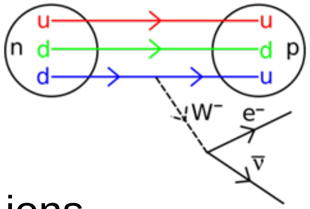
Beta Beams

ion production

Elena Wildner

Beta Beams, recall

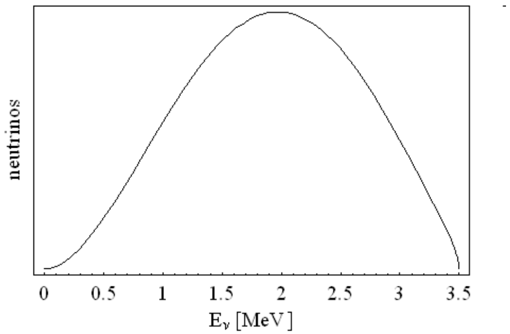


Aim: production of (anti-)neutrino beams from the beta decay of radio-active ions circulating in a storage ring (race track).

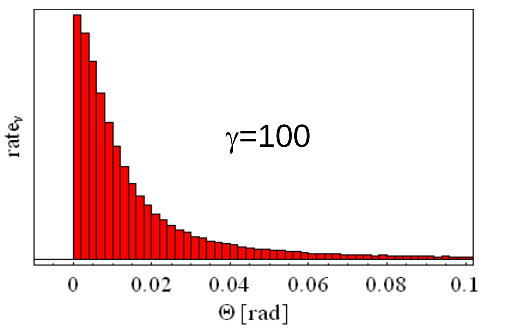
- Similar concept to the neutrino factory, but parent particle is a beta-active isotope instead of a muon.
- Both neutrinos and antineutrinos are needed

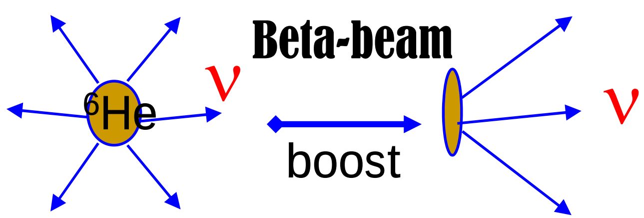
Piero Zucchelli:
Phys. Let. B, 532 (2002) 166-172

- Beta-decay at rest
  - ν–spectrum well known from electron spectrum
  - Reaction energy Q typically of a few MeV (neutrino energy)
  - Only electron (anti-)neutrinos



- Accelerated parent ion to relativistic γ_{max}
  - Boosted neutrino energy spectrum: $E_\nu \leq 2\gamma Q$
  - Forward focusing of neutrinos: $\theta \leq 1/\gamma$





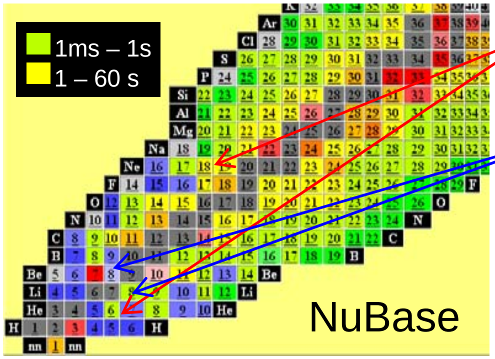
Choice of radioactive ion species

- Beta-active isotopes
  - Production rates
  - Life time

- Reasonable life-time at rest
  - If too short: decay during acceleration
  - If too long: low neutrino production
  - Optimum life time given by acceleration scenario
  - In the order of a second (at rest)

- Low Z preferred
  - Minimize ratio of accelerated mass/charges per neutrino produced
  - One ion produces one neutrino.
  - Reduce space charge problems

$t_{1/2}$ at rest (ground state)



