WP4 General &
The Beta Beam Accelerator Complex

Elena Wildner
for WP4

Layout of talk

EUROnu WP4, Beta Beams: Recall

Events

Overall Progress

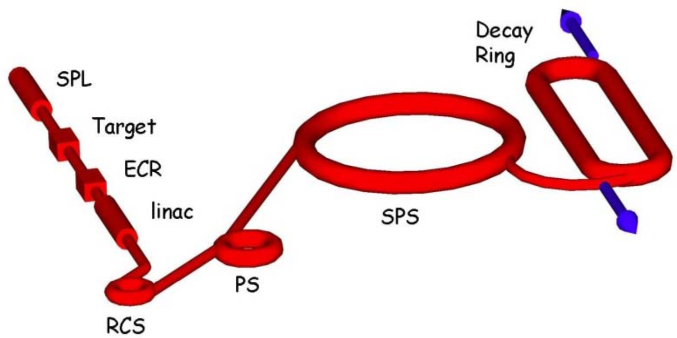
CERN Progress

Conclusion

The EURISOL scenario

EURISOL Design Study

EURISOL scenario



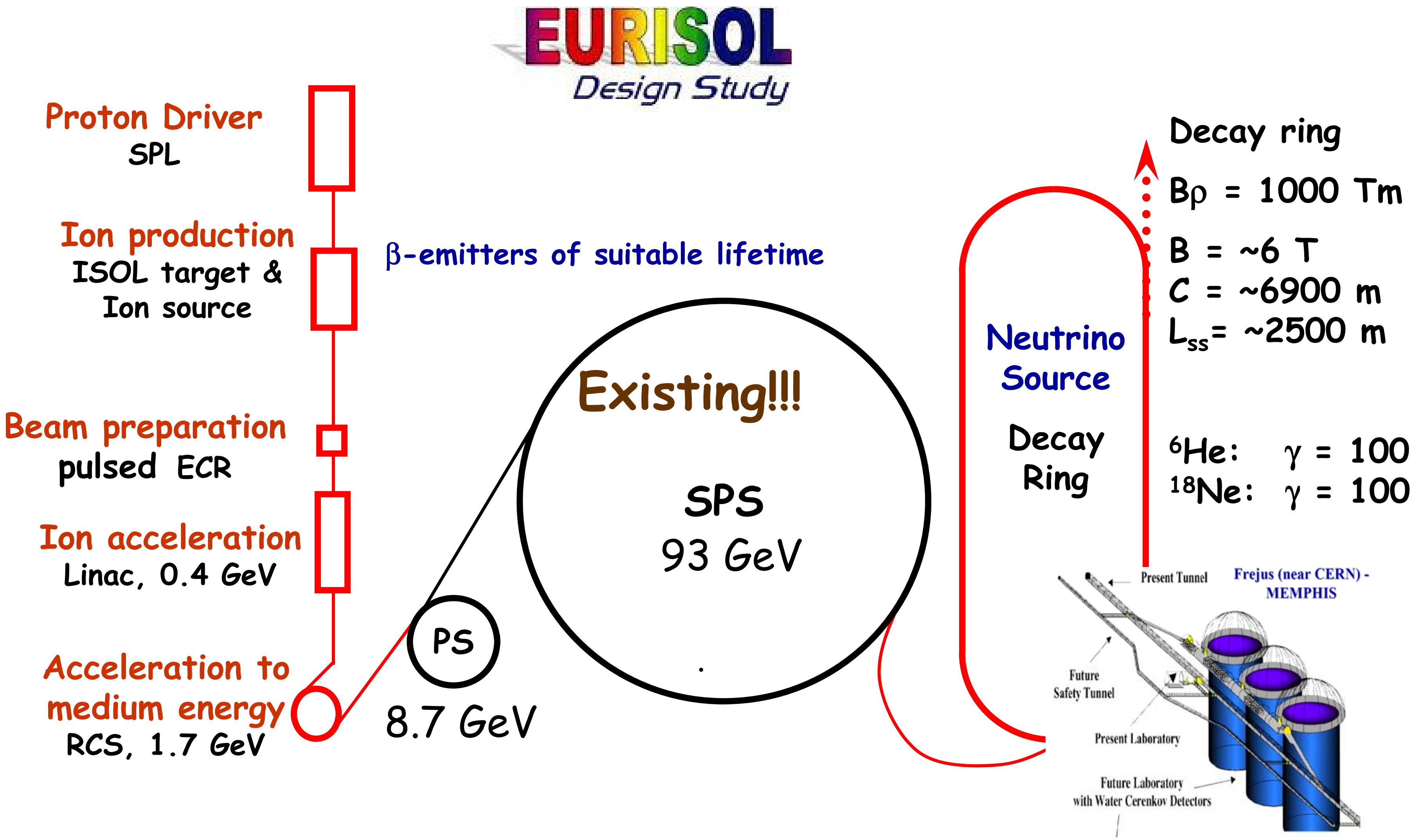
- Based on CERN boundaries
- Beta emitter ion choice: ^{6}He and ^{18}Ne
- Based on existing technology and machines
- Relativistic gamma is 100 for both ions
  - SPS allows maximum of 150 (^{6}He) or 250 (^{18}Ne)
  - Gamma-choice optimized for physics reach
- Opportunity to share a Mton Water Cherenkov detector with a CERN super-beam, proton decay studies and a neutrino observatory

- Achieve an annual neutrino rate of
  - 2.9×10^{18} anti-neutrinos from ^{6}He
  - $1.1\ 10^{18}$ neutrinos from ^{18}Ne

top-down approach

- The EURISOL scenario will serve as reference for further studies and developments: Within Euroν we will study ^{8}Li and ^{8}B

