NuFact 11 August 1-6, 2011 Geneva, Switzerland

Beta Beams

Elena Wildner, CERN

For the Beta Beam Collaboration

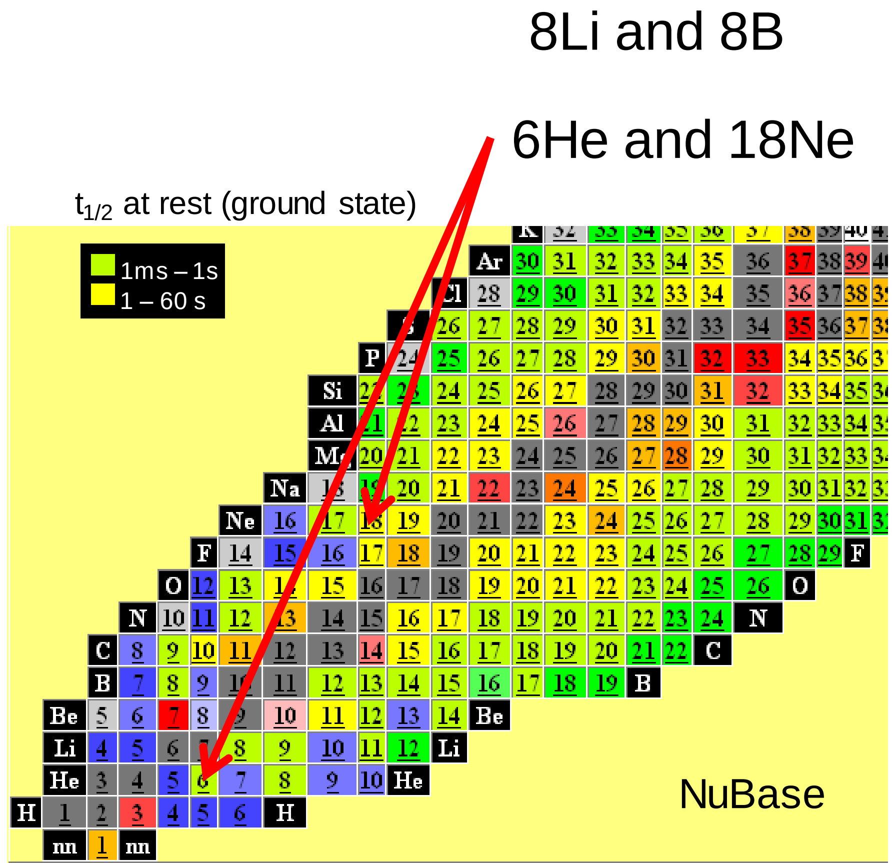
Beta Beams, Isotopes & Baselines

- Neutrino beam: decay of beta active isotopes in a decay ring
- Produce suitable beta (+/-) active isotopes
  - Available reaction energy of a specific isotope: Q
- Accelerate beta active isotopes
  - The ions will get a maximum gamma boost γ_{max} ($E_{\nu} \leq 2\gamma_{max}Q$)
- γ_{max}
  - depends on the available accelerators
  - depends on the Z/A of the ion
  - is chosen for the physics reach wanted
- Merit factor: γ/Q
  - Lower flux with distance
  - Higher x-sections with energy
  - Higher flux with γ

High-Q and Low-Q pairs

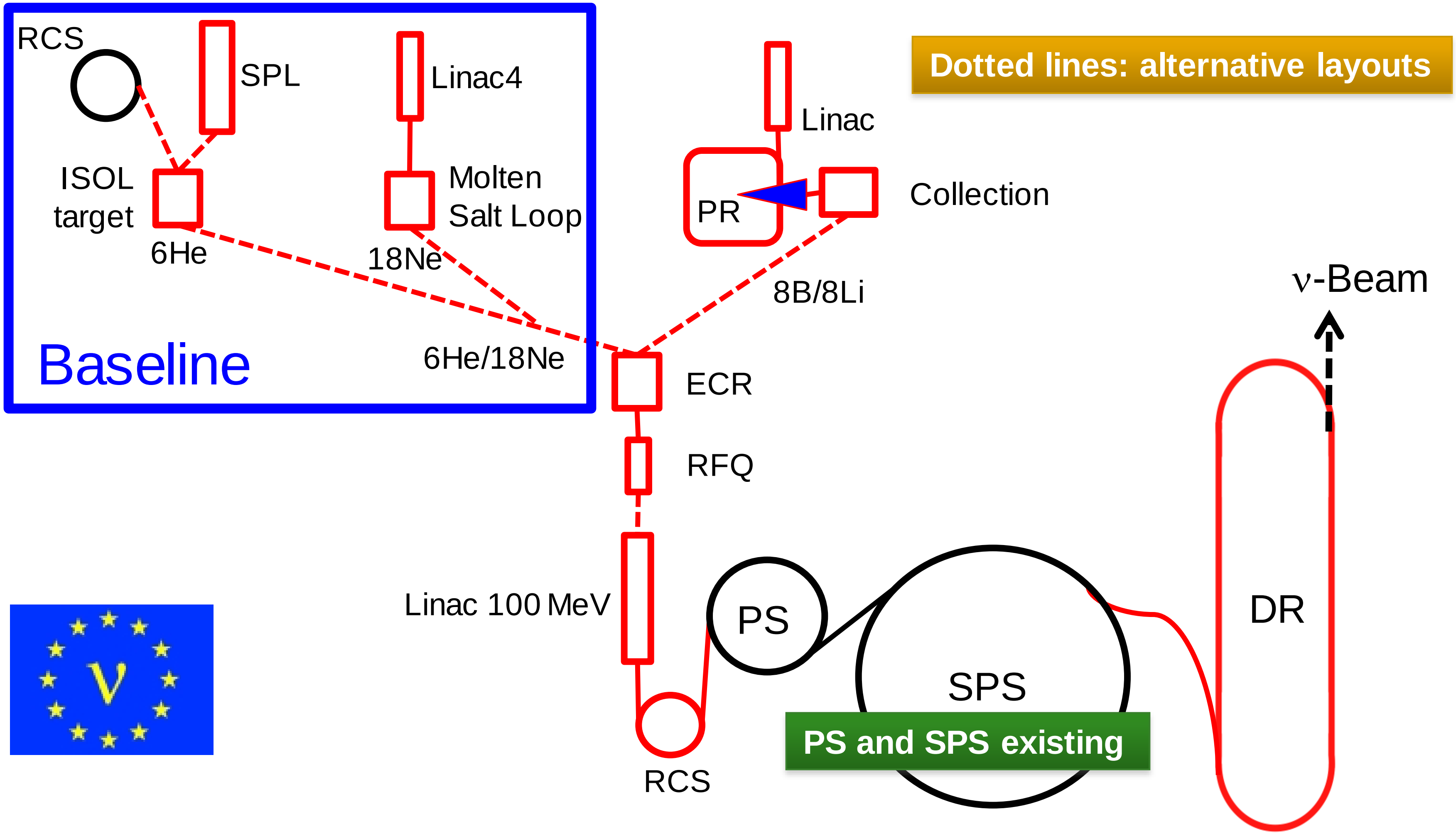
Isotope	^{6}*He*	^{18}*Ne*
A/Z	*3*	*1.8*
decay	β^-	β^+
$\tau_{1/2}$ *[s]*	*0.81*	*1.67*
Q [MeV]	*3.51*	*3.0*

Isotope	^{8}*Li*	^{8}*B*
A/Z	*2.7*	*1.6*
decay	β^-	β^+
$\tau_{1/2}$ *[s]*	*0.83*	*0.77*
Q [MeV]	*12.96*	*13.92*



