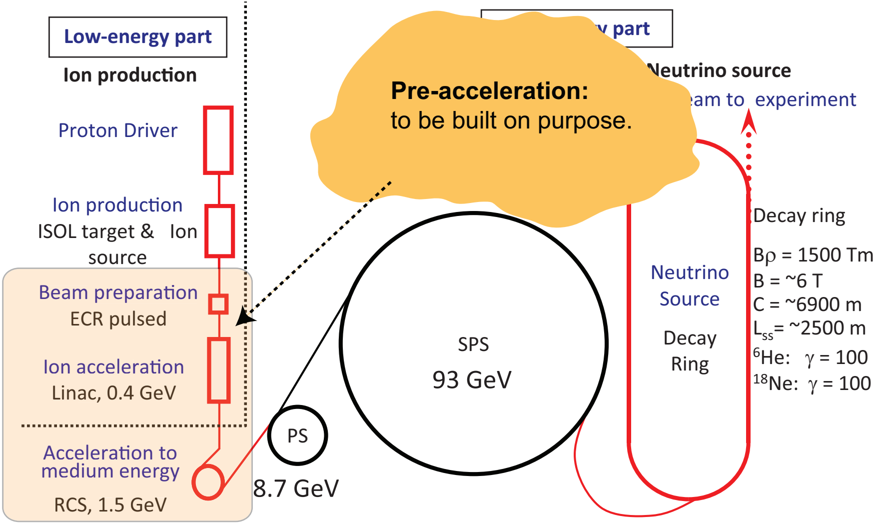

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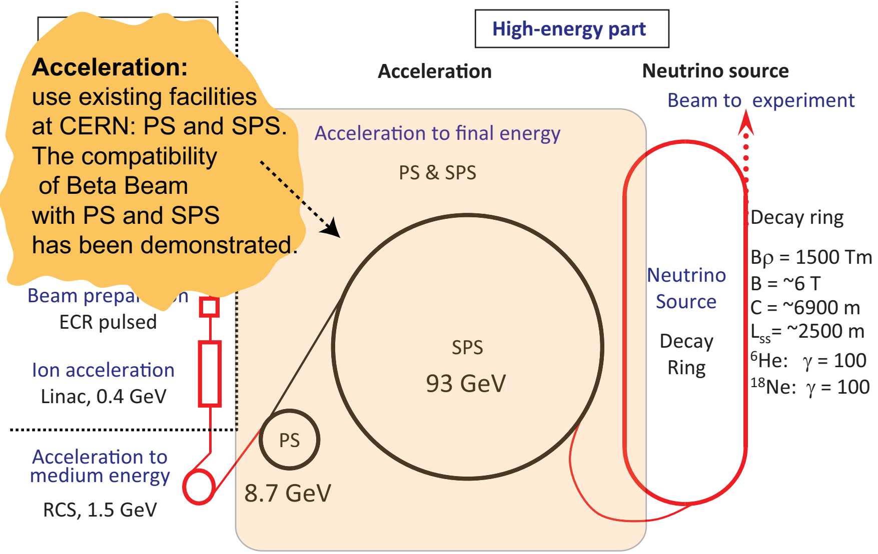

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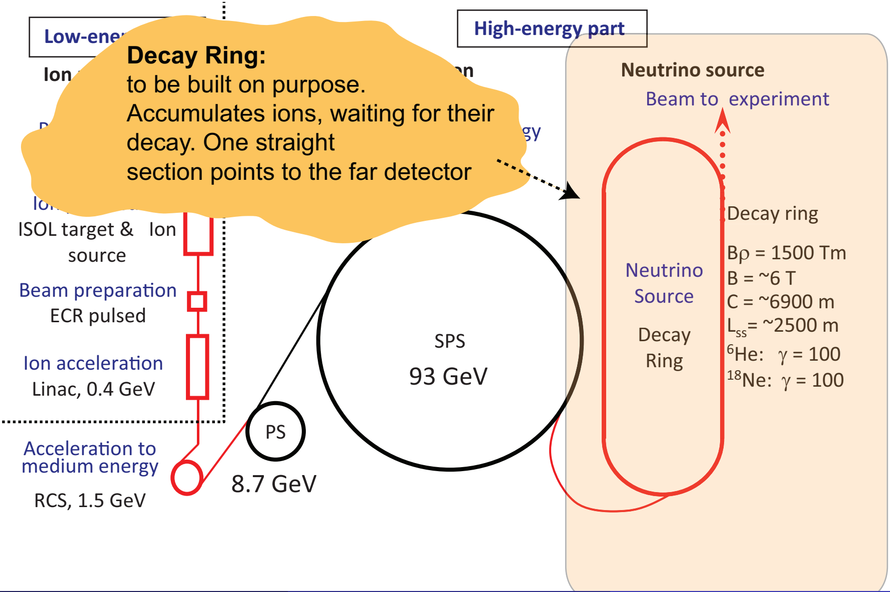

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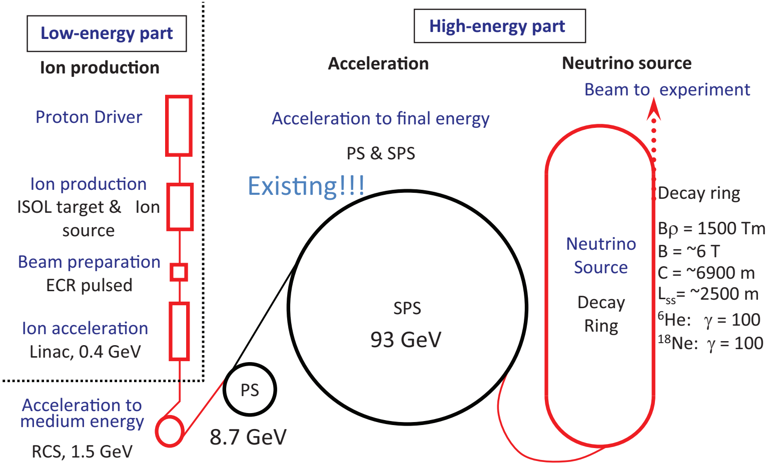
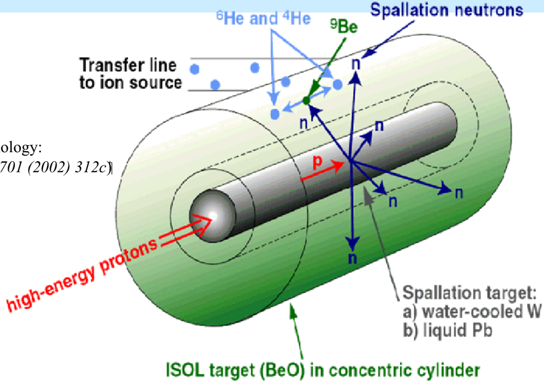


- $\overline{\nu}_e$ generated by He^6, 100 μA, $\Rightarrow 2.9 \cdot 10^{18}$ ion decays/straight session/year.
- ν_e generated by Ne^{18}, 100 μA, $\Rightarrow 1.1 \cdot 10^{18}$ ion decays/straight session/year.

^{6}He production from ^{9}Be(n,α)



Converter technology:
(*J. Nolen, NPA 701 (2002) 312c*)

- **Converter technology preferred to direct irradiation (heat transfer and efficient cooling allows higher power compared to insulating BeO).**
- **^{6}He production rate is ~2x10^{13} ions/s (dc) for ~200 kW on target.**

Beta-beam team

Isotope production rates

Aim: 2.0 10^{13} for low-Q

Targets below MWatt is preferred !!!