Recall of Beta Beam scenario, EURISOL



Detector in the Frejus tunnel

Radioactive ion production rates

- 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)
Ne 1.1 10^{18} (2.0 10^{13}/s)

Courtesy M. Lindroos

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

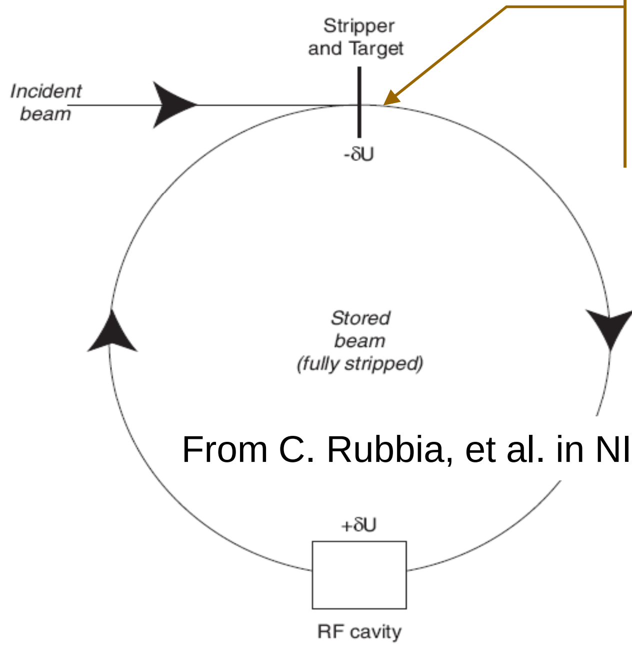
New approach for ion production

"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 A562(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

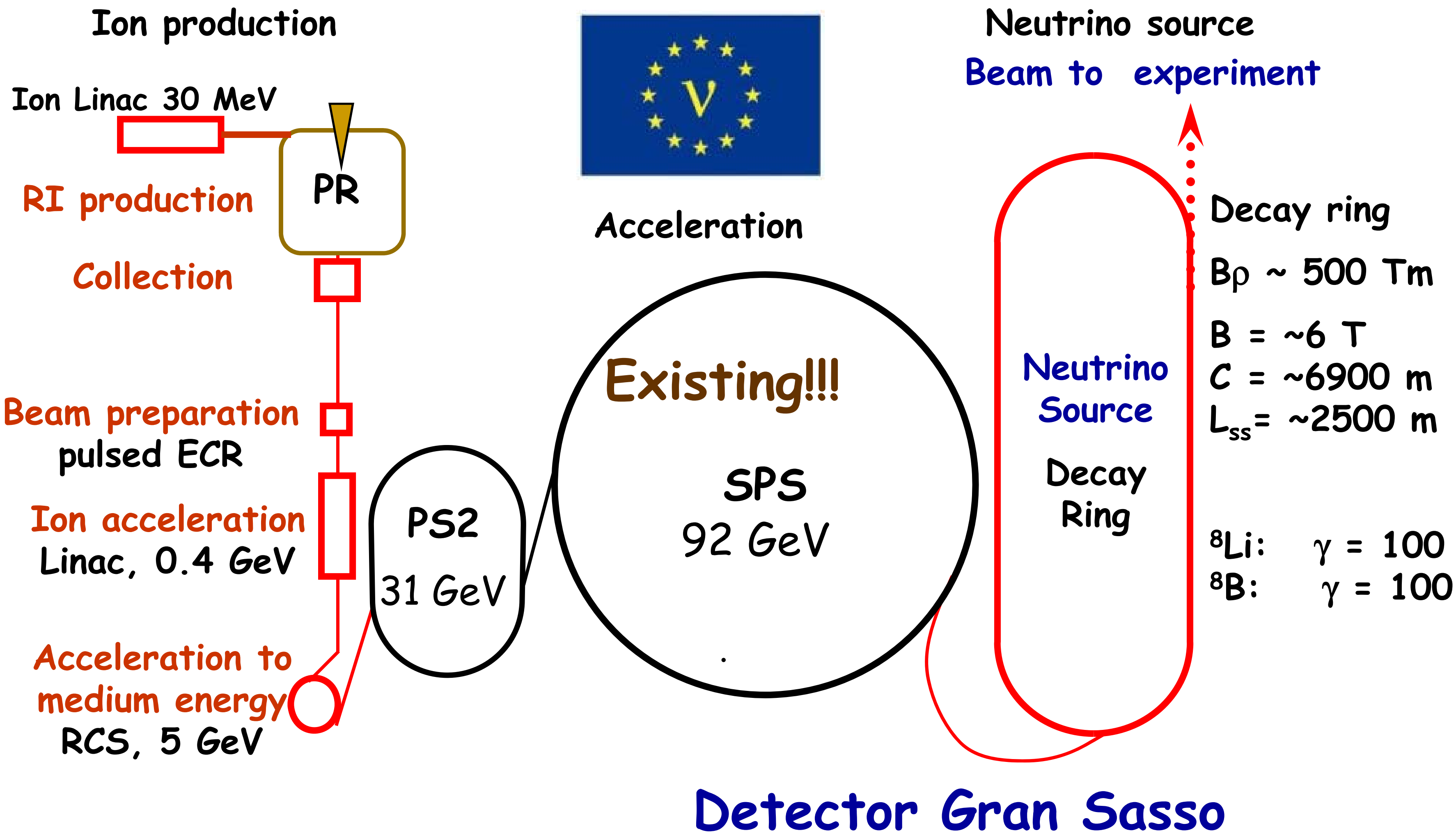
Chemistry with Boron?