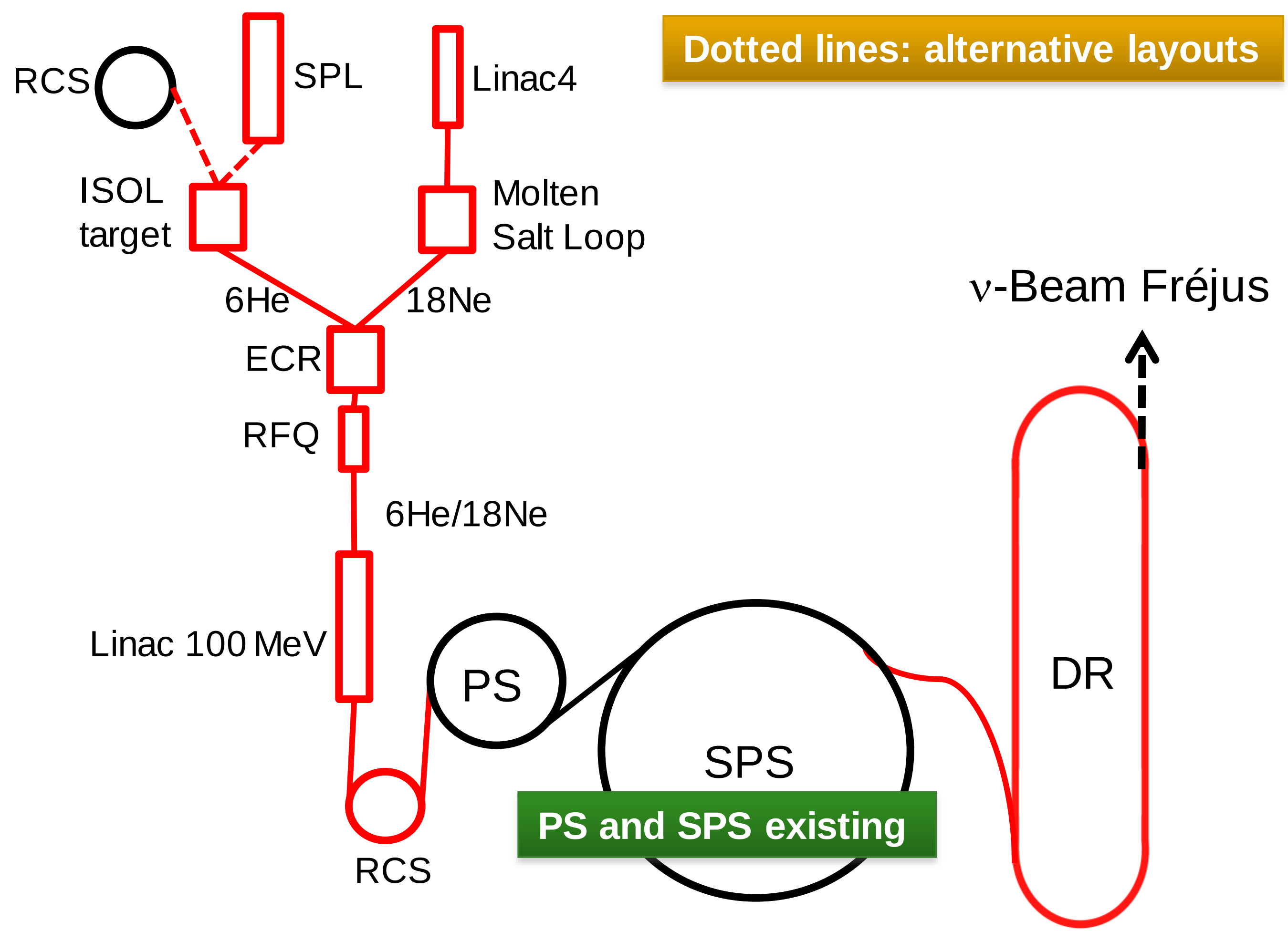
Higher Q-value gives higher ν-energy, better x-sections but needs longer baseline

CERN Beta Beams, Synoptic



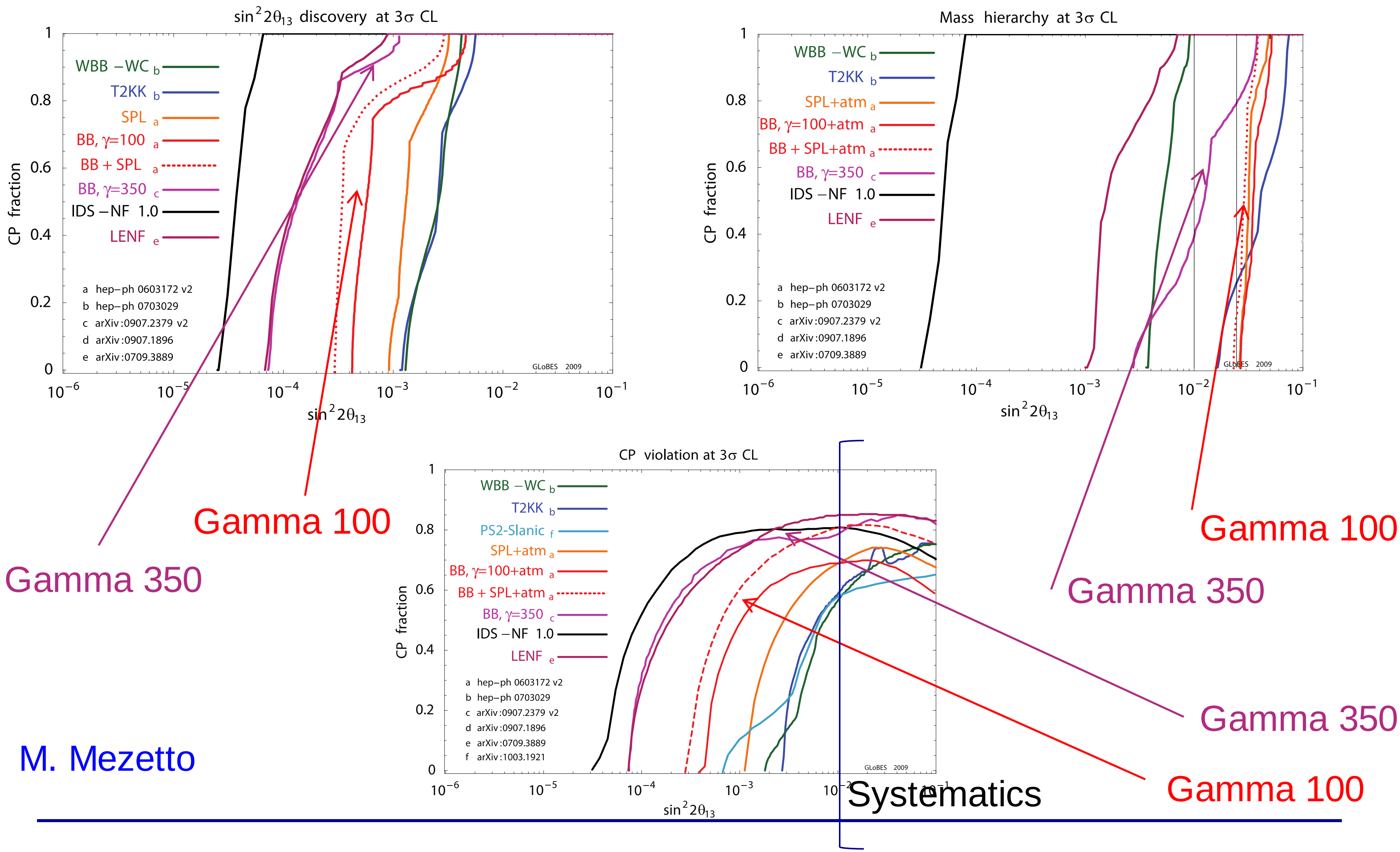
Decay Ring: Bρ ~ 500 Tm, B = ~6 T, C = ~6900 m, L_{ss}= ~2500 m, γ = 100, all ions