Type	Accelerator	Beam	I_{beam} mA	E_{beam} MeV	P_{beam} kW	Target	Isotope	Flux s^{-1}	Ok?
ISOL & n-converter	SPL	p	0.1	2 10^3	200	W/BeO	6He	5 10^{13}	
ISOL & n-converter	Saraf/GANIL	d	15	40	600	C/BeO	6He	5 10^{13}	
ISOL	Linac 4	p	6	160	700	19F Molten NaF loop	18Ne	1 10^{13}	
ISOL	Cyclo/Linac	p	10	70	700	19F Molten NaF loop	18Ne	2 10^{13}	
ISOL	LinacX1	3He	> 170	21	3600	MgO 80 cm disk	18Ne	2 10^{13}	
P-Ring	LinacX2	d	0.160	25	4	7Li	8Li	3 10^{13}	
P-Ring	LinacX2	3He	0.160	25	4	6Li	8B	8 10^{11}	

Need experiments

Experimentally OK

On paper, may be OK

Not OK yet

T. Stora, P Valko, E. Benedetto, E. Wildner…

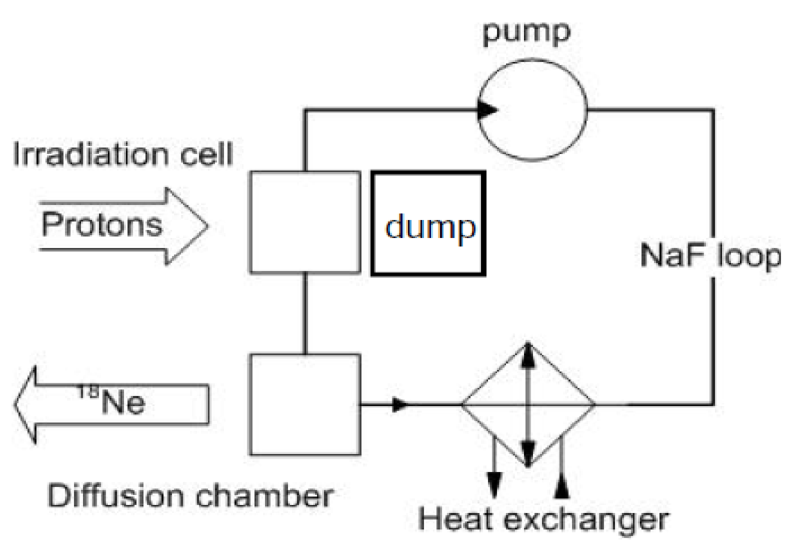
Experiments ^{18}Ne for Beta Beams

- Measure production and release from a sodium target at ISOLDE
  - Proposal sent to INTC (ISOLDE and Neutron Time-of-flight Committee)
  - Accepted !!
- Molten salt loop to produce 18Ne !
  - Experimental setup and measurements, from May 2011

The ν_e beam needs production of 2.0 10^{13} ^{18}Ne/s

Theoretically possible with 10 mA 70 MeV protons on NaF

We need measurements of the crossection ^{19}F(p, 2n)^{18}Ne !



T. Stora, P. Valko

Possible β^- emitters ($\bar{\nu}_e$)

Isotope	Z	A	A/Z	$T_{1/2}$	$Q_{\beta\ (gs>gs)}$	$Q_{\beta\ eff.}$	$E_{\beta\ av.}$	$E_{\nu\ av.}$	<E_LAB> (MeV)
				s	MeV	MeV	MeV	MeV	(@ 450 GeV/p)
6He	2	6	3.0	0.807	3.5	3.5	1.57	1.94	582
8He	2	8	4.0	0.119	10.7	9.1	4.35	4.80	1079
8Li	3	8	2.7	0.838	16.0	13.0	6.24	6.72	2268
9Li	3	9	3.0	0.178	13.6	11.9	5.73	6.20	1860
11Be	4	11	2.8	13.81	11.5	9.8	4.65	5.11	1671
15C	6	15	2.5	2.449	9.8	6.4	2.87	3.55	1279
16C	6	16	2.7	0.747	8.0	4.5	2.05	2.46	830
16N	7	16	2.3	7.13	10.4	5.9	4.59	1.33	525
17N	7	17	2.4	4.173	8.7	3.8	1.71	2.10	779
18N	7	18	2.6	0.624	13.9	8.0	5.33	2.67	933
23Ne	10	23	2.3	37.24	4.4	4.2	1.90	2.31	904
25Ne	10	25	2.5	0.602	7.3	6.9	3.18	3.73	1344
25Na	11	25	2.3	59.1	3.8	3.4	1.51	1.90	750
26Na	11	26	2.4	1.072	9.3	7.2	3.34	3.81	1450

From P..Zucchelli talk at Nufact 03. Table compiled by U. Koster

Possible β^+ emitters (ν_e)

Isotope	Z	A	A/Z	$T_{1/2}$	Q_{β} (gs>gs)	Q_{β} eff.	E_{β} av.	E_{ν} av.	<E_LAB> (MeV)
				s	MeV	MeV	MeV	MeV	(@450 GeV/p)
8B	5	8	1.6	0.77	17.0	13.9	6.55	7.37	4145
10C	6	10	1.7	19.3	2.6	1.9	0.81	1.08	585
14O	8	14	1.8	70.6	4.1	1.8	0.78	1.05	538
15O	8	15	1.9	122.2	1.7	1.7	0.74	1.00	479
18Ne	10	18	1.8	1.67	3.4	3.4	1.50	1.86	930
19Ne	10	19	1.9	17.34	2.2	2.2	0.96	1.25	594
21Na	11	21	1.9	22.49	2.5	2.5	1.10	1.41	662
33Ar	18	33	1.8	0.173	10.6	8.2	3.97	4.19	2058
34Ar	18	34	1.9	0.845	5.0	5.0	2.29	2.67	1270
35Ar	18	35	1.9	1.775	4.9	4.9	2.27	2.65	1227
37K	19	37	1.9	1.226	5.1	5.1	2.35	2.72	1259
80Rb	37	80	2.2	34	4.7	4.5	2.04	2.48	1031

From P..Zucchelli talk at Nufact 03. Table compiled by U. Koster

Exercise

Characterize a Beta Beam as function of γ and Q.

Take ^{6}He, with end point energy $Q = 3.5$ MeV.
Discuss neutrino charged current rate of events as function of γ, in the range $0 < \gamma \leq 150$, having the detector at the first oscillation maximum.

Keep $\gamma = 150$, what are the arguments in favour of a ion with Q bigger than ^{6}He and those in favor of a smaller Q?
Compare these results with a Neutrino Factory running at 20 GeV.

Some scaling laws in Beta Beams

β^+ emitters			β^- emitters		
Ion	Q_{eff} (MeV)	Z/A	Ion	Q_{eff} (MeV)	Z/A
^{18}Ne	3.30	5/9	^{6}He	3.508	1/3
^{8}B	13.92	5/8	^{8}Li	12.96	3/8

- Proton accelerators can accelerate ions up to Z/A $\times$ the proton energy.
- Lorentz boost: end point of neutrino energy $\Rightarrow 2\gamma Q$
- In the CM neutrinos are emitted isotropically $\Rightarrow$ neutrino beam from accelerated ions gets more collimated $\propto \gamma^2$
- Merit factor for an experiment at the atmospheric oscillation maximum: $\mathcal{M} = \frac{\gamma}{Q}$
- Ion lifetime must be:
  - As long as possible: to avoid ion decays during acceleration
  - As short as possible: to avoid to accumulate too many ions in the decay ring

  $\Rightarrow$ optimal window: lifetimes around 1 s.
- Decay ring length scales $\propto \gamma$, following the magnetic rigidity of the ions.
- Two body decay kinematics : going off-axis the neutrino energy changes (feature used in some ECB setup and in the low energy setup)

Beta Beam baseline scenario

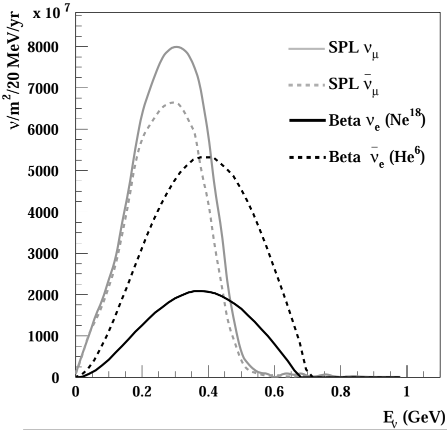
Boundary conditions:

- CERN SPS can accelerate $^6\mathrm{He}$ up to $\gamma = 150 \Rightarrow E_\nu \simeq 0.5\,GeV$ $\Rightarrow$ baselines within 300 km.
- The only viable candidate to host a megaton detector is Frejus lab, 130 km away from CERN

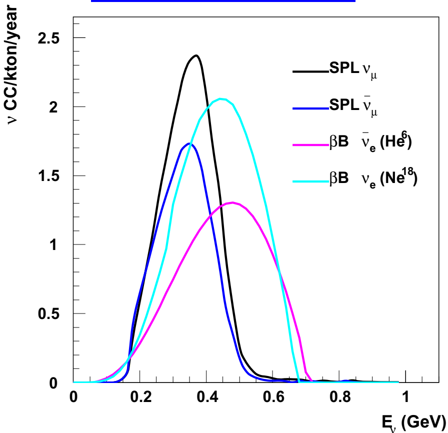
Optimal γ: $\gamma = 100$.