6He and 18Ne

8Li and 8B

EURISOL DS

Isotope	A/Z	T ½ (s)	Q_β g.s to g.s (MeV)	Q_β eff (MeV)	E_β av (MeV)	E_ν av (MeV)	Ions/bunch	Decay rate	rate / $E_{\nu\ av}$ (s^{-1})
^{6}He	3.0	0.80	3.5	3.5	1.57	1.94	$5\cdot10^{12}$		
^{8}He	4.0	0.11	10.7	9.1	4.35	4.80	$5\cdot10^{12}$		
^{8}Li	2.7	0.83	16.0	13.0	6.24	6.72	$3\cdot10^{12}$		
^{9}Li	3.0	0.17	13.6	11.9	5.73	6.20	$3\cdot10^{12}$		
^{11}Be	2.8	13.8	11.5	9.8	4.65	5.11	$3\cdot10^{12}$		
^{15}C	2.5	2.44	9.8	6.4	2.87	3.55	$2\cdot10^{12}$		
^{16}C	2.7	0.74	8.0	4.5	2.05	2.46	$2\cdot10^{12}$		
^{16}N	2.3	7.13	10.4	5.9	4.59	1.33	$1\cdot10^{12}$		
^{17}N	2.4	4.17	8.7	3.8	1.71	2.10	$1\cdot10^{12}$		
^{18}N	2.6	0.64	13.9	8.0	5.33	2.67	$1\cdot10^{12}$	$2\cdot10^{10}$	$6\cdot10^{9}$

Isotope	A/Z	T ½ (s)	Q_β g.s. to g.s. (MeV)	Q_β eff (MeV)	E_β av (MeV)	E_ν av (MeV)	Ions/bunch	Decay rate (s^{-1})	rate / $E_{\nu\ av}$ (s^{-1})
^{8}B	1.6	0.77	17.0	13.9	6.55	7.37	$2\cdot10^{12}$	$2\cdot10^{10}$	$2\cdot10^{9}$
^{10}C	1.7	19.3	2.6	1.9	0.81	1.08	$2\cdot10^{12}$	$6\cdot10^{8}$	$6\cdot10^{8}$
^{14}O	1.8	70.6	4.1	1.8	0.78	1.05	$1\cdot10^{12}$	$1\cdot10^{8}$	$1\cdot10^{8}$
^{15}O	1.9	122.	1.7	1.7	0.74	1.00	$1\cdot10^{12}$	$7\cdot10^{7}$	$7\cdot10^{7}$
^{18}Ne	1.8	1.67	3.3	3.0	1.50	1.52	$1\cdot10^{12}$	$4\cdot10^{9}$	$3\cdot10^{9}$
^{19}Ne	1.9	17.3	2.2	2.2	0.96	1.25	$1\cdot10^{12}$	$4\cdot10^{8}$	$3\cdot10^{8}$
^{21}Na	1.9	22.4	2.5	2.5	1.10	1.41	$9\cdot10^{11}$	$3\cdot10^{8}$	$2\cdot10^{8}$