Other optimization possible

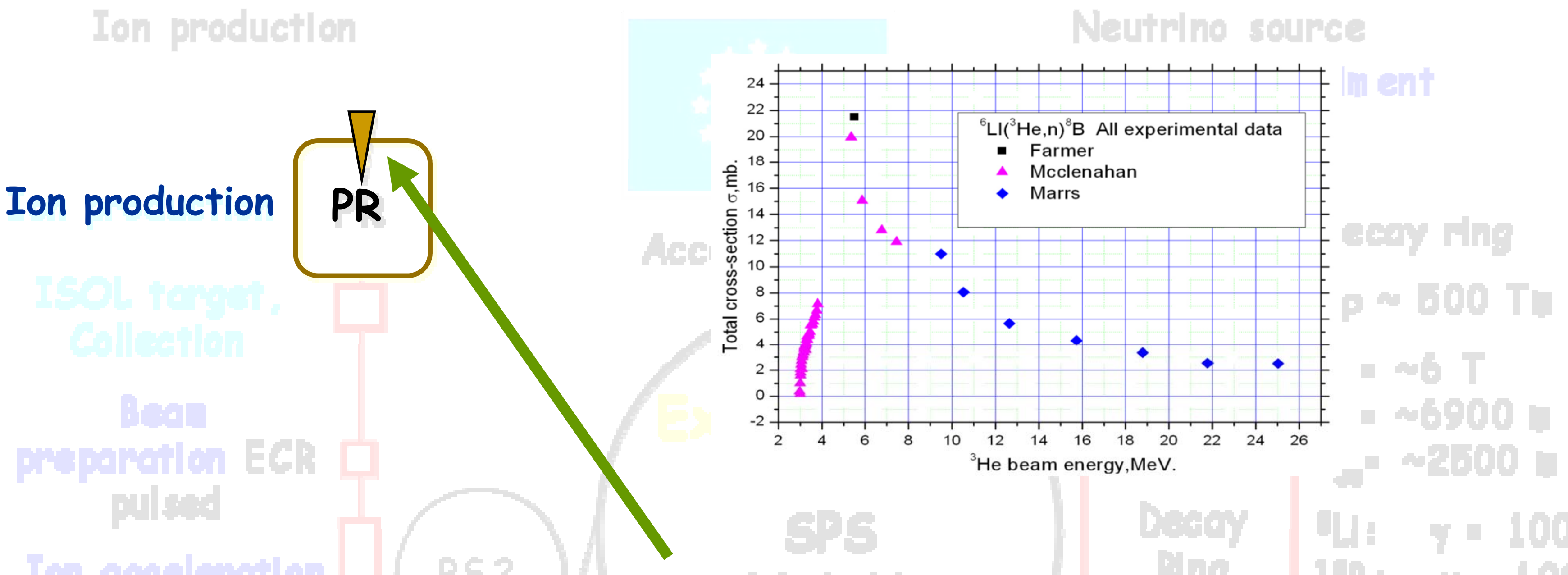
Not all directly Euronu mandate

- Overall accelerator chain cycle optimization
- Decay Ring RF (no specific duty cycle needed for higher Q ions)
- Decay Ring layout (shorter arcs)
- Low energy accumulator (profit of cycle dead times for production)
- Multiple charge state LINACs
- Review project with SPS+ (higher gamma)
- Green Field Scenarios
- Carefully follow research and adapt accordingly
  - 18Ne/6He production
  - Electron capture beta beams
- …