CERN Beta Beams, Synoptic



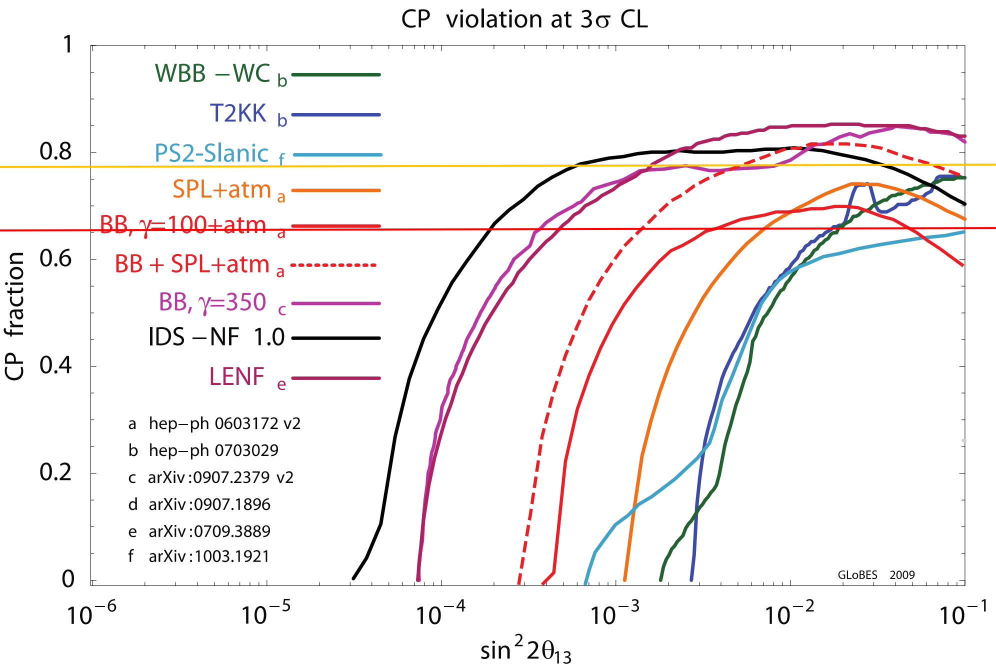
$B\rho$ ~ 500 Tm, B = ~6 T, C = ~6900 m, L_{ss}= ~2500 m, γ = 100, all ions

EUROnu physics



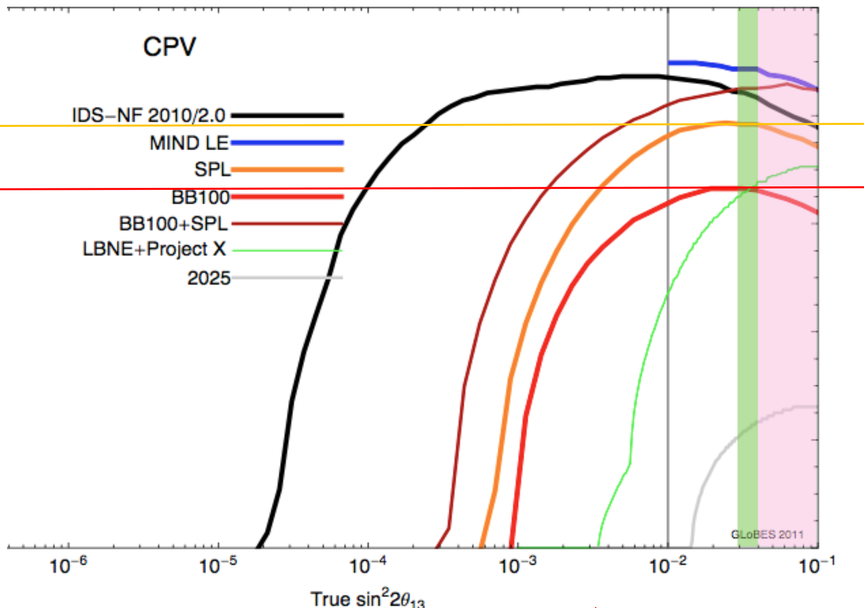
M. Mezetto

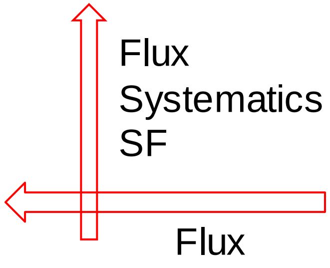
CPV



T2K 2.5σ 0.03 < $\sin^2\theta_{13}$ (normal hierarchy)

T2K 2.5σ 0.04 < $\sin^2\theta_{13}$ (inverted hierarchy)

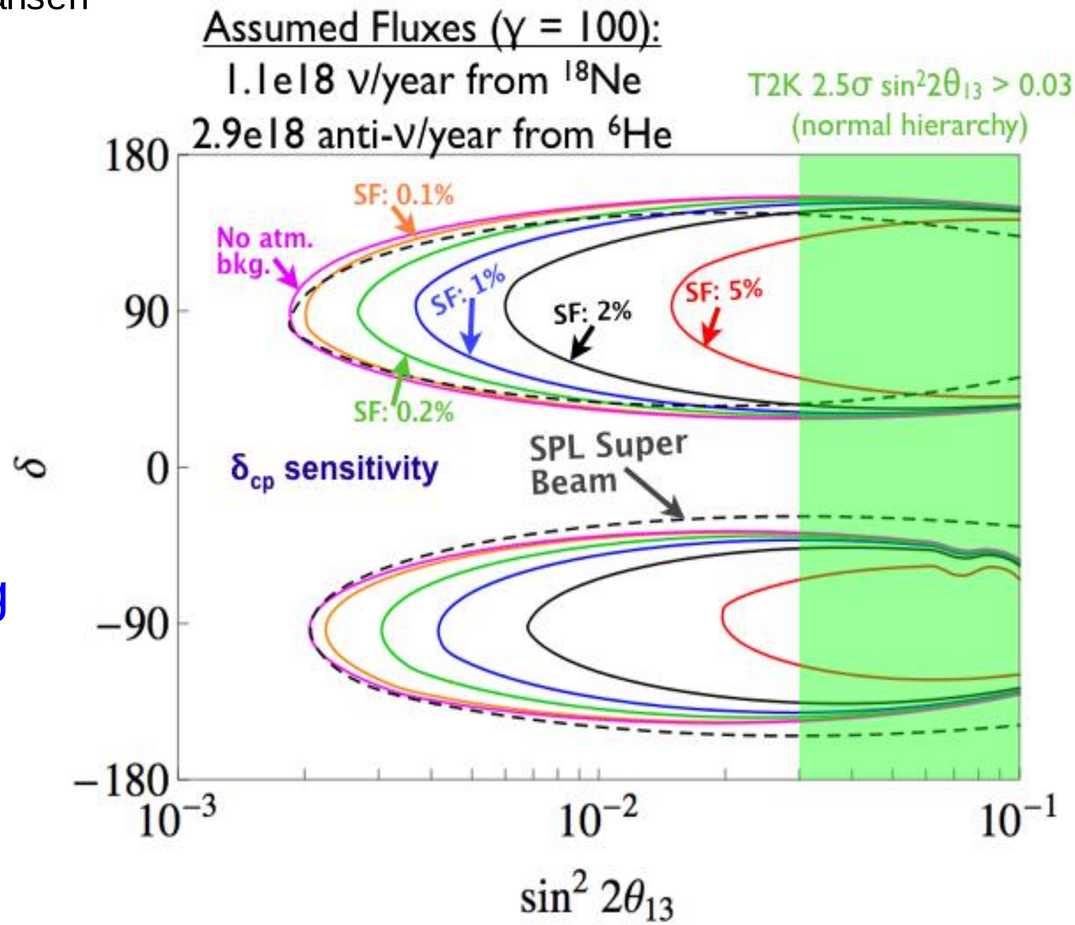




The systematic error estimation is important (detectors and beam)
Beta beam neutrino flux can be calculated with current monitors in the accelerator.
Pure e-neutrinos
Reduction of Suppression needed for atmospheric background !!!