The EURISOL scenario

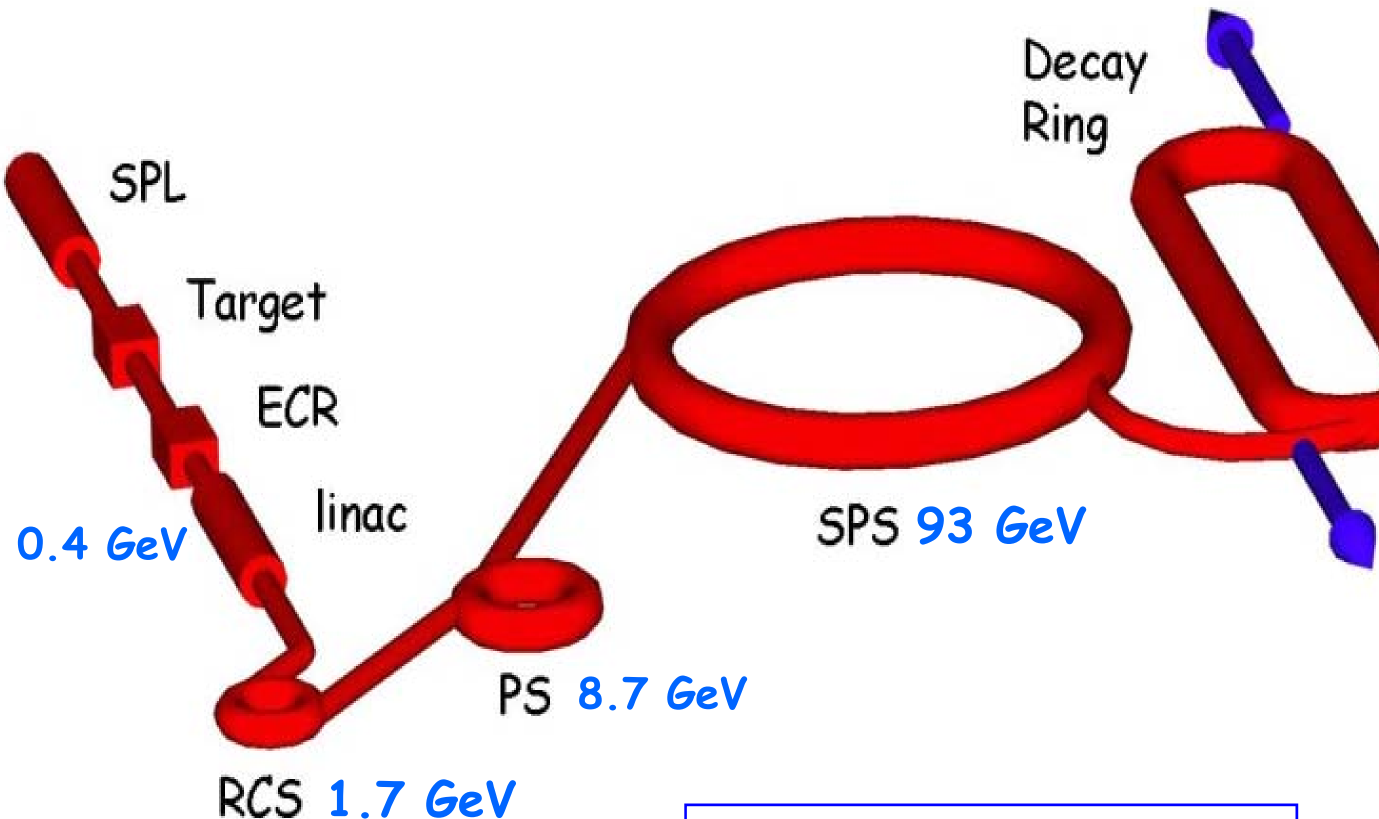
Design Study

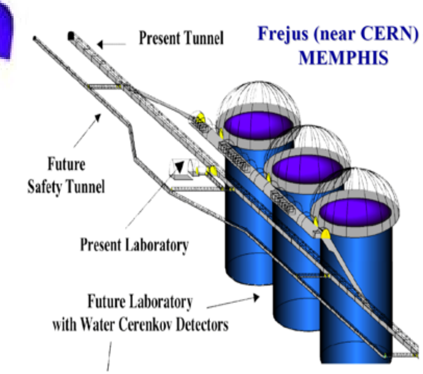
Decay ring

$B\rho$ = 1500 Tm

B = ~6 T
C = ~6900 m
L_{ss}= ~2500 m

^{6}He: γ = 100
^{18}Ne: γ = 100





Design report July 2009 !

Ion production (overview)

- ISOL method at 1-2 GeV (200 kW)
  - >1 10^{13} ^{6}He per second
  - <8 10^{11} ^{18}Ne per second
  - Studied within EURISOL
- Direct production
  - >1 10^{13} (?) ^{6}He per second
  - 1 10^{13} ^{18}Ne per second
  - ^{8}Li ?
  - Studied at LLN, Soreq, WI and GANIL
- Production ring
  - 10^{14} (?) ^{8}Li
  - >10^{13} (?) ^{8}B
  - **Will be studied within EUROν**

Aimed:
He 2.9 10^{18} (2.0 10^{13}/s after target)
Ne 1.1 10^{18} (2.0 10^{13}/s after target)