WP4, Beta Beam scenario EUROnu



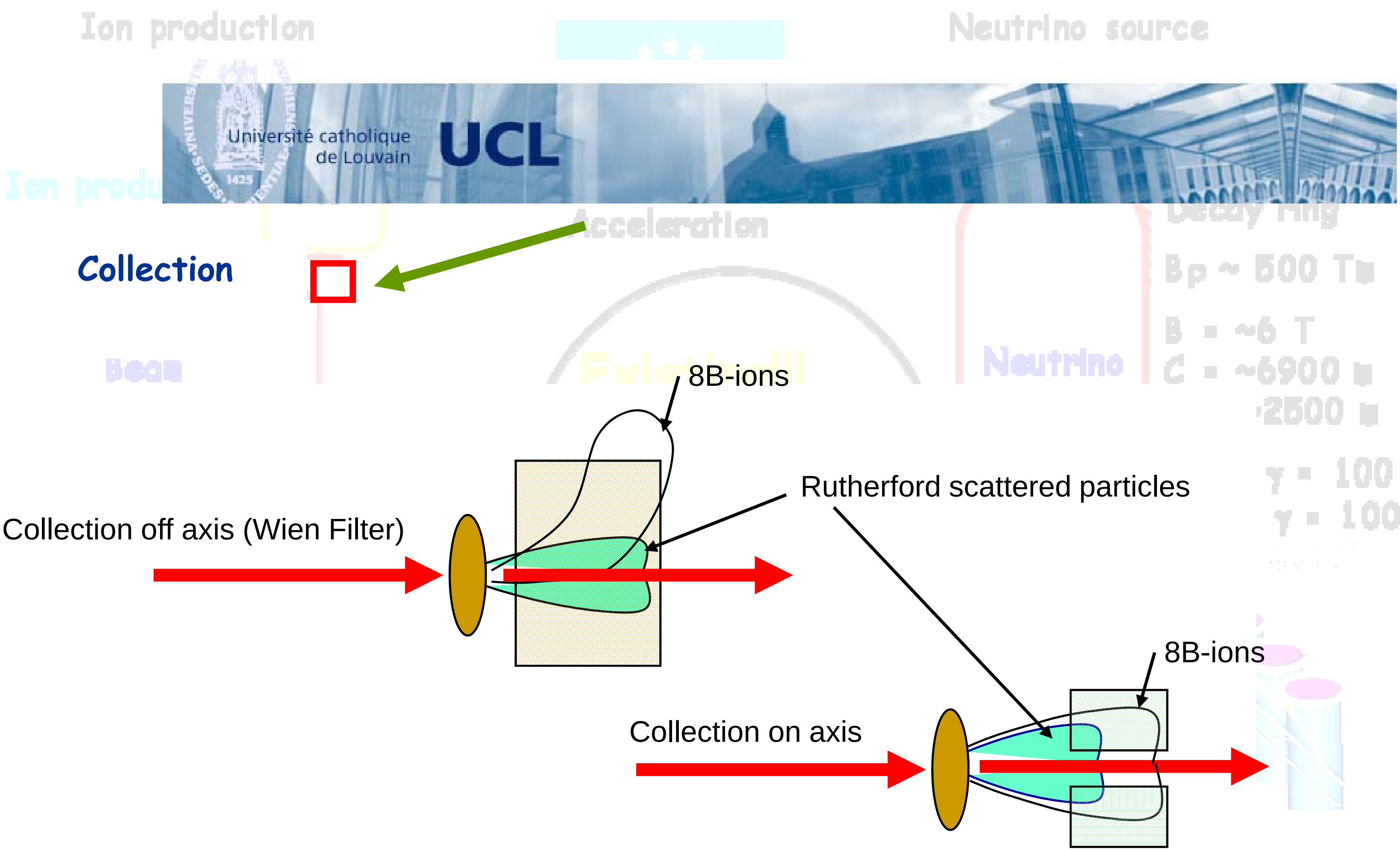
Cross Section Measurements, INFN LNL



INFN Istituto Nazionale di Fisica Nucleare

Laboratori Nazionali di Legnaro

Collection device, UCL

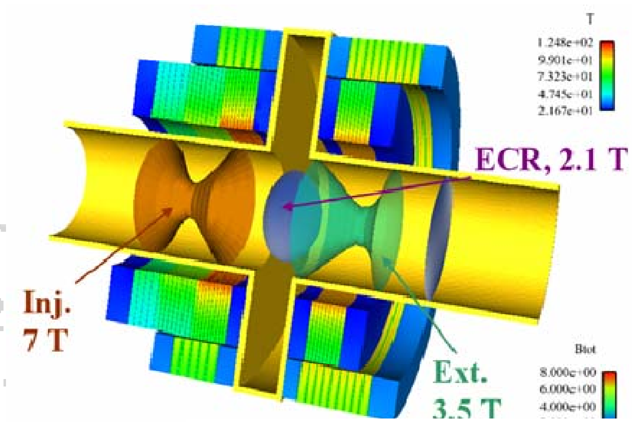


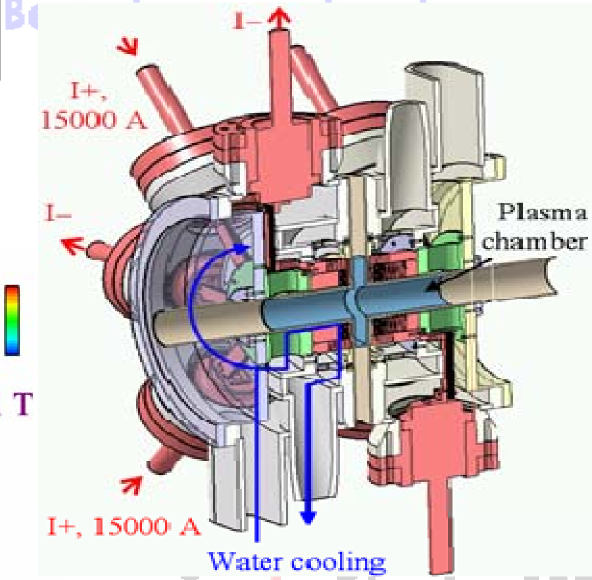
ECR Source