CPV for the Fréjus option (^{6}He&^{18}Ne)

Courtesy E. Fernandez, P. Coloma, C. Hansen



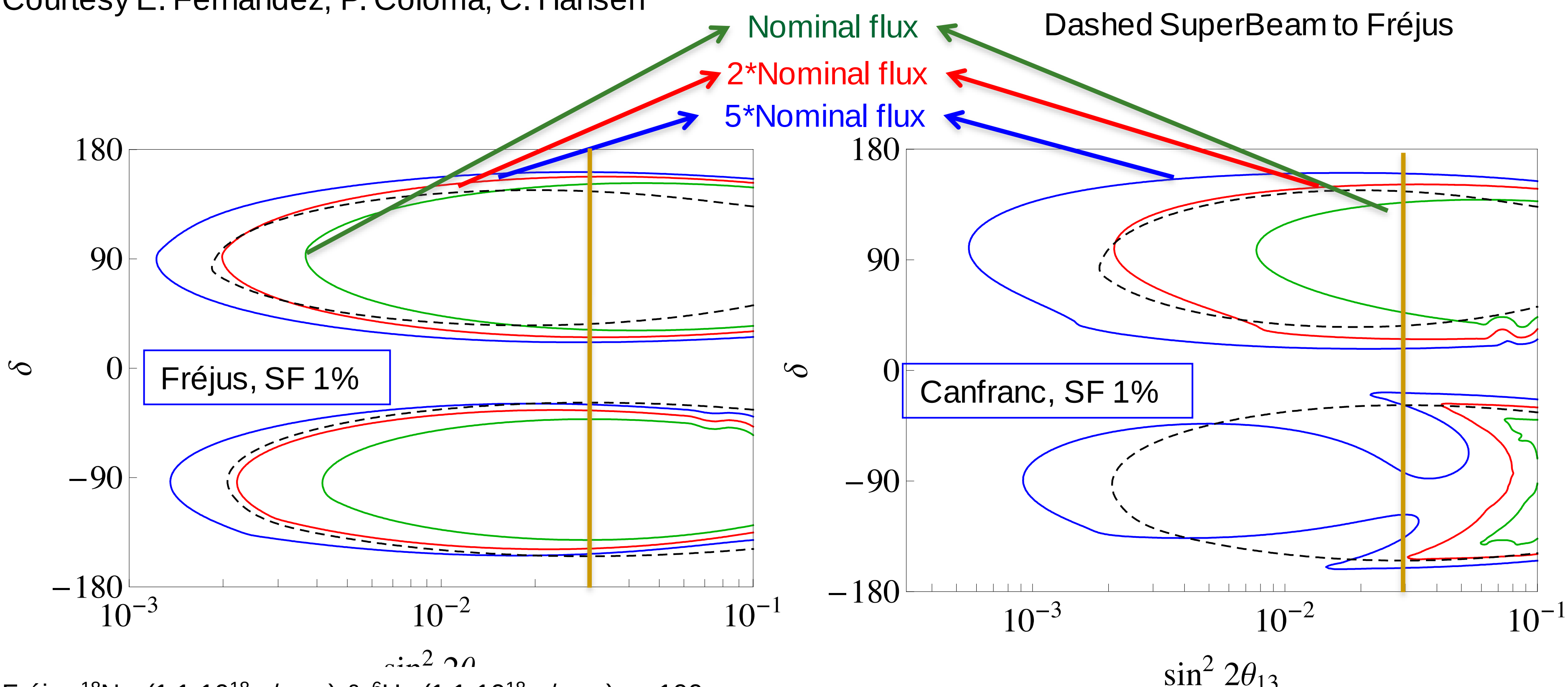
Larger $\sin^2 2\theta_{13}$

- Relax background suppression?
- Larger bunches permitted
- Less instabilities
- Higher neutrino fluxes
- Iterations necessary and ongoing

SF 2% seems sufficient for larger $\sin^2 2\theta_{13}$ (0.6% used up till now)

CPV - νFlux: Fréjus & Canfranc

Courtesy E. Fernandez, P. Coloma, C. Hansen

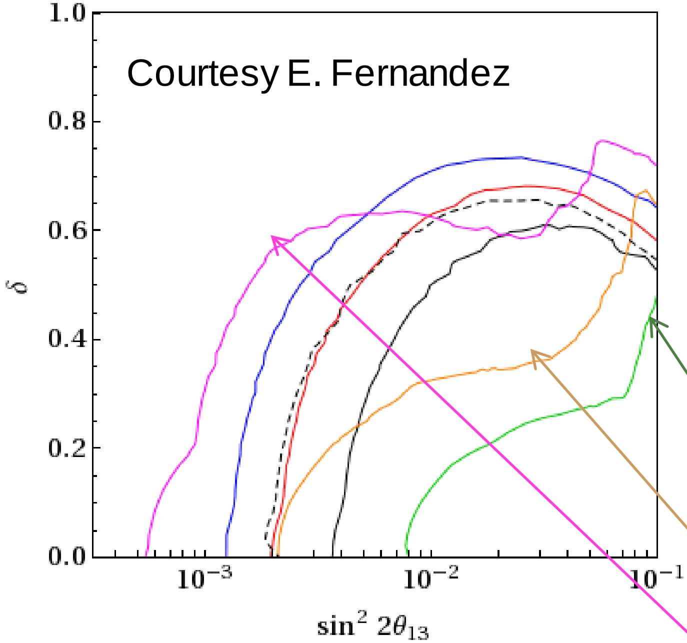


Fréjus: ^{18}Ne (1.1 10^{18} ν/year) & ^{6}He (1.1 10^{18} ν/year), γ=100
Canfranc: ^{18}Ne (4.4 10^{17} ν/year, γ=250) & ^{8}He (2.9 10^{18} ν/year, γ=100)
Other ion combinations may be efficient (A. Donini)

Negative delta, matter effects give degeneracies with the mass hierarchy. Larger flux: no degeneracies.

CPV: First optimization attempts

Only relative Comparison !



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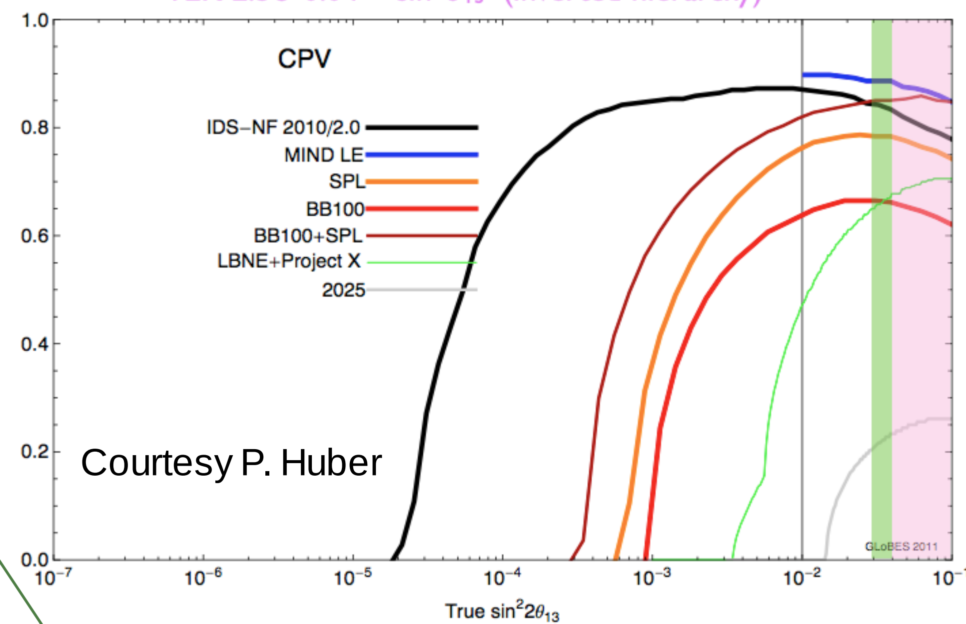


Flux to Fréjus:

Nominal

2* Nominal

5* Nominal

Flux to Canfranc:

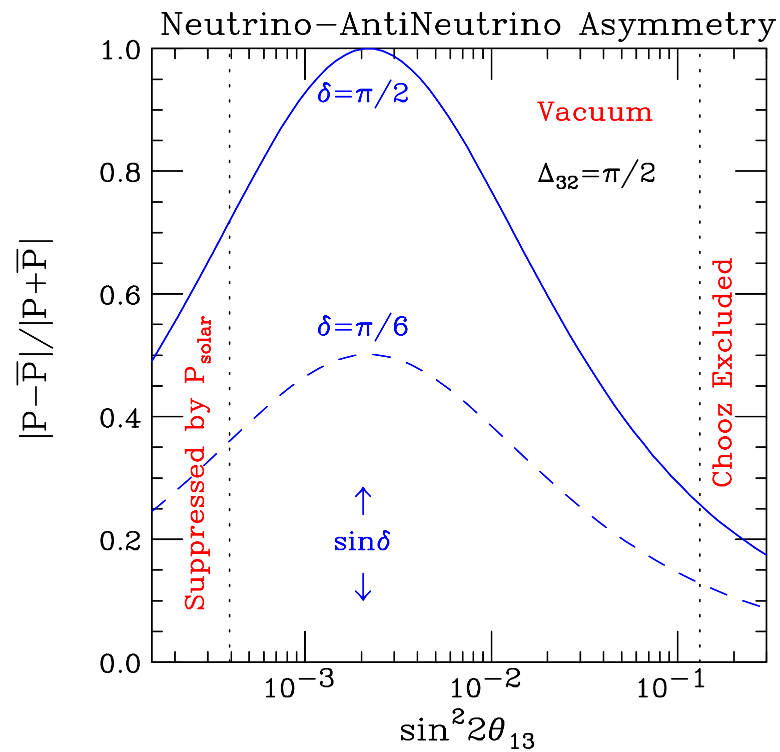
Nominal

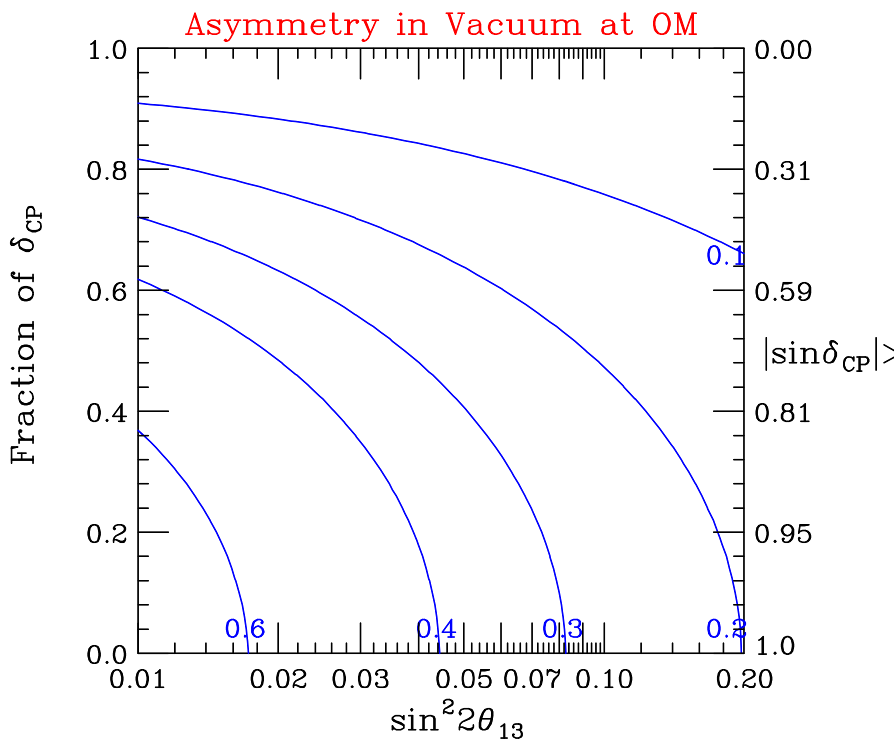
2* Nominal ^{8}Li@100 and ^{18}Ne@250

5* Nominal

LCPV: Assymmetry

Vacuum, at 1st oscillation maximum



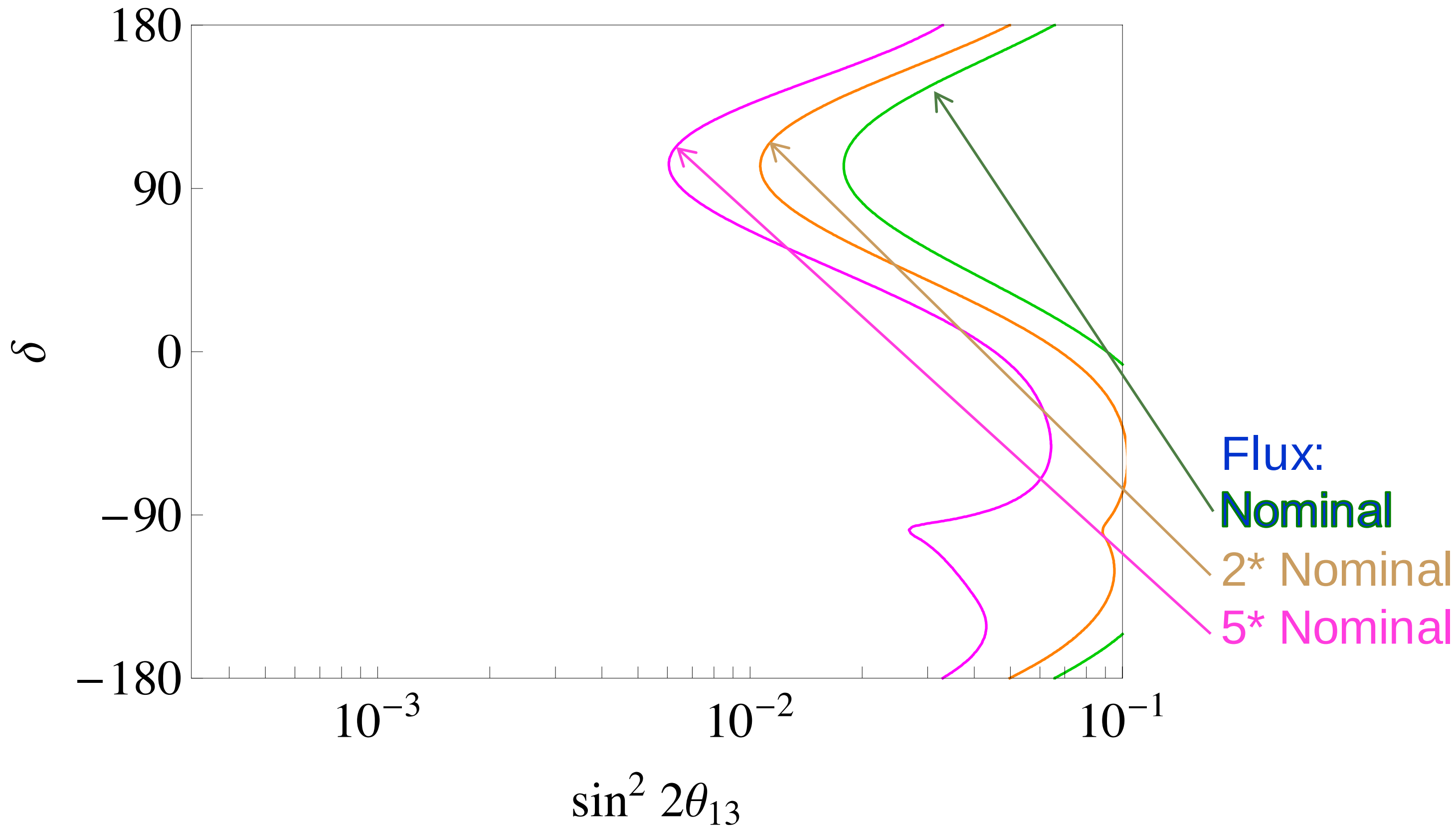


A~1/11 $(\sin 2\Theta_{13} \sin\delta)/(\sin^2 2\Theta_{13}+0.002)$

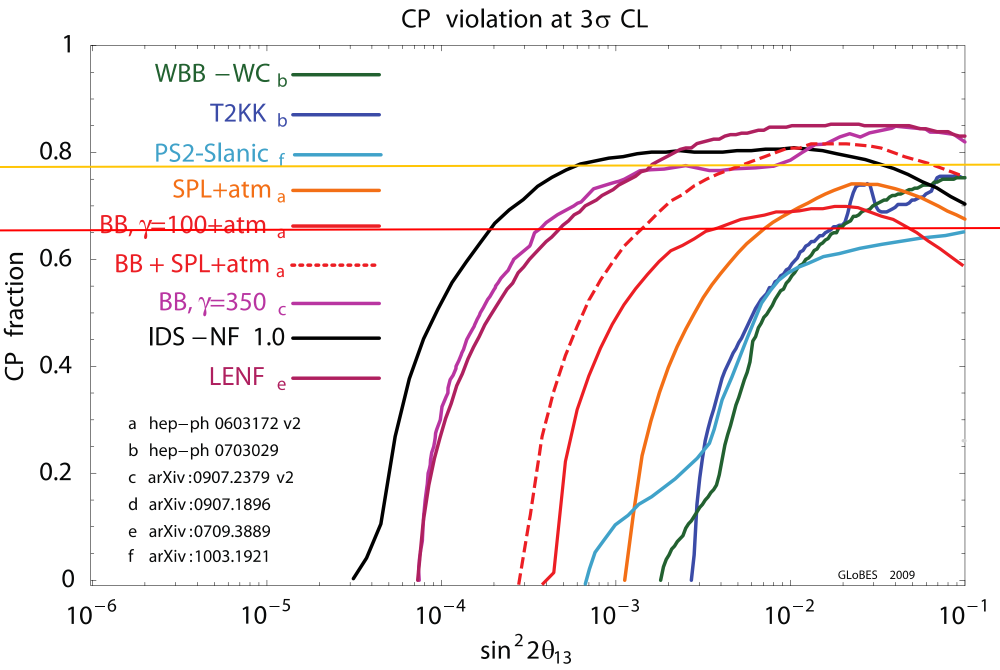
Courtesy S. Parke

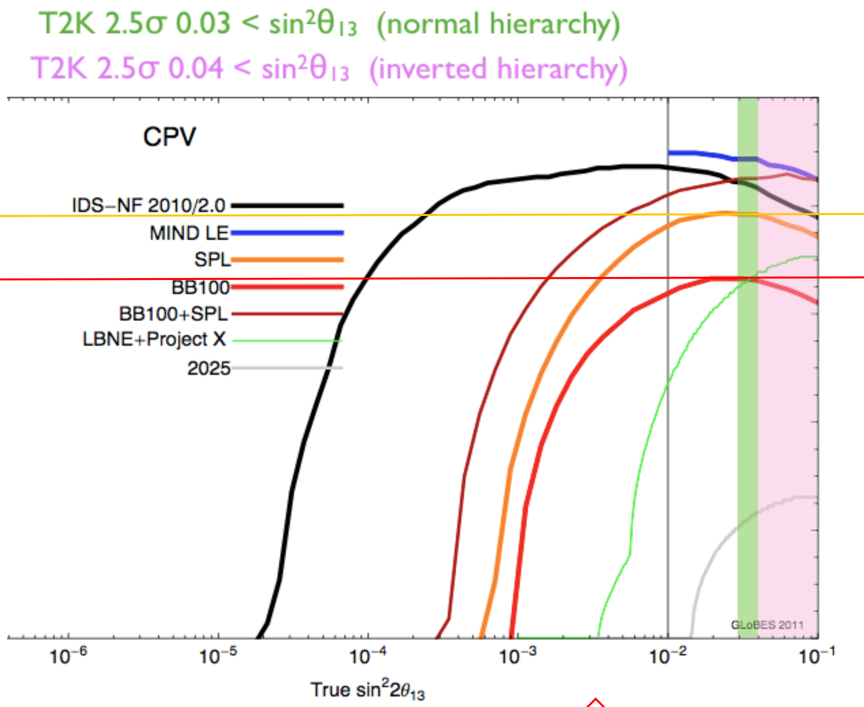
Mass Hierarchy

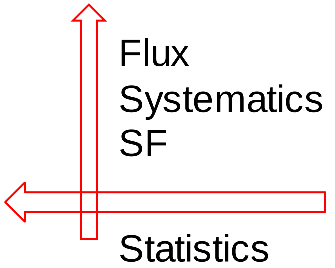
Canfranc, Beta Beam setting:
$^{8}Li@100$ and $^{18}Ne@250$



Comparisons, how ?







The systematic error estimation is important (detectors and beam)
Beta beam neutrino flux can be calculated with current monitors in the accelerator.
We can relax requirements for atmospheric background suppression !!!

Systematic uncertainty to be re-evaluated

- Wish:
  - A document treating all systematic uncertainty for the 3 different facilities
- For Beta Beams
  - Detector WC up to 1.5-2 GeV
  - Pure Beam (SB ~ 1%)
  - Beam Spectrum well known
  - 1% systematic errors on beam fluxes in far detector (SB 5%)
  - Cross sections not well measured, 5-10%
  - Close detector will help
    - Full scan with varying gamma
  - Total systematic uncertainty not negligible !

Conclusion

- T2K: Optimization for excellent physics reach is ongoing
- We can now reduce the Suppression Factor for atmospheric background suppression (if T2K confirmed)
  - Neutrino flux will be increased

- Optimization of L/E
  - SPS can give gamma up to 250 for ^{18}Ne, may be interesting now

- **Systematic uncertainties** need complete evaluation
  - Detector, WC but also Liquid Argon (EUROnu WP5)
  - Beam (alignment and current monitoring in accelerator)
  - To be included in the comparison analysis (all facilities)