This is the option studied by the Eurisol design study and now by the EuroNu design study

Yearly Fluxes



CC rates, 440 kton/yr



	Fluxes @ 130 km $\nu/m^2/yr$	$\langle E_\nu \rangle$ (GeV)	CC rate (no osc) events/kton/yr	$\langle E_\nu \rangle$ (GeV)	Years	Integrated events (4400 kton/yr)
SPL Super Beam						
ν_μ	$11.80 \cdot 10^{11}$	0.29	121.7	0.36	2	107127
$\overline{\nu}_\mu$	$9.66 \cdot 10^{11}$	0.28	23.1	0.35	8	81164
Beta Beam						
$\overline{\nu}_e(\gamma = 100)$	$10.92 \cdot 10^{11}$	0.40	46.0	0.46	5	101262
$\nu_e(\gamma = 100)$	$4.06 \cdot 10^{11}$	0.38	65.4	0.44	5	143887

Experimental strategy

Beta Beam signal is ν_μ appearance.
To profit of the no-background beam, detector backgrounds should be taken at minimum:

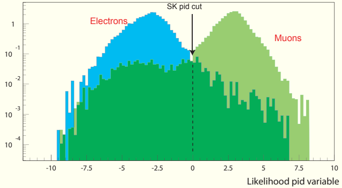
- ν_e events mis-identified as ν_μ events
- Charged pions from NC and NC-like ν_e interactions mis-identified as muons.
- Atmospheric neutrinos

As described in the following, background reduction will not rely on kinematical cuts.

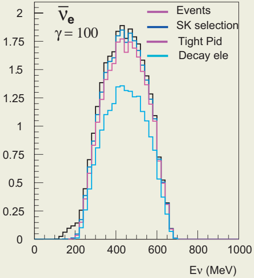
Particle identification and signal efficiency

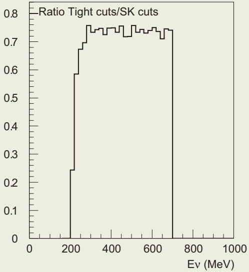
Electron/muon misidentification must be suppressed much more than in standard SK analysis to guarantee a negligible background level.

Pid in SK is performed through a Likelihood, $Pid > 0$ identifies muons. Use $Pid > 1$



To further suppress electron background ask for the signal of the Michel electron from μ decay.
Final efficiency for positive muons.
Negative muons have an efficiency smaller by $\sim 22\%$ because they can be absorbed before decaying.
Electron mis-identification suppressed to $\sim 10^{-5}$.

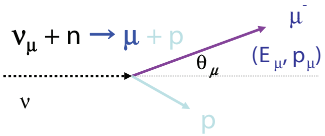




Energy reconstruction for beam neutrinos

Slide of K. Nishikawa

Select single ring events and assume they are Quasi Elastic

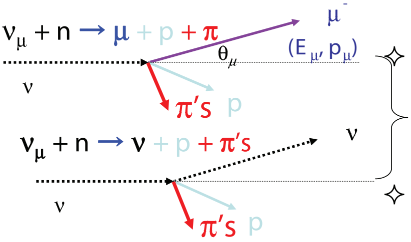


- **CC QE**
  - can reconstruct $E_\nu \leftarrow (\theta_\mu, p_\mu)$

$$E_\nu^{rec} = \frac{m_N E_\mu - m_\mu^2/2}{m_N - E_\mu + p_\mu \cos\theta_\mu}$$

$\delta E \sim 60$ MeV $\delta E/E \sim 10\%$

Single ring non Quasi Elastic are badly measured

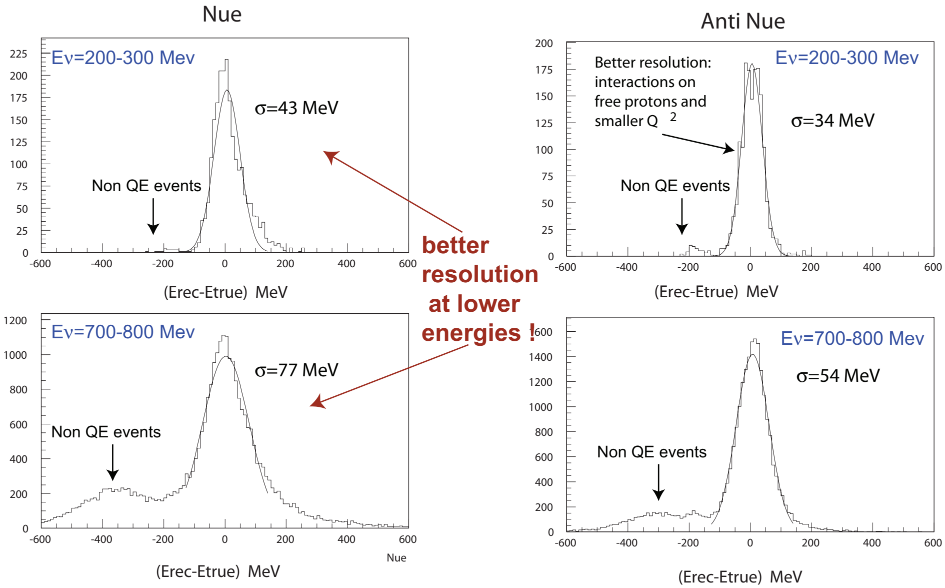


- bkg. for E_ν measurement

High energy part

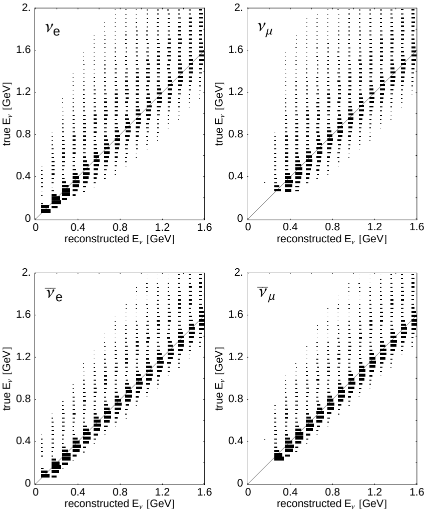
- bkg.for e-appearance

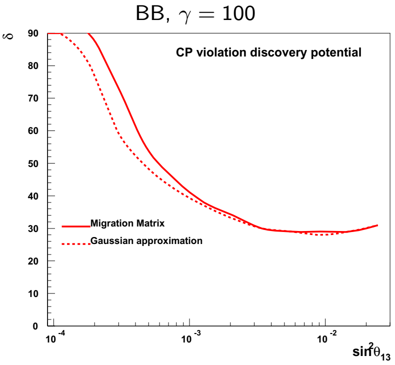
Goodness of energy reconstruction



Migration Matrixes

A gaussian assumption for energy resolution is a too crude approximation

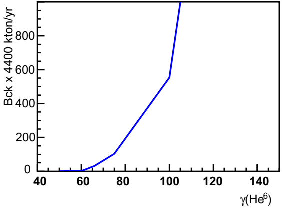




The pion background

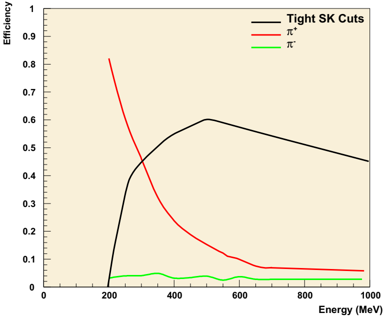
The pions generated in NC events can fake the muon signal.
They are the main concern at high gammas.

Pion backgrounds as function of γ

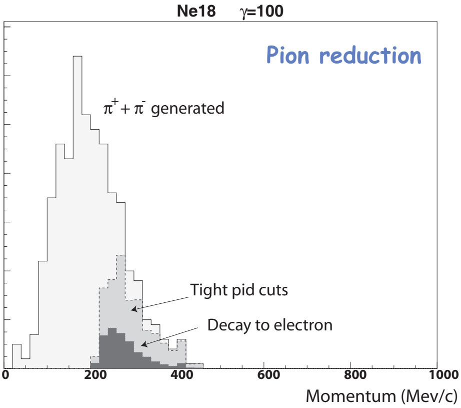


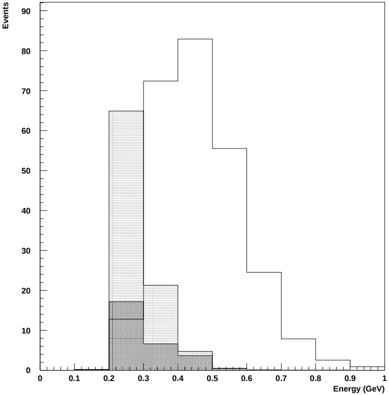
To estimate these backgrounds

- Generate CC and NC events with Nuance
- Count events with a pion and no other track above the Čerenkov threshold (single ring events)
- Apply the tight pid cuts of SuperKamiokande
- Follow pions in water (Geant 3.21) to compute the probability for $\pi \to \mu \to e$.
- Reconstruct the neutrino energy from the survived pions treating them as the signal muons



The pion background (cont.)