Laboratoire de Physique Subatomique et de Cosmologie

Laboratoire National des Champs Magnétiques Intenses
Site Grenoble

Beam preparation:
pulsed ECR

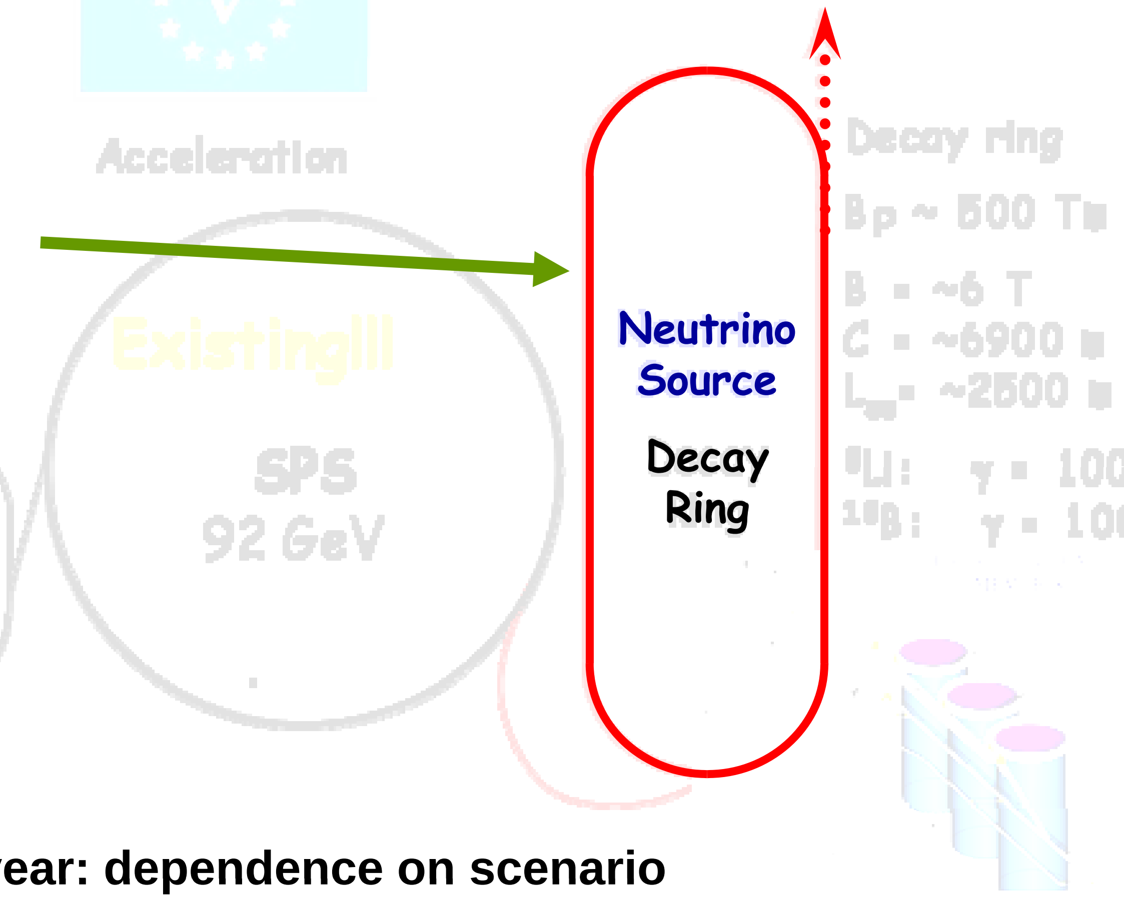




60 GHz ECR Ion Source (B, Li, He, Ne)
Short pulses (50 msec) of radioactive ion beams
The 3D magnetic field structure to confine plasma