- All results have to be iterated
  - Work on physics and accelerators in collaboration to be continued

Support slides

Isotope production rates

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

Targets below MWatt is a considerable advantage!

Type	Beam	I [mA]	E [MeV]	P [kW]	Target	Isotope	Flux
ISOL(n)	SPL(p)	0.07	2000	200	W/BeO	^{6}He	$> 5 \cdot 10^{13}$
ISOL	Linac4(p)	6	160	960	^{23}Na^{19}F	^{18}Ne	$> 1 \cdot 10^{13}$
P-ring	Linac(d)	0.160	25	4	^{7}Li	^{8}Li	$> 1 \cdot 10^{12}$
P-ring	Linac(^{3}He)	0.160	25	4	^{6}Li	^{8}B	$> 8 \cdot 10^{11}$

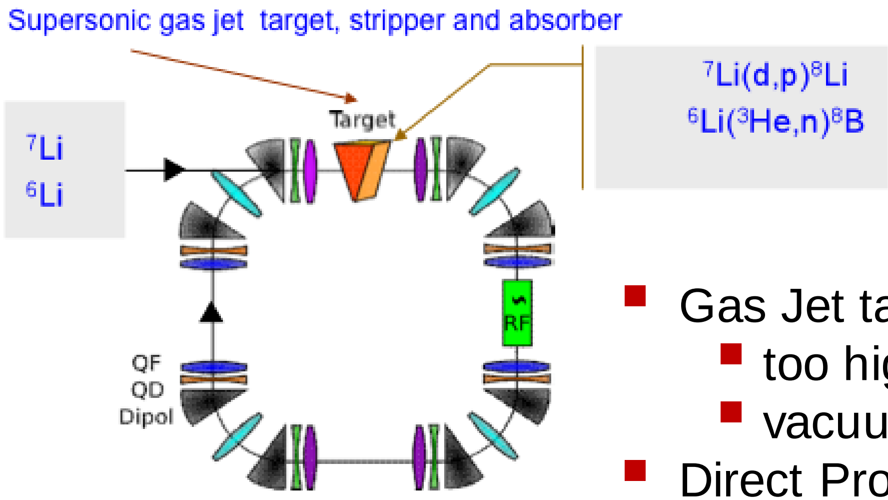
More is possible

Planned experiments

NB :8Li can be produced in rates comparable to 6He using similar technology

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

The Production Ring (8B and 8Li)



Aachen Univ., GSI, CERN

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

- Gas Jet target proposed in FP7:
  - too high density would be needed
  - vacuum problems
- Direct Production (D. Neuffer) with liquid film targets
  - Collaboration ANL (Benedetto/Nolen)

- High-Q 8B and 8Li will not be considered for the time being
- We will not explore the low-Q gamma 350 option

Managing intensities: "Ion Cocktails"

Collective effects important

Less collective effects

SETUP	γ	Ions	Fluxes $[10^{18}]$	Years	$(\sin^2 2\theta_{13})_{min}$	NH,$(\sin^2 2\theta_{13})_{min}$
CERN-Frèjus, 1 Ref. [1] L = 130 Km 440 Kton (FV) WC	100	^{6}He ^{18}Ne	$\Phi_0 = 2.9$ $\Phi_0 = 1.1$	5 5	5×10^{-4}	No Sensitivity
CERN-Frèjus, 2 Ref. [1]	100	^{6}He ^{18}Ne	$\bar{\Phi}_0 \times 2$ $\Phi_0/2$	2 8	6×10^{-4}	No Sensitivity
CERN-Frèjus, 3 Ref. [1]	100	^{6}He ^{18}Ne	$\bar{\Phi}_0 \times 2$ $\Phi_0/5$	2 8	1×10^{-3}	No Sensitivity