Chizue Ishihara,arXiv:0912.1002v2

Beta Beam signals and backgrounds recalculated with theSuperKamiokande analysis tools: full simulation and full reconstruction.

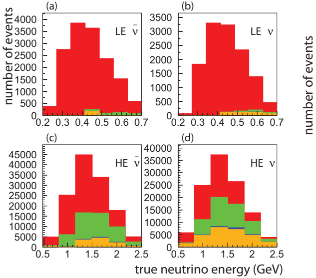


Figure 3: The final sample neutrino true energy distributions for each beam type, in case of $\sin^2 2\theta_{13} = 0.15$. The different event types are shown in different colors as shown right side.

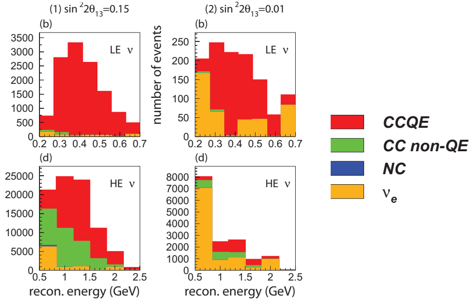


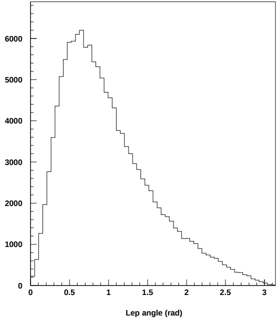
Figure 4: (1) are the reconstructed energy distributions in case of $\sin^2 2\theta_{13} = 0.15$. (2) are in case of $\sin^2 2\theta_{13} = 0.01$.

Why are they dangerous?

Atmospheric neutrinos come in two flavors: ν_e and ν_μ so they can fake any signal.

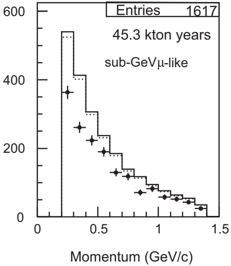
Their energy spectrum fully covers Beta Beam spectrum.

They don't necessary come from the decay ring, but outgoing lepton direction is loosely correlated with the neutrino energy direction in QE events.



The only viable tool to keep them at a negligible rate is to keep very short the live time of the neutrino beam. This is a tight requirement for the Beta Beam accelerator complex.

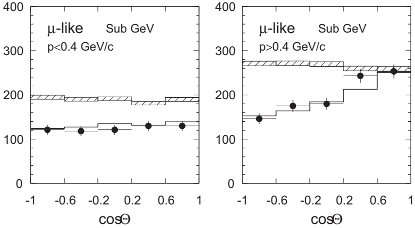
Question: why atmospherics are not a great concern at T2K phase 1, that has much smaller signal neutrino fluxes?



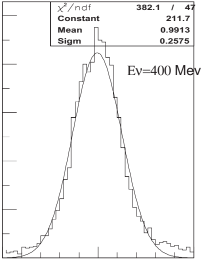
Atmospheric neutrino background

Sub-GeV μ-like events in SK integrated over the solid angle. 45.3 kton year exposure

Sub-GeV μ-like events zenithal distribution



Event direction resolution at 400 MeV. Take $\pm 2\sigma$ as acceptance, equivalent to $\pm 40°$. Solid angle reduced to 1/8



True-Reconstructed ν direction

Kamioka to Frejus flux correction: + 20%

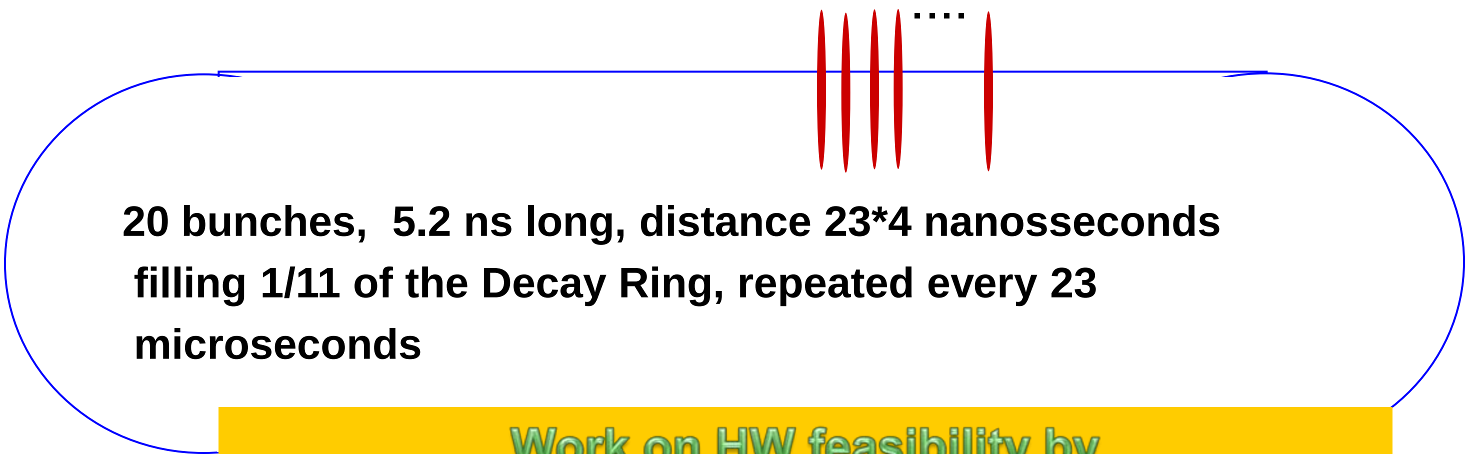
Signal efficiency with respect to standard SK algorithms: 54% (flat in energy)

A duty cycle of 1% would keep the atmospheric background rate below the pion bkg rate (Eurisol DS duty cycle: 0.45%).

Duty factor and RF Cavities

10^{14} ions circulating ,

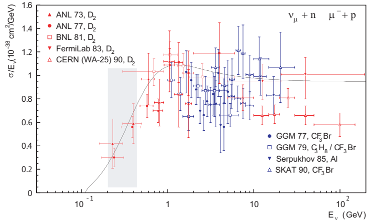
~0.5% duty (supression) factor for atmospheric neutrino background suppression !!!

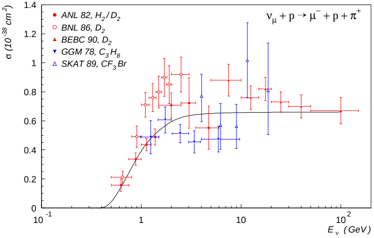


20 bunches, 5.2 ns long, distance 23*4 nanosseconds filling 1/11 of the Decay Ring, repeated every 23 microseconds

Work on HW feasibility by
Cockroft institute/Lancaster Univ.
First results will be presented in June 2011

The cross sections problem





Neutrino cross-sections are poorly measured around 300 MeV.
Nuclear effects are very important at these energies.
No surprise that different MonteCarlo codes predict rates with a 50% spread.

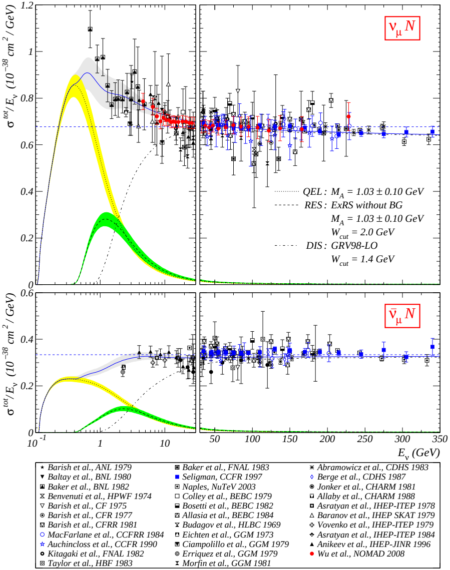
On the other hand: Beta Beam is the ideal place where to measure neutrino cross sections

- Neutrino flux and spectrum are completely defined by the parent ion characteristics and by the Lorentz boost γ.
- Just one neutrino flavour in the beam.
- You can scan different γ values starting from below the Δ production threshold.
- A close detector can then measure neutrino cross sections with unprecedent precision.