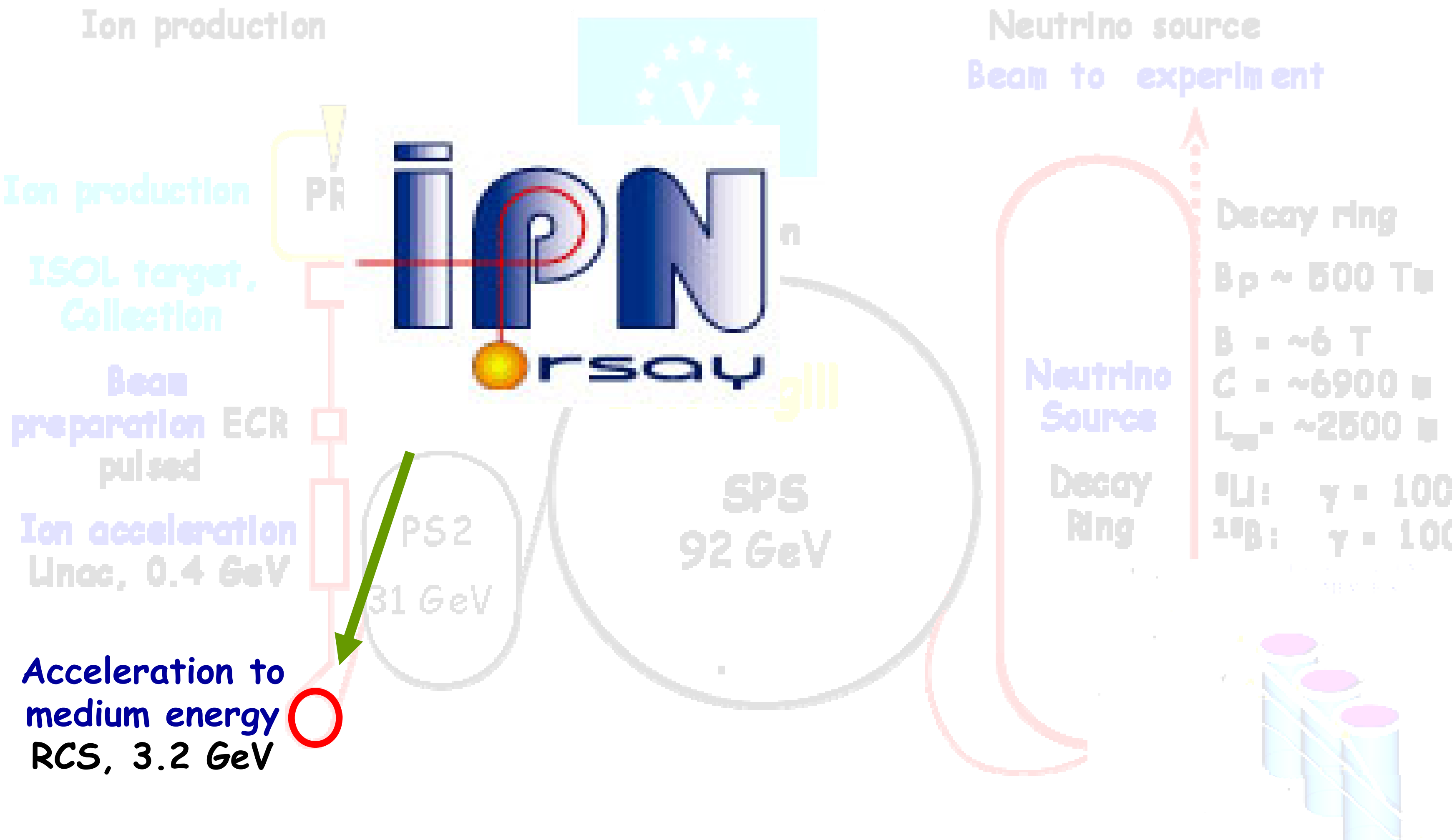
Decay ring Layout and Lattice

CEA, L'Irfu, Institut de Recherches sur les lois Fondamentales de l'Univers

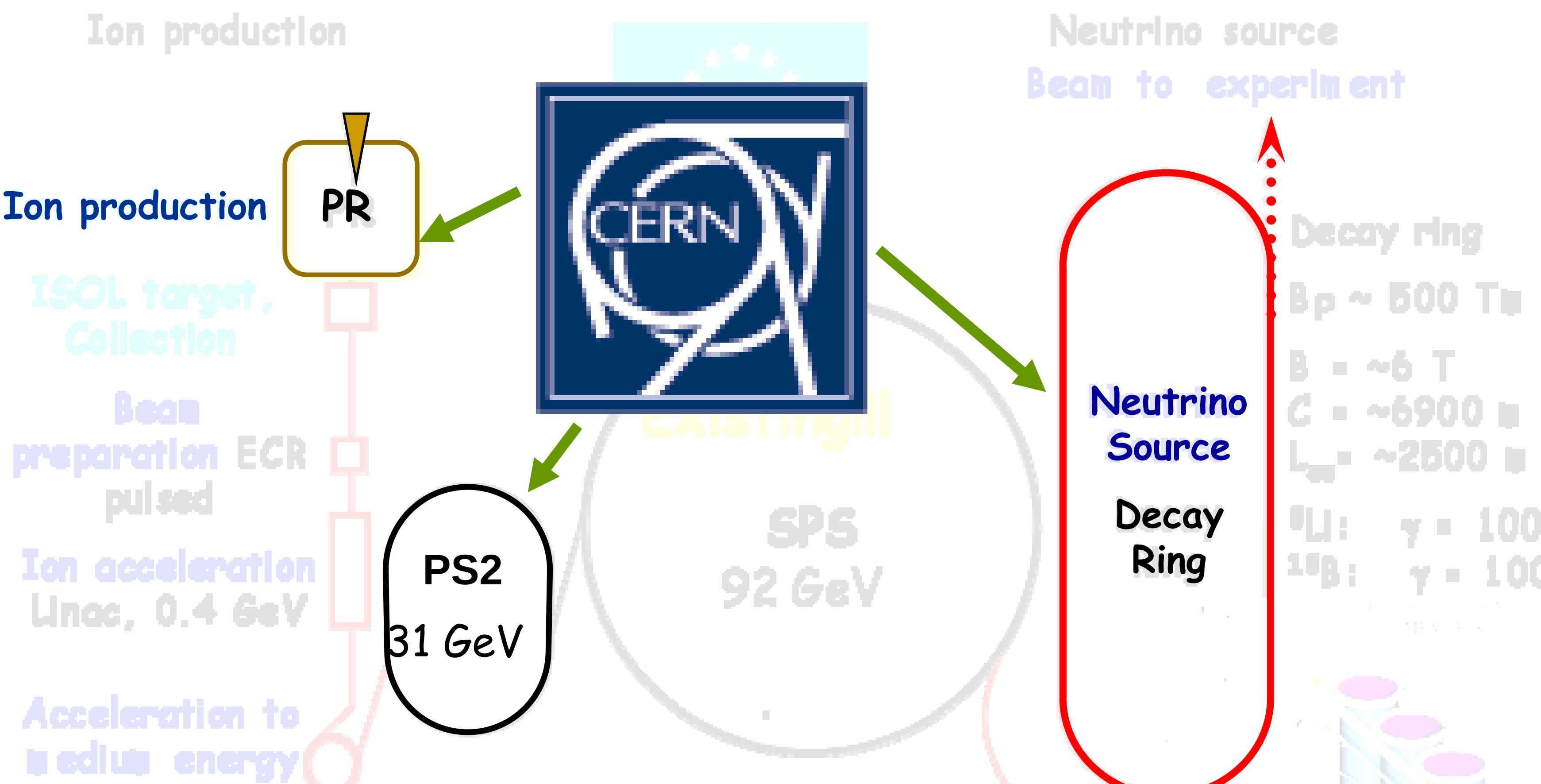


Start second year: dependence on scenario

WP4, Beta Beam scenario EUROnu



WP4, Beta Beam scenario EUROnu



Overall accelerator & parameter data base
Radio Protection

Associates

Argonne National Laboratory (Multiple charge state LINACs)

Russian Academy of Sciences Institute of Applied Physics (ECR)

PPPL Princeton Plasma Physics Laboratory (Gas Jet Target)

TRIUMF (Decay Ring Simulations, ACCIM beam code, tracking of decaying ions)