SETUP	γ	Ions	Fluxes $[10^{18}]$	Years	$(\sin^2 2\theta_{13})_{min}$	NH,$(\sin^2 2\theta_{13})_{min}$
CERN-Canfranc, 1 Ref. [1] L = 650 Km 440 Kton (FV) WC	100	^{8}Li ^{8}B	$\bar{\Phi}_0$ Φ_0	5 5	1.5×10^{-3}	3×10^{-2}
CERN-Canfranc, 2 Ref. [1]	100	^{8}Li ^{8}B	$\bar{\Phi}_0 \times 2$ $\Phi_0 \times 2$	5 5	7×10^{-4}	1.5×10^{-2}
CERN-Canfranc, 3 Ref. [1]	100	^{8}Li ^{8}B	$\bar{\Phi}_0 \times 5$ $\Phi_0 \times 5$	5 5	2×10^{-4}	8×10^{-3}
CERN-Canfranc, 4 Ref. [1]	100	^{8}Li ^{8}B ^{6}He	$\bar{\Phi}_0$ Φ_0 $\bar{\Phi}_0$	3 5 2	1.7×10^{-3}	3×10^{-2}
CERN-Canfranc, 5 Ref. [1]	100	^{8}Li ^{8}B ^{6}He	$\bar{\Phi}_0 \times 2$ $\Phi_0 \times 2$ $\bar{\Phi}_0 \times 2$	3 5 2	7×10^{-4}	1.5×10^{-2}
CERN-Canfranc, 6 Ref. [1]	100	^{8}Li ^{8}B ^{6}He	$\bar{\Phi}_0 \times 5$ $\Phi_0 \times 5$ $\bar{\Phi}_0 \times 5$	3 5 2	3×10^{-4}	8×10^{-3}

Summary by A. Donini

Collective Effects limits, Decay Ring

	Bunch Intensity Limit, N_b^{th}		
	[e12]	[N_b^{nom}]	[N_b^{nom}]
^{18}Ne	0.6	0.1	0.3
^{6}He	5.0	1.0	0.5
^{8}B	1.1	0.1	0.3
^{8}Li	3.0	0.1	0.3

Ions	Fluxes [10^{18}]	Years	$(\sin^2 2\theta_{13})_{min}$	NH,$(\sin^2 2\theta_{13})_{min}$
^{6}He	$\bar{\Phi}_0 = 2.9$	5	5×10^{-4}	No Sensitivity
^{18}Ne	$\Phi_0 = 1.1$	5		
^{8}Li	$\bar{\Phi}_0 \times 5$	5	2×10^{-4}	8×10^{-3}
^{8}B	$\Phi_0 \times 5$	5		
^{6}He	$\bar{\Phi}_0 \times 2$	2	6×10^{-4}	No Sensitivity
^{18}Ne	$\Phi_0/2$	8		
^{8}Li	$\bar{\Phi}_0 \times 2$	5	7×10^{-4}	1.5×10^{-2}
^{8}B	$\Phi_0 \times 2$	5		

Only Transverse Mode Coupling Instabilities

Recent Encouraging results, redesigned decay ring !

	Bunch Intensity Limit, N_b^{th}		
	[e12]	[N_b^{nom}]	[N_b^{nom}]
^{18}Ne	1.2	0.3	0.6
^{6}He	10	2.1	1.0
^{8}B	2.1	0.2	0.6
^{8}Li	5.9	0.2	0.6

Ions	Fluxes [10^{18}]	Years	$(\sin^2 2\theta_{13})_{min}$	NH,$(\sin^2 2\theta_{13})_{min}$
^{6}He	$\bar{\Phi}_0 = 2.9$	5	5×10^{-4}	No Sensitivity
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^{6}He	$\bar{\Phi}_0 \times 2$	2	6×10^{-4}	No Sensitivity
^{18}Ne	$\Phi_0/2$	8		
^{8}Li	$\bar{\Phi}_0 \times 2$	5	7×10^{-4}	1.5×10^{-2}
^{8}B	$\Phi_0 \times 2$	5		

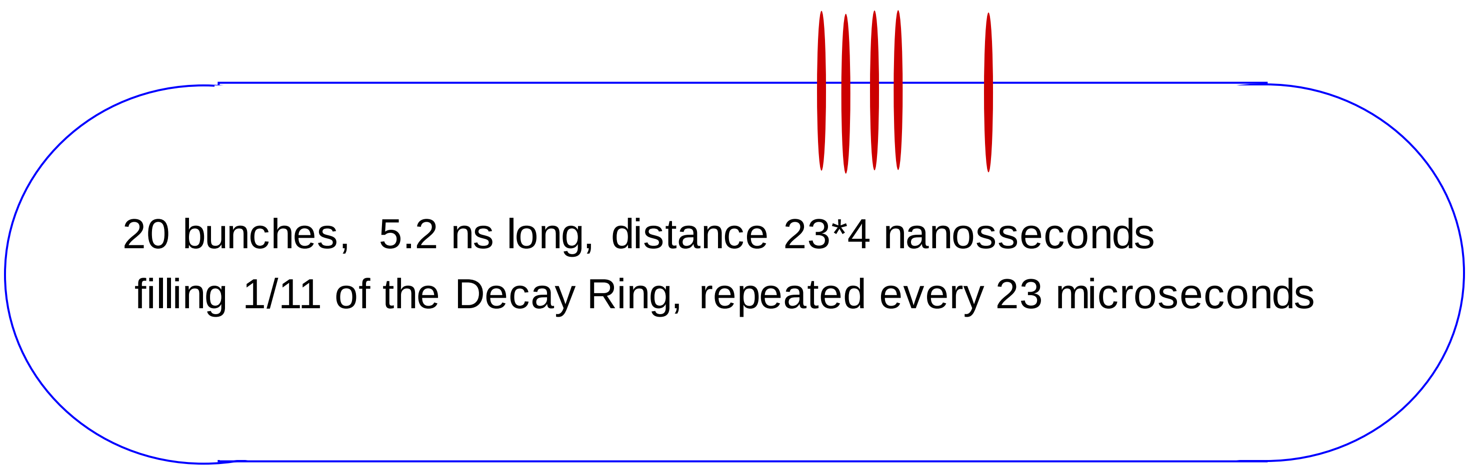
Phase slip factor changed

C. Hansen, CERN & A. Chance, CEA

Atm. Background suppression

10^{14} ions, ~0.5% duty (supression) factor can now be reduced

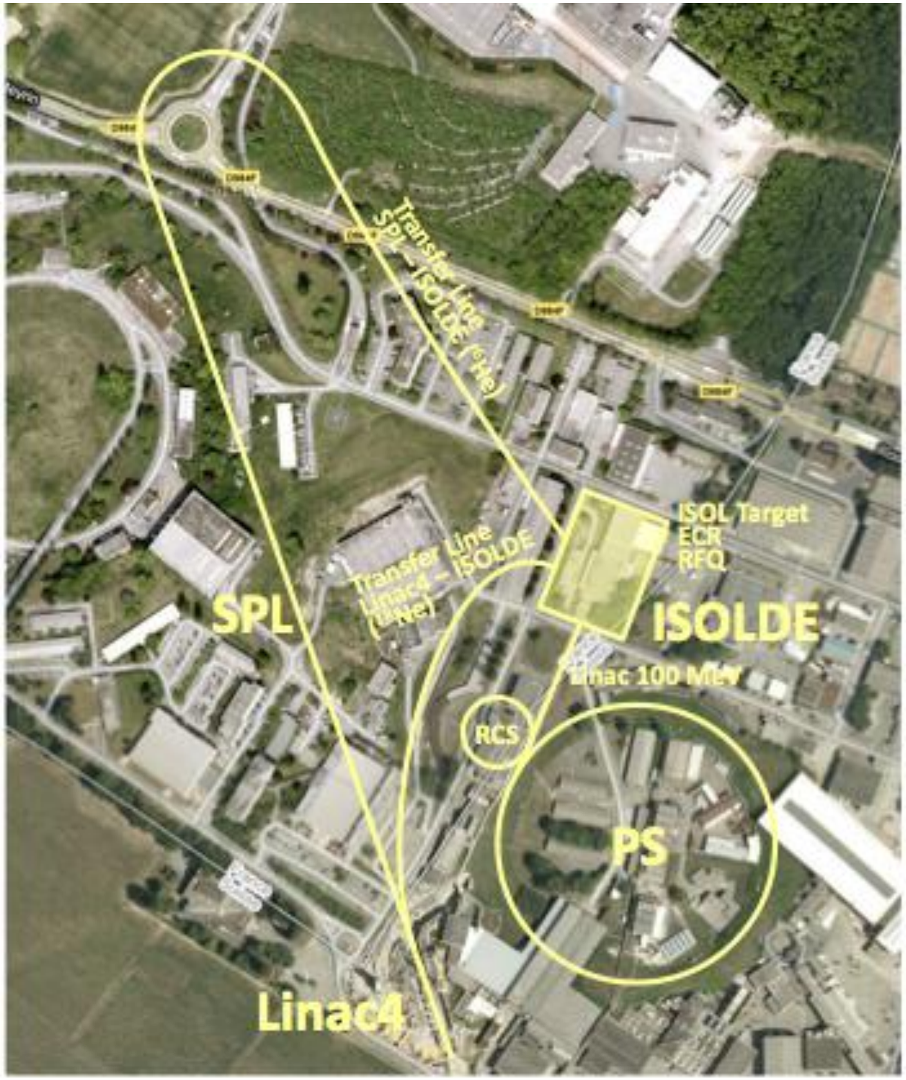
Gives possibilities to give more neutrino flux