A systematic error ranging from 2% to 5% both in signal and backgrounds is used in the following

Neutrino Cross Sections

From: NOMAD Collaboration, Eur. Phys. J. C **63** (2009) 355 [arXiv:0812.4543 [hep-ex]].



Oscillation signals

From J.E.Campagne, M. Maltoni, M.M., T.Schwetz, hep-ph/0603172, revised

	βB		SPL		T2HK	
	$\delta_{CP} = 0$	$\delta_{CP} = \pi/2$	$\delta_{CP} = 0$	$\delta_{CP} = \pi/2$	$\delta_{CP} = 0$	$\delta_{CP} = \pi/2$
appearance ν						
background	113		600		1017	
$\sin^2 2\theta_{13} = 0$	24		41		84	
$\sin^2 2\theta_{13} = 10^{-3}$	66	76	93	10	181	18
$\sin^2 2\theta_{13} = 10^{-2}$	285	314	387	126	754	240
appearance $\bar{\nu}$						
background	127		500		1428	
$\sin^2 2\theta_{13} = 0$	23		36		90	
$\sin^2 2\theta_{13} = 10^{-3}$	64	10	74	104	188	261
$\sin^2 2\theta_{13} = 10^{-2}$	271	100	297	390	746	977

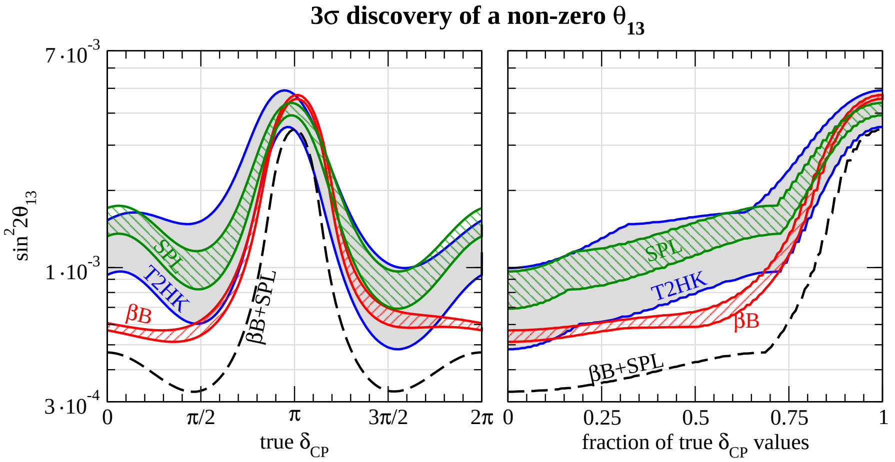
Do we have some tool for this job?

What should be done:

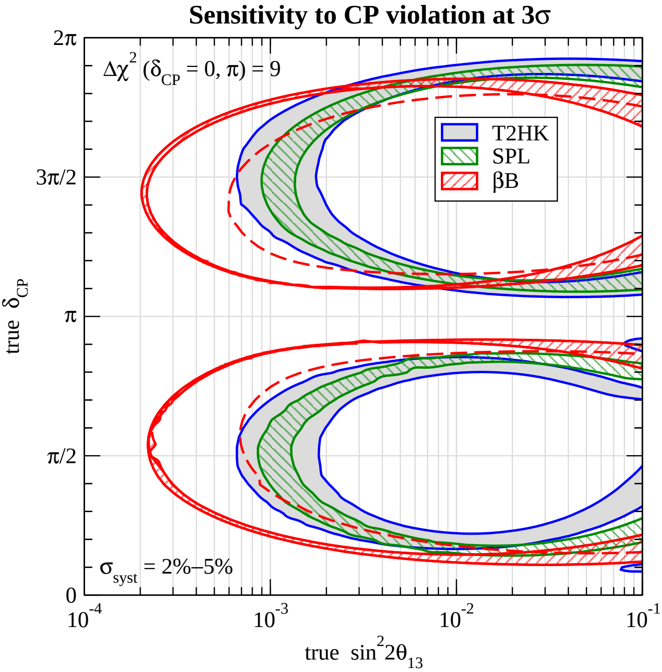
- Describe the experiment: fluxes, signal efficiencies, backgrounds.
- Describe the cross sections.
- Take care of systematic errors
- Take care of known parameter errors
- Manage several complicated 3 ν formulas ($P(\nu_\mu \to \nu_\mu)$, $P(\nu_e \to \nu_e)$, $P(\nu_\mu \to \nu_e)$, etc.)
- Manage matter effects with the correct matter densities in the earth.
- Multi parameters fit and search for different solutions for the fit
- Combine different experimental results

Happily enough a powerful open source tool has been developed: **Globes**.

http://www.mpi-hd.mpg.de/personalhomes/globes/



Line width: 5% systematic errors.



Sensitivity to CP violation at 3σ
Δχ² (δCP = 0, π) = 9
T2HK
SPL
βB
σsyst = 2%–5%
2π
3π/2
π
π/2
0
true δCP
10⁻⁴
10⁻³
10⁻²
10⁻¹
true sin²2θ13

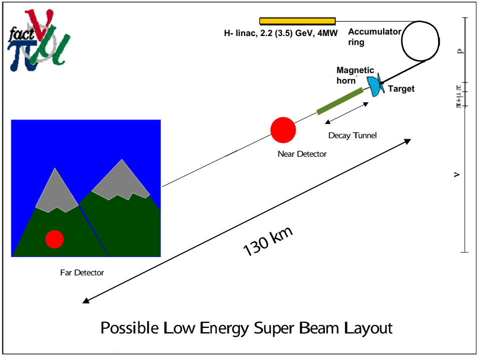
Additional signals at the Frejus detector.

Can the θ_{13} and LCPV searches be improved?
Two pathways explored so far. In order of comparison:

- Fire a conventional neutrino beam (the SPL-SuperBeam) to the same detector.
- Combine BB information with the atmospheric neutrinos that the megaton detector will record for free

P.S. Also ν_e disappearance could help in determining θ_{13} and in removing degeneracies (it's the same channel of reactor experiments). However it would help if systematic errors could be pushed below 0.5%. At present 2% seems to be the ultimate level of systematics for a Beta Beam. You should consider that is very unpractical to build a close detector IDENTICAL to the far detector.

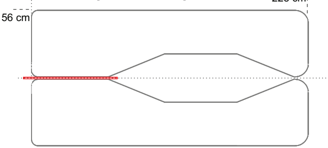
SuperBeams - SPL ν beam at CERN



- A 3.5 GeV, 4MW Linac: the SPL.
- A target station capable of managing the 4 MW proton beam. R&D required.
- A conventional neutrino beam optics capable to survive to the beam power, the radiation and the mercury. Already prototyped.
- Up to here is the first stage of a neutrino factory complex.
- A sophisticated close detector to precisely measure signal and backgrounds.
- A megaton class detector under the Frejus, L=130 km: Memphys.

SPL revised (A. Longhin, arXiv:1106.1096)

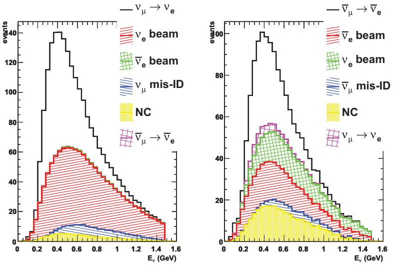
Shape of the optimal horn



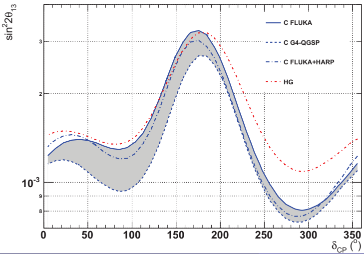
L_1	58.9	$r_1 = r_2$	10.8
L_2	46.8	R_1	1.2
L_3	60.3	$R_1 + R_2 + R_3$	56.2
L_4	47.5	$R_1 + R_2$	20.3
L_5	1.08	z_0^{tg}	-6.8
L^{tg}	78	R^{tg}	1.5
L^{tun}	2500	R^{tun}	200

Parameters of the optimized system expressed in cm.