Courtesy M. Lindroos

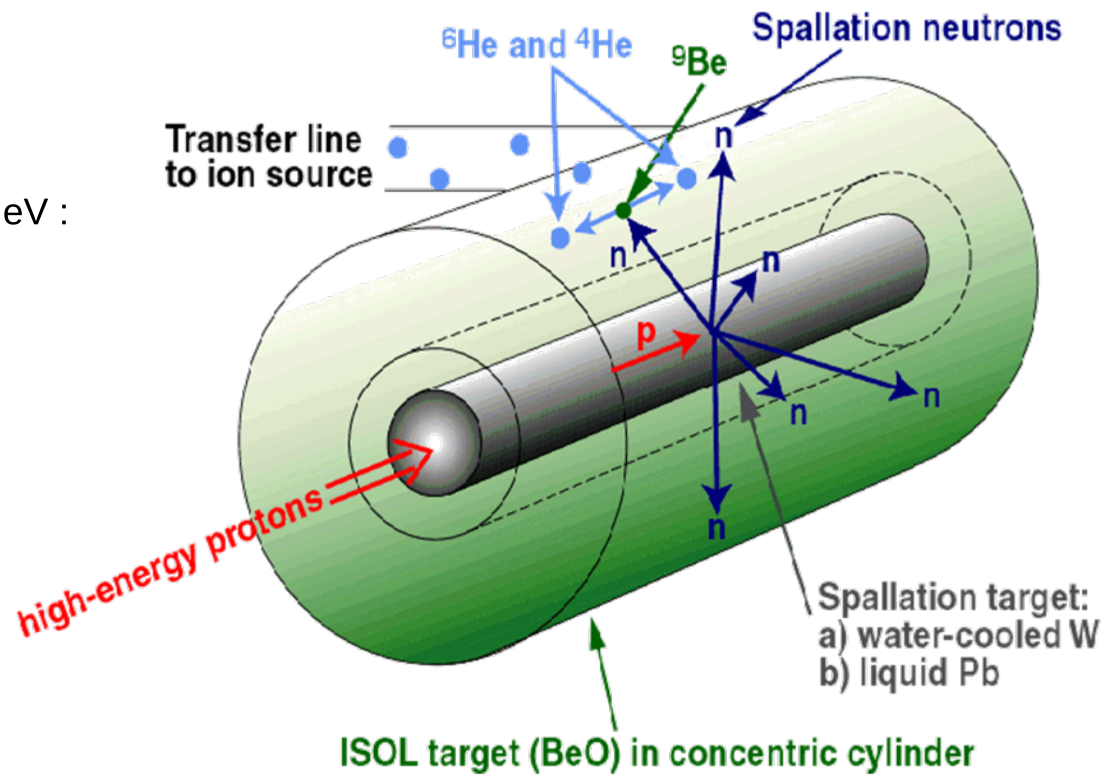
N.B. Nuclear Physics has limited interest in those elements ->> Production rates not pushed!

^{6}He (ISOL)

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

Solid converter W avec protons 1/1.4 GeV :
standard technology at ISOLDE

T. Stora, N. Thollieres, CERN

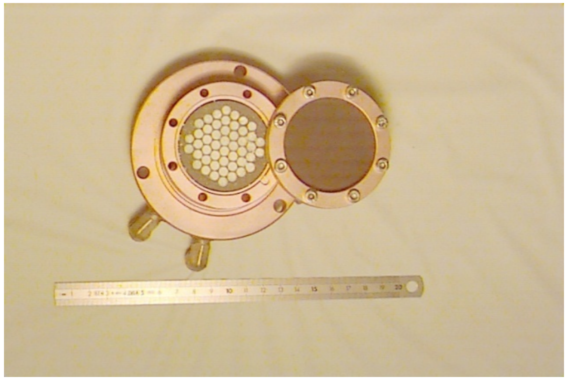


- Converter technology preferred to direct irradiation (heat transfer and efficient cooling allows higher power compared to insulating BeO).
- ^{6}He production rate ~2x10^{13} ions/s (dc) for ~200 kW on target could be expected.