Contributions from…

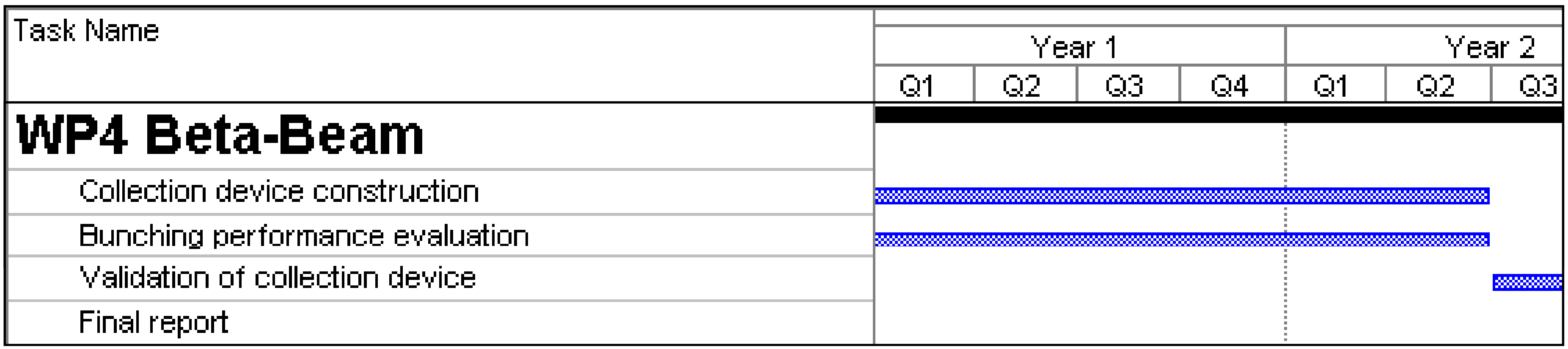
Antoine Chance
Giacomo Deangelis
Francois Debray
Pierre Delahaye
Thierry Delbar
Alfredo Ferrari
Christian Hansen
Michael Hass
Frederick Jones
Yacine Kadi
Thierry Lamy
Mats Lindroos
Michel Martini
Mauro Mezzetto
Semen Mitrofanov
Jerry Nolen

Peter Ostroumov
Vittorio Palladino
Jacques Payet
Jürgen Pozimski
Carlo Rubbia
Achim Stahl
Thomas Thuillier
Andre Tkatchen
Christophe Trophime
Stefania Trovati
Vasilis Vlachoudis
Elena Wildner
Vladimir Zorin
Antoine Lachaize
Elian Bouquerel
….

Kick-off meeting 23/10/08

AGENDA **FP7 EUROnu, Beta Beam Workpackage Kickoff-meeting 23/10/08,** **61-1-009 - Room B (Main Building)**		
10.00	**Welcome**	E. Wildner, CERN
10.10	Beta Beams FP7 overview	E.Wildner, CERN
10.30	Ideas of a beta beam facility at DESY	A. Stahl, Physikalisches Institut Aachen
11.10	Physics with beta beams, requirements and wishes	M.Mezzetto, INFN, Padova
12.00	**Lunch**	
14.00	Decay Ring for 8B and 8Li: lattice	A. Chance, CEA
14.20	60 GHz ECR ion source for RIB's production	L. Latrasse, LPSC
14.40	High Field Magnets	F. Debray, GHMFL, LCMI
15.00	8B and 8Li in the RCS	A. Lachaize, CNRS
15.20	**Coffee**	
15.40	LNL plans for production cross section measurements	G. Prete, INFN, LNL
16.00	Radioprotection (including equipment protection)	S. Trovati, CERN
16.20	High Yield Production of 6He and 8Li RIB forNeutrino Physics	T. Hirsch, Weizmann Institute
16.40	**End**	

Deliverables



Milestones

List and schedule of milestones					
Milestone no.	**Milestone name**	**WPs no's.**	**Lead beneficiary**	**Delivery date**	***Comments***
4.1	Baseline Beta-Beam scenario	4	**3**	12	Documentation reviewed
4.2	Design of collection device	4	**15**	15	Drawings qualified by external expert
4.3	Lattice frozen for production ring	4	**3**	18	Optics qualified by external expert
4.4	New decay ring optics for ^{8}Li and ^{8}B	4	**3**	21	Optics qualified by external expert
1.3	Review on interim milestones, deliverables & costs	All	**1**	24	Reviewed by Governing Board
4.5	Interim report on reaction channels, collimation and magnet protection	4	**3**	24	Report reviewed
6.3	Scenarios for the B and Li Beta Beams	6,4	**6**	24	Report reviewed
6.4	Physics performance of all facilities with update of fluxes	6,5,4	**6**	24	Report reviewed
4.6	Full simulation of production ring	4	**2**	36	Simulation results reviewed
6.6	Comparison of physics performance of all facilities	6,2,3,4,5	**6**	43	Report reviewed

Progress and Plans CERN

- Review of baseline design, ongoing
  - PS2 integration (minimum)
    - RCS
    - Overall cycle and bunch structure
- Relax of requirements of bunch structure in the Decay Ring
  - Barrier buckets in Decay Ring
  - Bunch structure of preceding accelerators
- Production ring
  - Selection of staffing ongoing
- Parameter list
  - Database structure and setup, ongoing
  - Filling, depending on baseline review, being prepared
- Decay Ring Superconducting Magnets
  - Open mid-plane dipole and quadrupole design has been done (energy deposition and radiation checks with 8B and 8Li beam remaining)

Dependencies

- ECR source
  - Specification of beam parameters after source
- RCS
  - Depends on PS2 integration, extraction energy, bunching and cycling
- Decay Ring Layout
  - Magnet layout
  - Injection (barrier buckets)
  - Collimation (barrier buckets)
  - RF
- Collection device
  - Production Ring Simulations
- Radio Protection Studies
  - Decay Ring Layout and RF
  - RCS design (Injection Chopper)
  - PS2