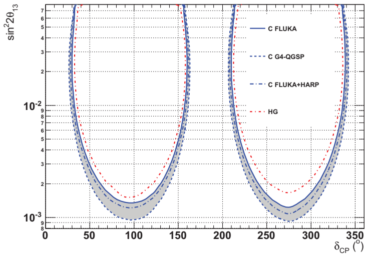
Event rates in MEMPHYS for $\sin^2 2\theta_{13} = 0.01$ and $\delta_{CP} = 0$.



θ_{13} discovery at 3σ ($\Delta\chi^2 = 9$). 5% sys.



CP violation discovery at 3σ ($\Delta\chi^2 = 9$). 5% sys.



The Beta Beam - SPL Super Beam synergy

MM, Nucl. Phys. Proc. Suppl. **149** (2005) 179.

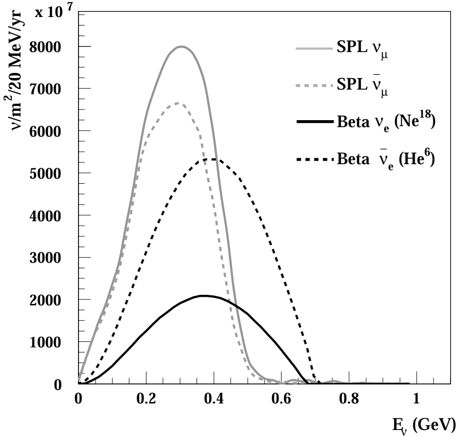
A Beta Beam has the same energy spectrum than the SPL SuperBeams and consumes 5% of the SPL protons.

The two beams could be fired to the same detector ⇒ LCPV searches through CP and T channels (with the possibility of using just neutrinos).

Access to CPTV direct searches.

Cross measurement of signal cross section in the close detectors

Yearly Fluxes



The synergy with atmospheric neutrinos

P. Huber et al., Phys. Rev. D 71, 053006 (2005): Combining Long Baseline data with atmospheric neutrinos (that come for free in the megaton detector):

- Degeneracies can be canceled, allowing for better performances in θ_{13} and LCPV searches
- The neutrino mass hierarchy can be measured
- The θ_{23} octant can be determined.

The main reasons are:

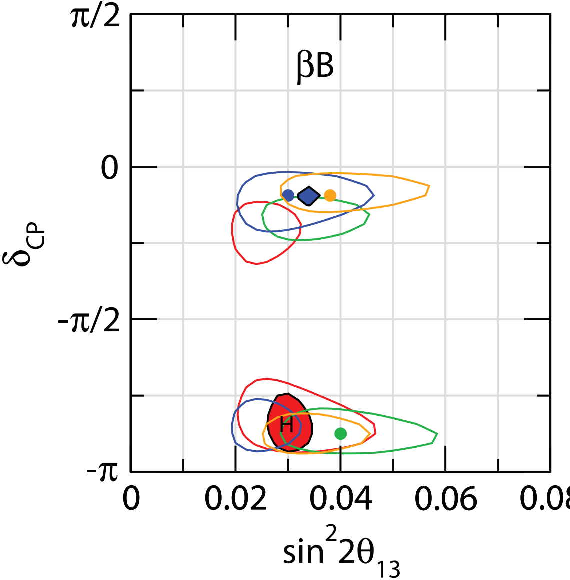
- **Octant** e-like events in the Sub-GeV data is $\propto \cos^2 \theta_{23}$
- **Sign** e-like events in the Multi-GeV data, thanks to matter effects, especially for zenith angles corresponding to neutrino trajectories crossing the mantle and core where a resonantly enhancement occurs.

NOTE: LBL and atmospherics are a true synergy. They add to each other much more that a simple gain in statistics. Atmospherics alone could not measure the hierarchy, the octant, θ_{13} and LCPV. While the Beta Beam at short baselines could not measure the hierarchy as well as the octant.

Synergy with atm. neutrinos: degeneracy removal

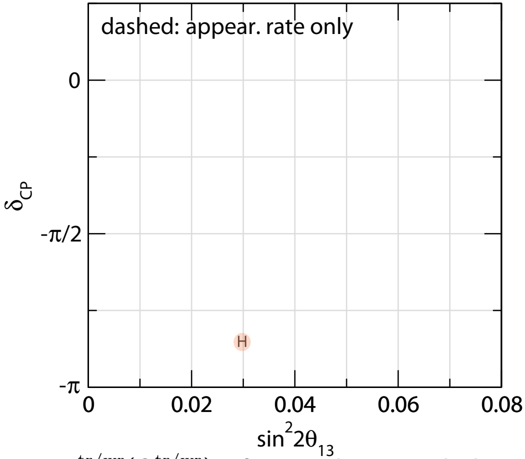
J.E.Campagne, M.Maltoni, M.M., T.Schwetz, JHEP **0704** (2007) 003

The red region is what is left after the atmospheric analysis.
Note how degeneracies were not influencing LCPV sensitivity too much.



Degeneracy removal: SPL

J.E.Campagne, M.Maltoni, M.M., T.Schwetz, JHEP **0704** (2007) 003



95% CL allowed regions. $\mathrm{H}^{\mathrm{tr/wr}}(\mathrm{O}^{\mathrm{tr/wr}})$ refers to solutions with the true/wrong mass hierarchy (octant of θ_{23}). The true parameter values are $\delta_{\mathrm{CP}} = -0.85\pi$, $\sin^2 2\theta_{13} = 0.03$, $\sin^2\theta_{23} = 0.6$. The running time is $(2\nu + 8\bar{\nu})$ yrs.

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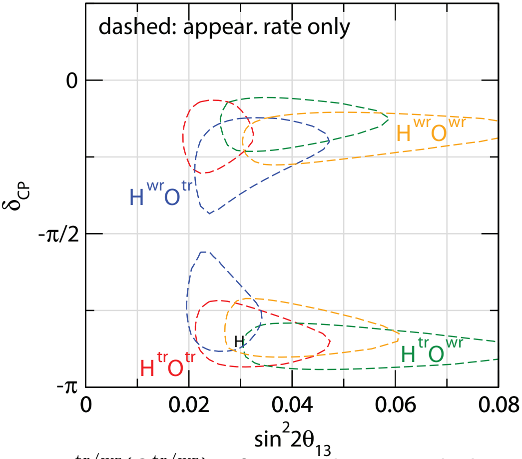

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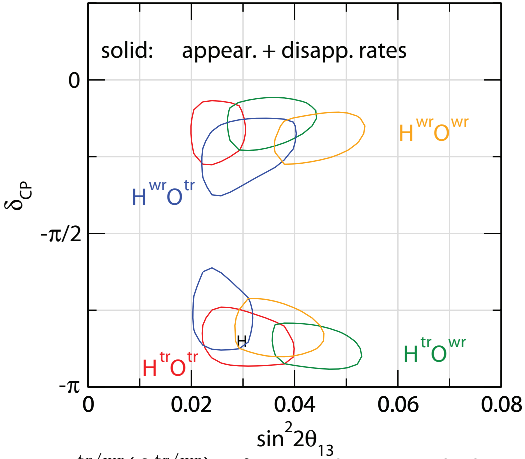

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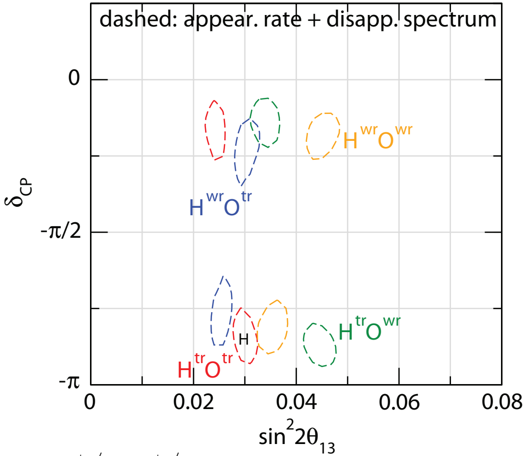

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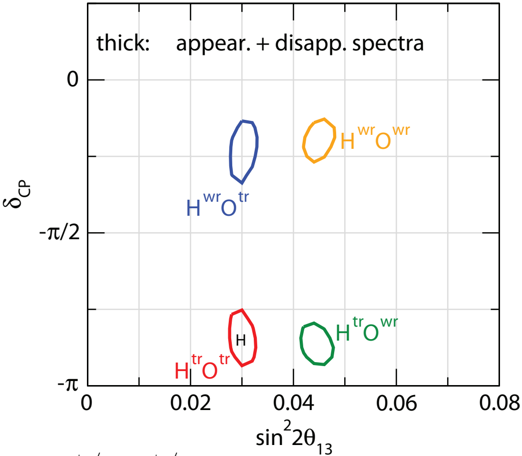