Work on HW feasibility by
Cockroft institute/Lancaster Univ.
G. Burt

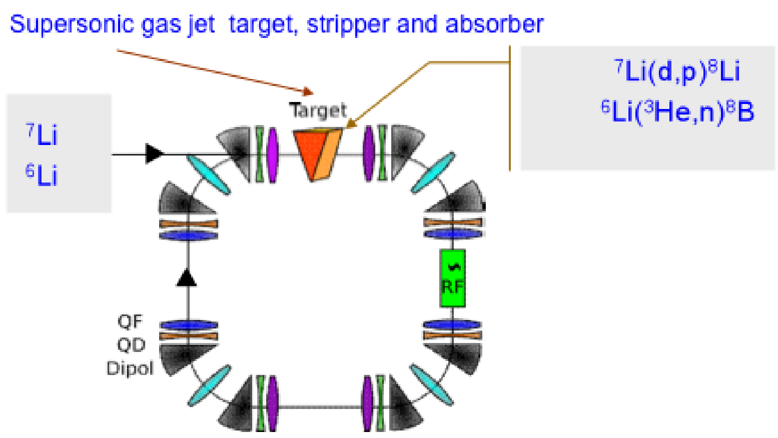
Implementation and Costing

- How to chose a facilty?
- Performance/Cost
- Part of EUROnu mandate
- Synergy βB/SB
- Safety has to be included

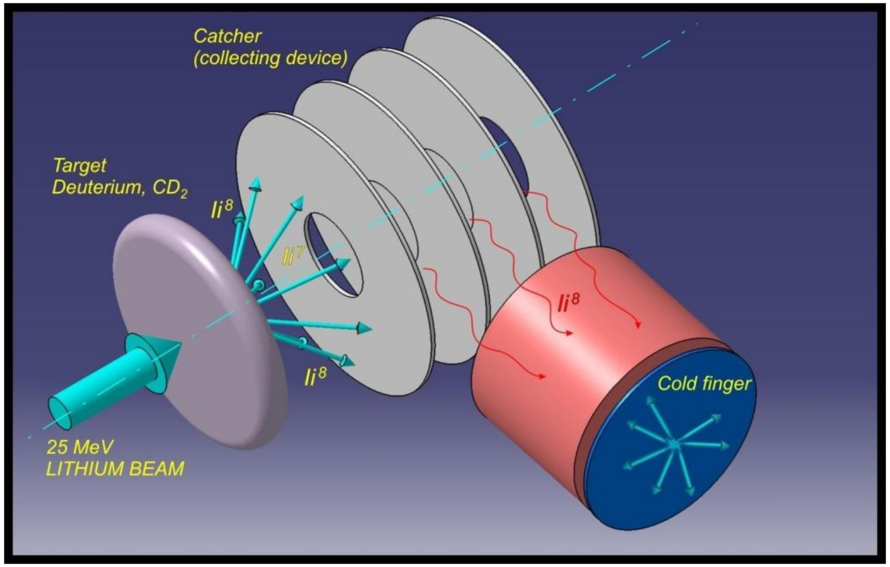


Collection device

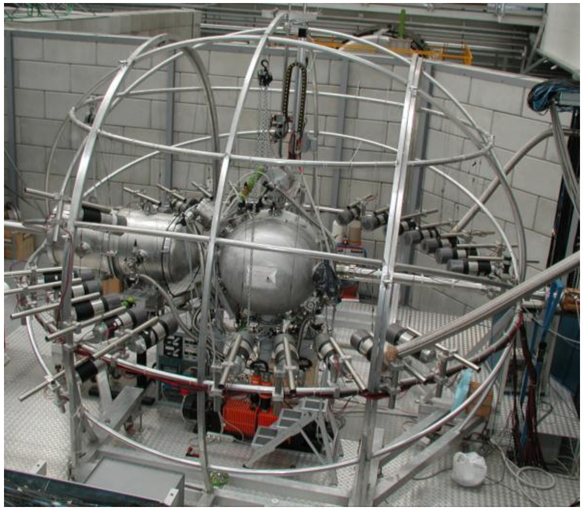
- **Measurements/Analysis ongoing for the collected 8Li**
- **Direct kinematics is possible, efficiencies to be evaluated**
- **Setup and measurements for 8B production and collection ongoing**



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*

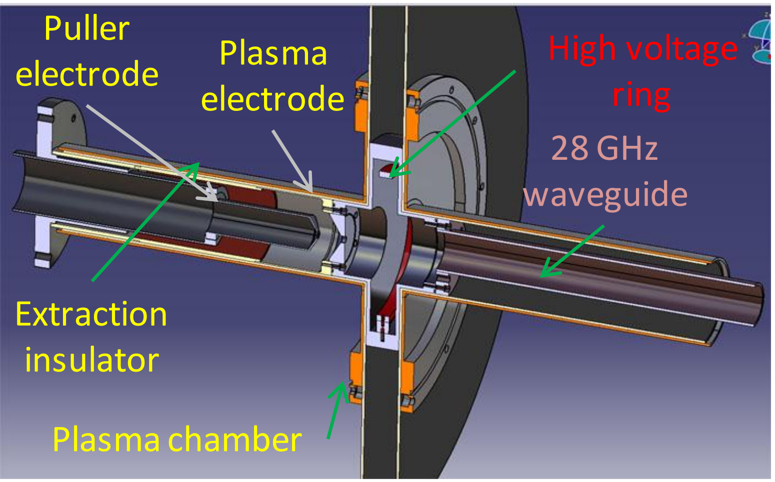
Spokesperson: V.L. Kravchuk - kravchuk@lnl.infn.it
Spokesperson: E. Wildner - Elena.Wildner@cern.ch

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

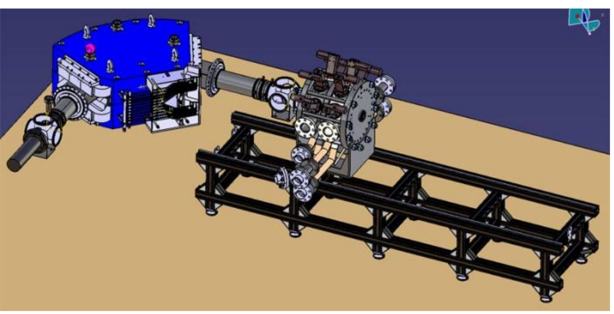
Measurements are finished !

INFN, Legnaro

60 GHz Source status



Conceptual design of the internal parts of the ECRIS prototype
Delivery of the GANIL 28 GHz gyrotron to LPSC
LPSC-LNCMI discussions for experiments
Ion beam at 28 GHz with SEISM prototype (fall 2011)
Magnetic field measurements, 30000 A (60 GHz)



Design of the High intensity beam line
Follow-up the 60 GHz gyrotron building

The SEISM Collaboration

LPSC Euronu contract status
Hiring a one year post-doc

T. Lamy