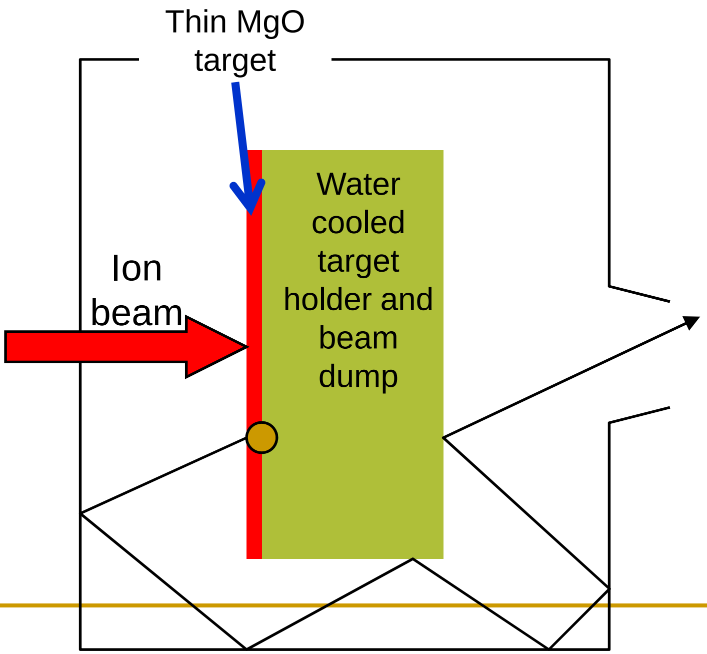
Measurements ISOLDE April 2009

^{18}Ne (Direct Production)

Geometric scaling



- Producing 10^{13} ^{18}Ne could be possible with a beam power (at low energy, 30-40 MeV) of 2 MW (or some 130 mA ^{3}He beam on MgO).
- To keep the power density similar to LLN (today) the target has to be 60 cm in diameter.
- To be studied:
  - Extraction efficiency
  - Optimum energy
  - Cooling of target unit
  - High intensity and low energy ion linac
  - High intensity ion source



S. Mitrofanov and M. Loislet at CRC, Belgium

New approach for ion production

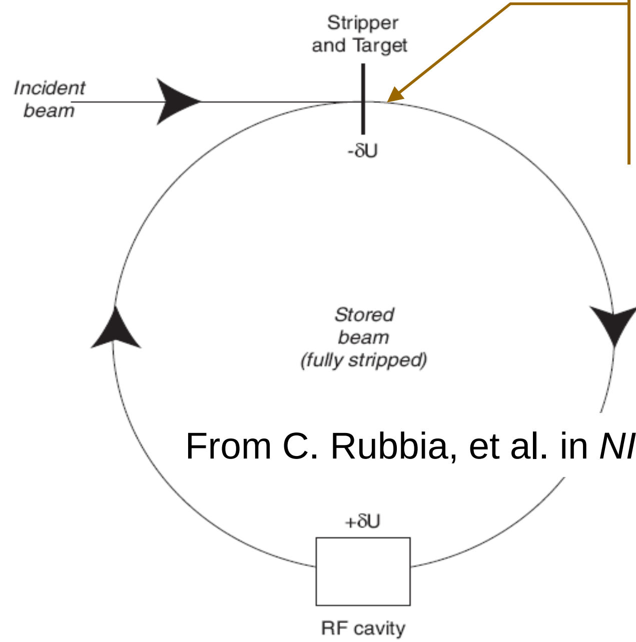
"Beam cooling with ionisation losses" – C. Rubbia, A Ferrari, Y. Kadi and V. Vlachoudis in *NIM A 568 (2006) 475–487*

"Development of FFAG accelerators and their applications for intense secondary particle production", -- Y. Mori, *NIM A 562(2006)591*