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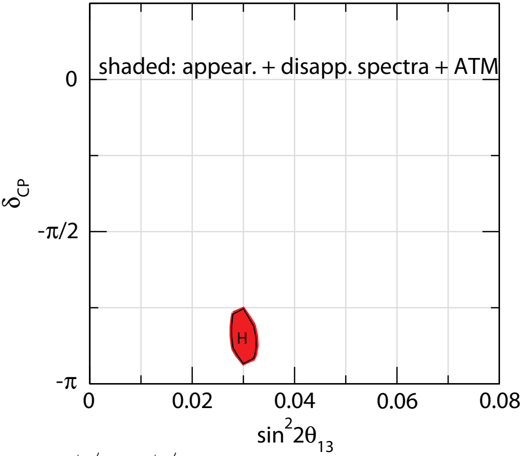

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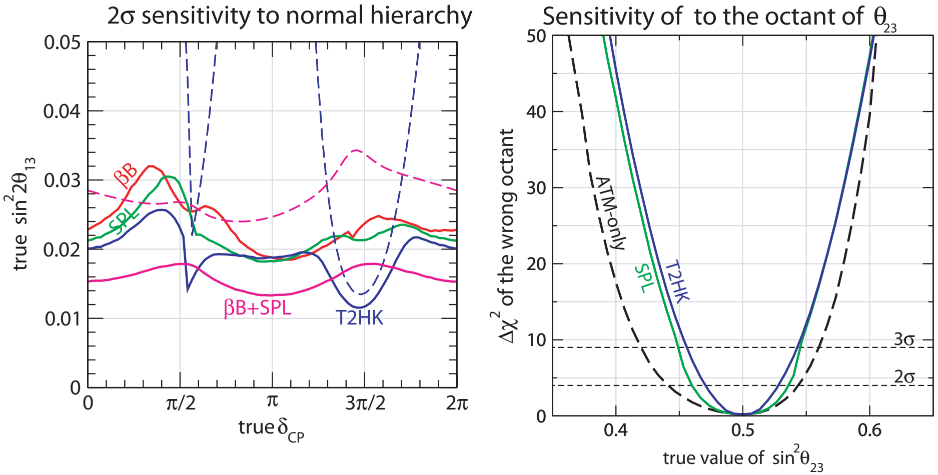
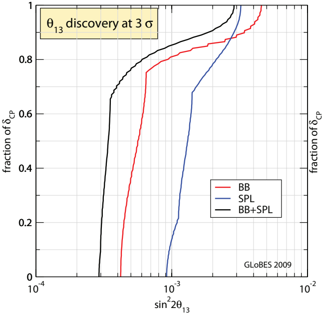
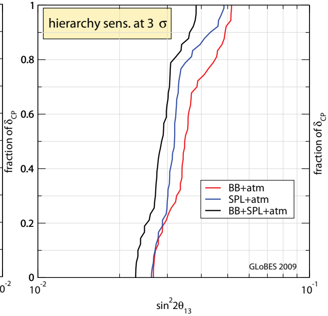
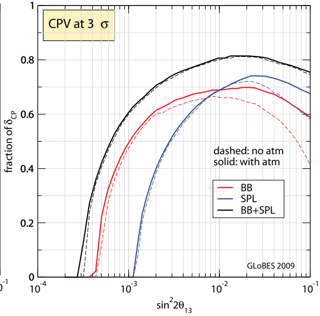
Beta Beam plus atmo: determining mass hierarchy and the octant



Updated sensitivities of SPL, BB and SPL+BB







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Ways to have more neutrinos in the far detector

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2. Higher γ

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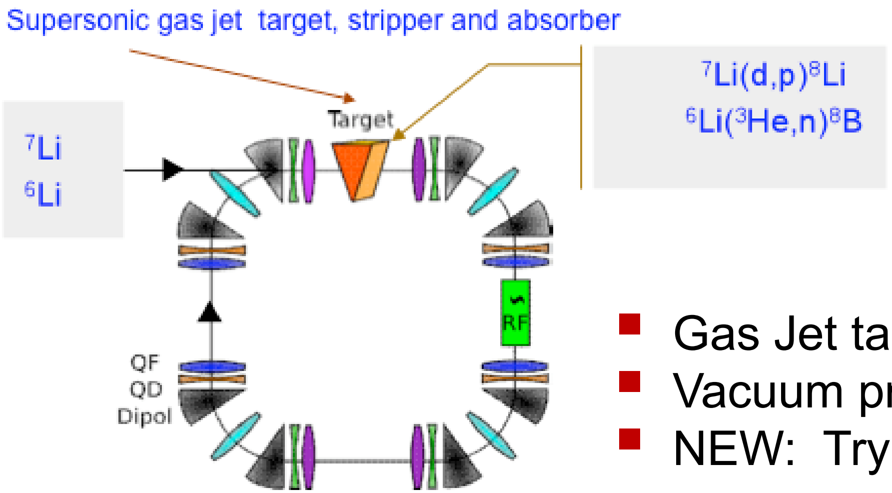
- **Electron capture Beta Beams**: monochromatic neutrino beams, a very attractive option
  - They require long lived, high-A, far from the stability valley ions, r$\Rightarrow$ challenging R&D to match the needed fluxes.

The Production Ring (8B and 8Li)



Production of 8B and 8Li
C. Rubbia, EUROnu proposal

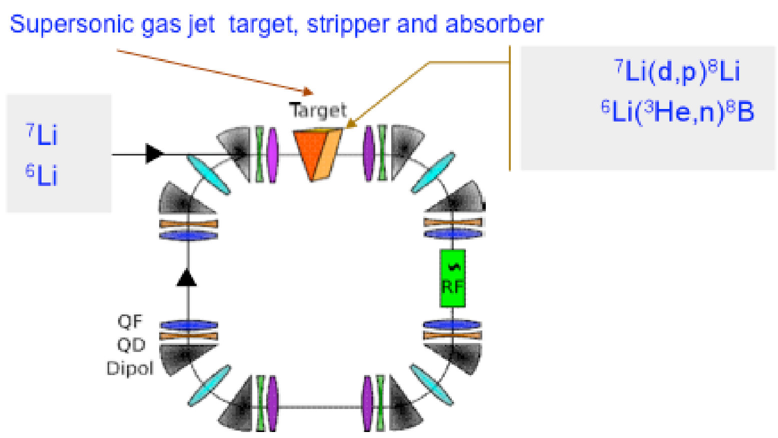
- Gas Jet target proposed in FP7: too high density
- Vacuum problems
- NEW: Try Direct Production (D. Neuffer)

- Basic lattice and 6D tracking ok, RF feasible (10 MHz, 300 kV)
- Charge exchange injection to be designed
- Direct kinematics could give good production efficiencies
- Simulations done so far can be scaled, tune for cooling
- Experiment/simulations at ERIT, (FFAG solution, larger aperture)
- Experiment/simulations at TSR, ion storage ring, Heidelberg or CERN

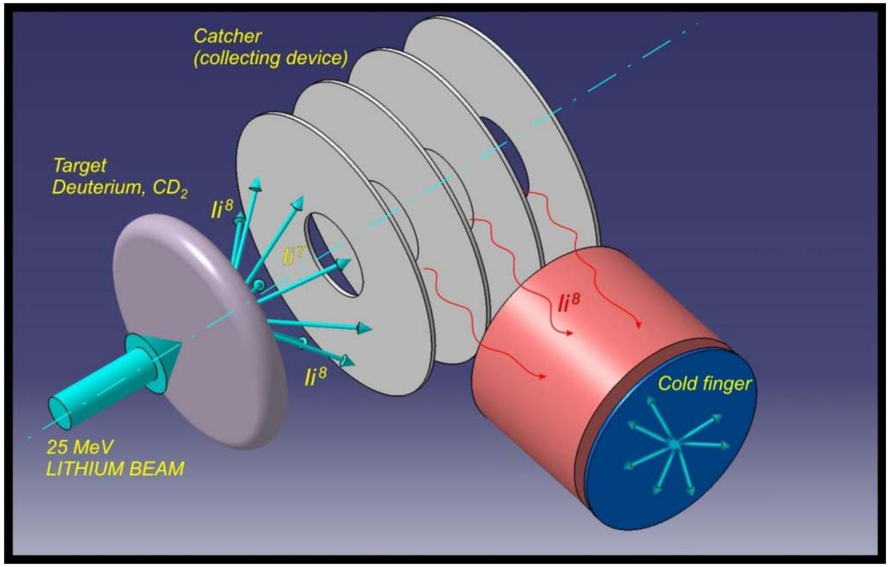
Aachen Univ., GSI, CERN

Collection device

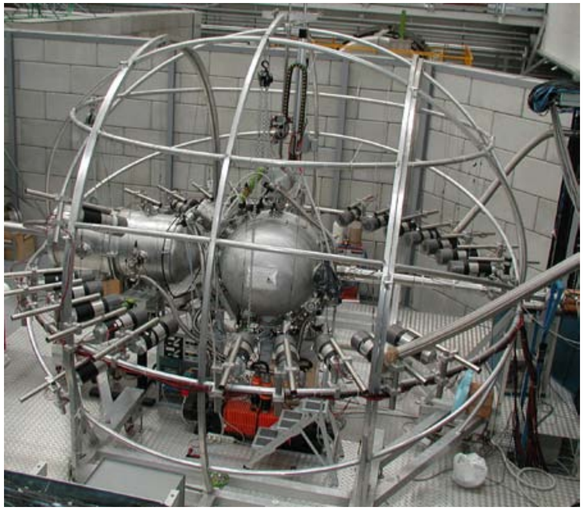
- Device constructed, measurement equipment on line
- Commissioning ok
- Measurements/Analysis ongoing for the collected 8Li
- Direct kinematics should be discussed
- Setup and measurements for 8B production and collection ongoing



CRC, Louvain la Neuve



X-sections, Energies and Angles, Li and B



2011

CN proposal: BETABEAM

^{8}B PRODUCTION MEASUREMENT FOR THE FP7 BETA BEAM DESIGN STUDY

V.L. Kravchuk[1], **E. Wildner**[2], M. Cinausero[1], G. De Angelis[1], F. Gramegna[1], T. Marchi[1], G. Prete[1], E. Benedetto[2], C. Hansen[2], G. Collazuol[3], M. Mezzetto[3], G. Derosa[4], V. Palladino[4], E. Vardaci[4]

FOR THE EUROnu WP4 COLLABORATION

[1]*Laboratori Nazionali di Legnaro, Legnaro (PD), Italy*
[2]*CERN, Geneve, Switzerland*
[3]*Dipartimento di Fisica, Universita' di Padova and INFN sezione di Padova, Padova, Italy*
[4]*Dipartimento di Fisica, Universita' di Napoli and INFN sezione di Napoli, Napoli, Italy*

Spokesperson: V.L. Kravchuk - kravchuk@lnl.infn.it
Spokesperson: E. Wildner - Elena.Wildner@cern.ch

$$^{6}_{3}\mathrm{Li} + ^{3}_{2}\mathrm{He} \rightarrow ^{8}_{5}\mathrm{B} + \mathrm{n}$$

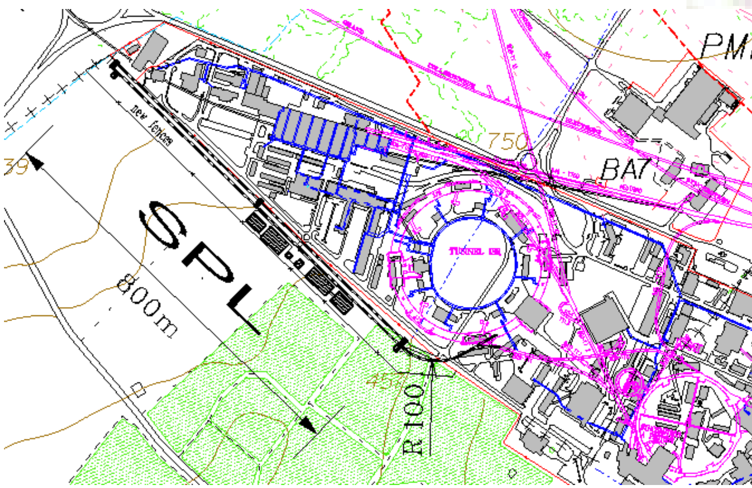
Proposal Accepted

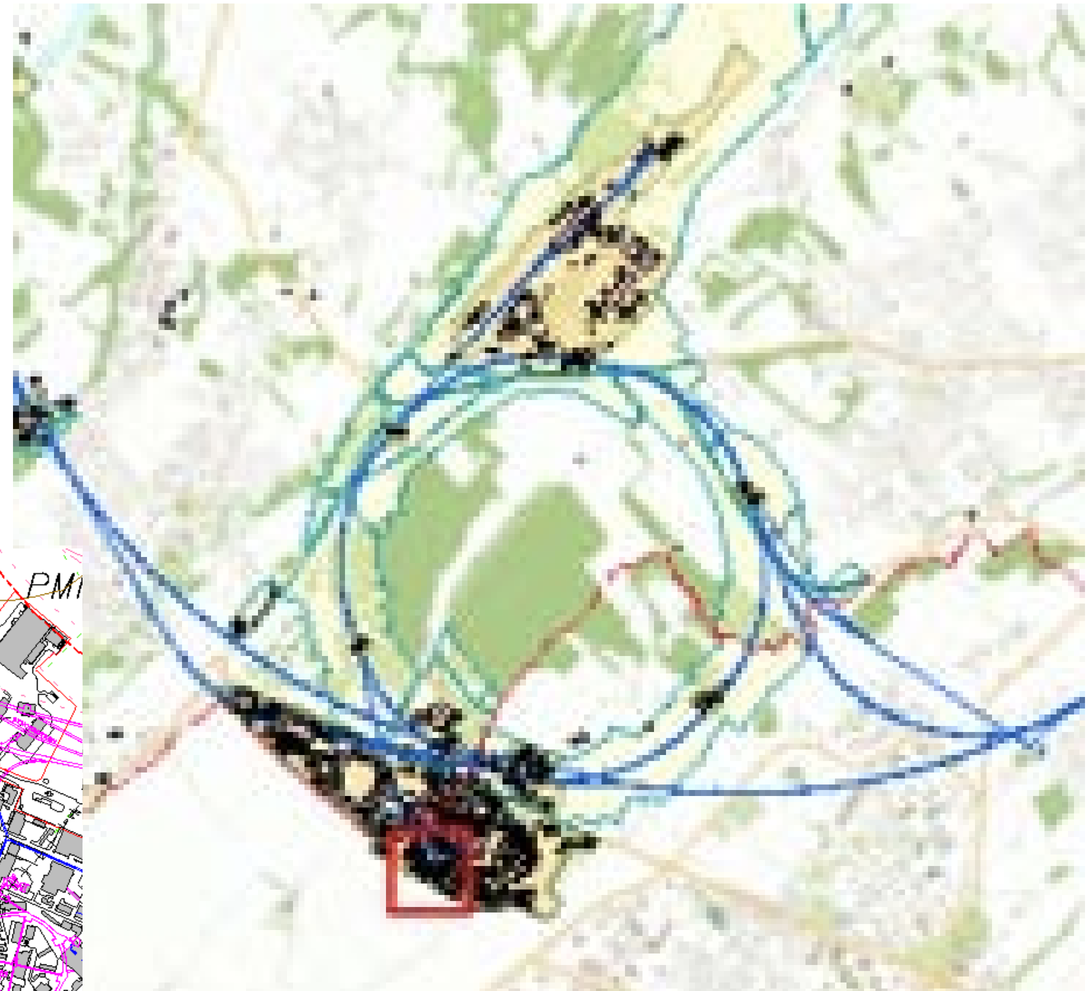
Data successfully taken June this year !!!

INFN, Legnaro

Implementation and Costing

- Part of EUROnu mandate
- Synergy βB/SB
- Place βB on site * 2
- Place SB (SPL ?)
- Radiation
- Integration (CLIC, other?)
- Costing excersise





Continuation (2011-

- Experiments on 18Ne production (molten salt loop)
- Cooling and production simulations for 8Li and 8B
- Cross-section measurements of 8B
- Experimental setups for Heidelberg Ring and for a cyclotron
- 8B collection setup and experiment
- ECR fields for plasma -> 30 000A (structures supra…), Gyrotron tests, beam extraction, Proto -> ECR Source
- Collective effects studies, all machines, DR optimization
- Participation in upgrades of injectors for LHC
- Decay Ring RF, technical feasibility studies
- Costing and Safety, for performance/cost evaluation (EUROnu)