^{7}Li

^{6}Li

20-30 MeV



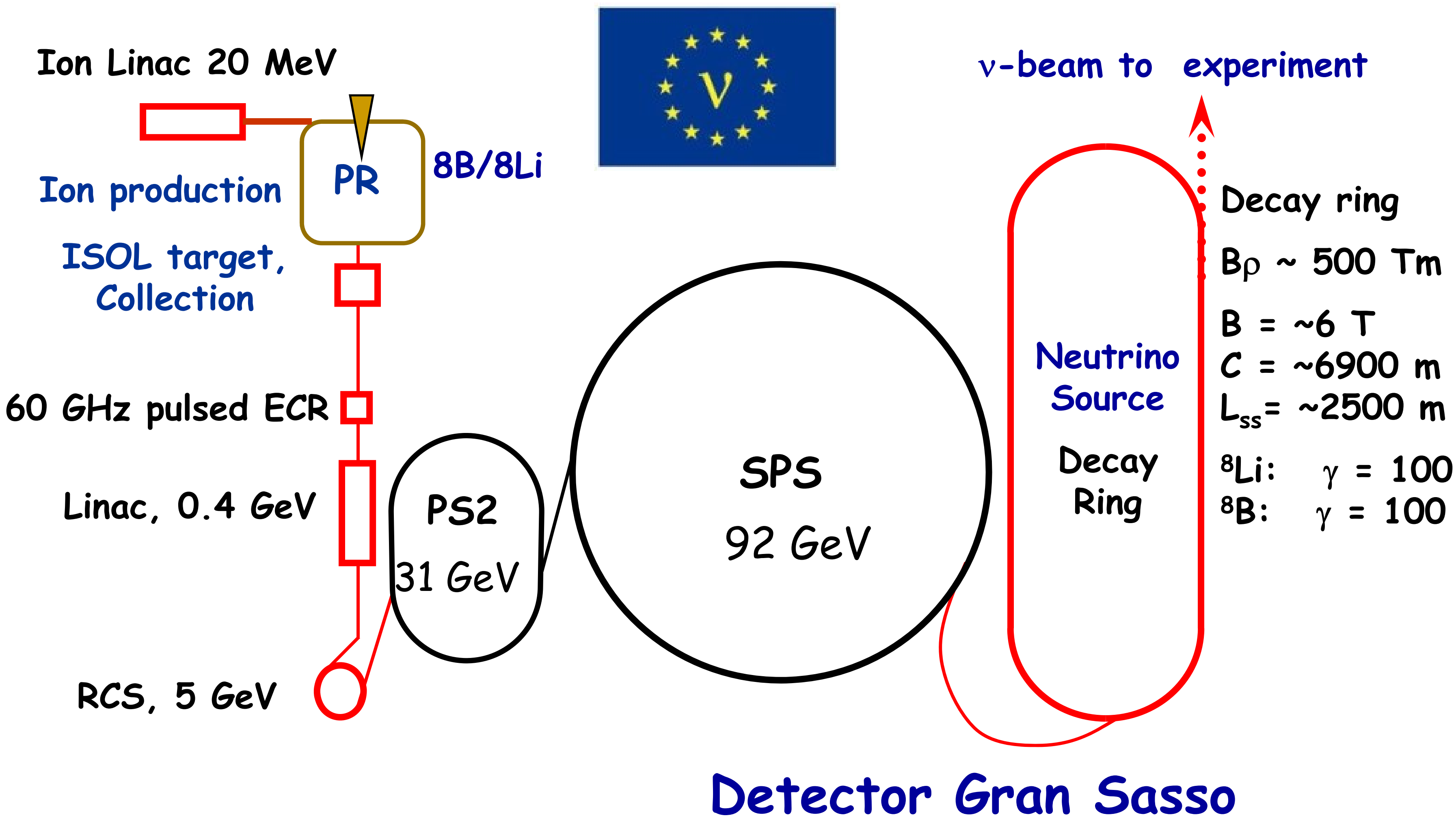
$^{7}Li(d,p)^{8}Li$

$^{6}Li(^{3}He,n)^{8}B$

From C. Rubbia, et al. in *NIM A 568 (2006) 475–487*

Chemistry with Boron?

Beta Beam scenario EUROν (FP7)



ISOL, 6He/18Ne and 8B/8Li

- 6He
  - Tests of BeO at 3 kW at ISOLDE, analysis ongoing, encourageing!
  - 2 GeV, 200kW, on water-cooled W
- 18Ne
  - To be studied (Frame-work, Priority?)
  - 4MW, 1 GeV on Hg?
  - Rotating/multiple targets/large beams (Ta, W)?
- 8Li
  - Similarities with 6He: should be possible
  - To be measured
- 8B
  - No beam ever produced
  - Many ideas exist. Need development (Frame-work, Priority?)
  - B is reactive (difficulties to get it out of the target)

ISOL, Rare Earth Metals

- Other possible scenarios in a beta beam complex
  - Electron capture and beta decay, Barnabeu et. al*
  - Electron capture: mono energetic ν-beam
  - One species only
  - Interesting physics reach
- Yb…
  - Similarities with 18Ne
  - To be studied (Frame-work, Priority?)
  - 4MW, 1 GeV on Hg?
  - Rotating/multiple targets/large beams (Ta, W)?

** arXiv: 0902.4303v1 [hep-ph] 27 Feb 2009*

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- EUROnu FP7 program specification

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