Ion production, first steps

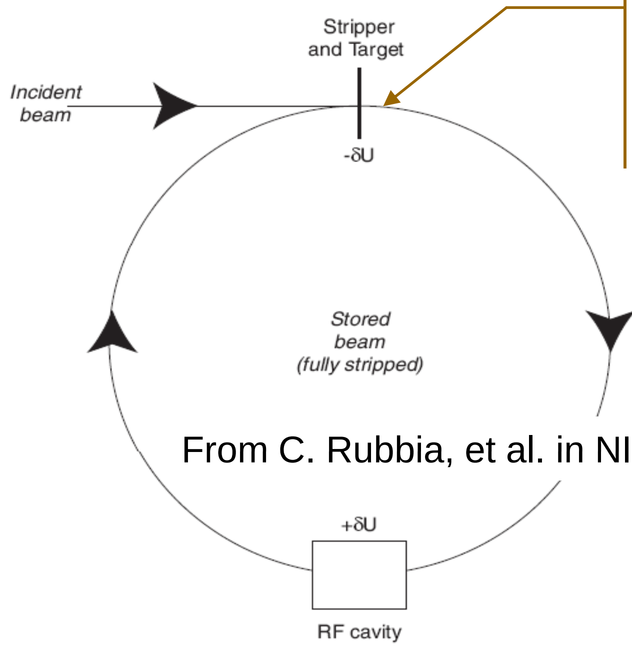
- Lattice for Production Ring
- 6D Cooling
- Simulation with target

Start 01/08/09

^{7}Li

^{6}Li

20-30 MeV

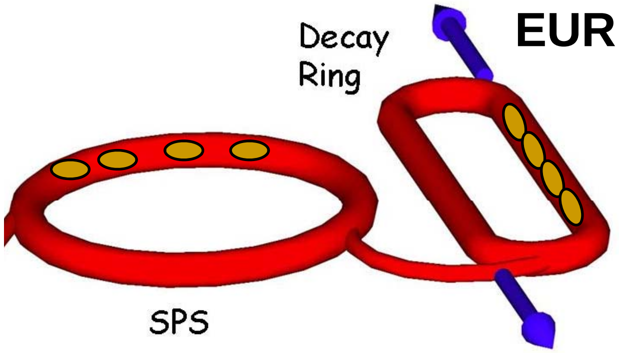


$^{7}Li(d,p)^{8}Li$

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

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

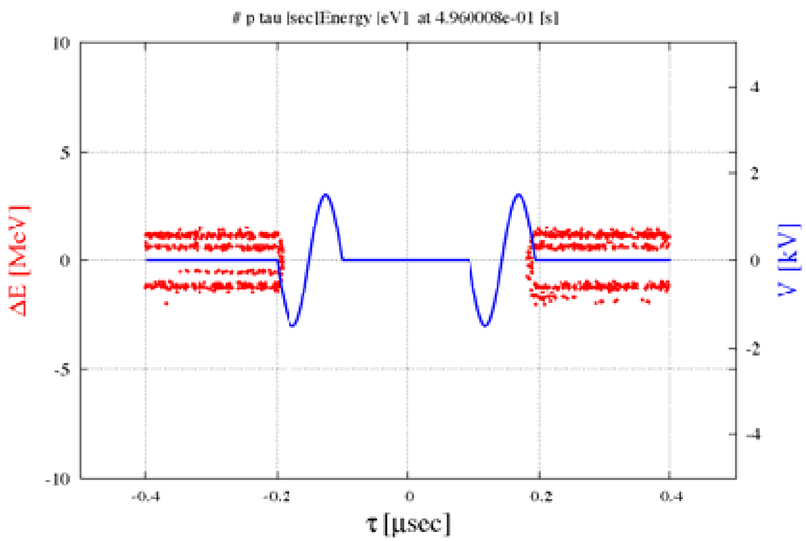
Relaxing the duty-cycle for higher energy neutrinos

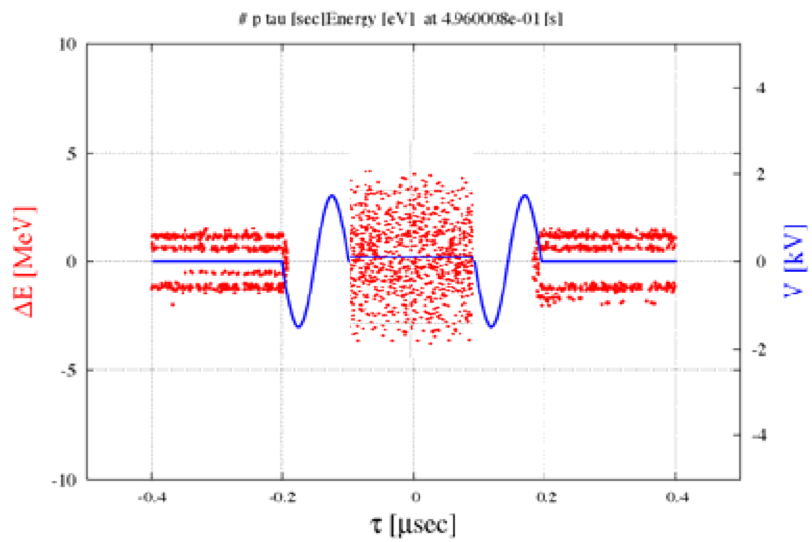


EURISOL Scenario

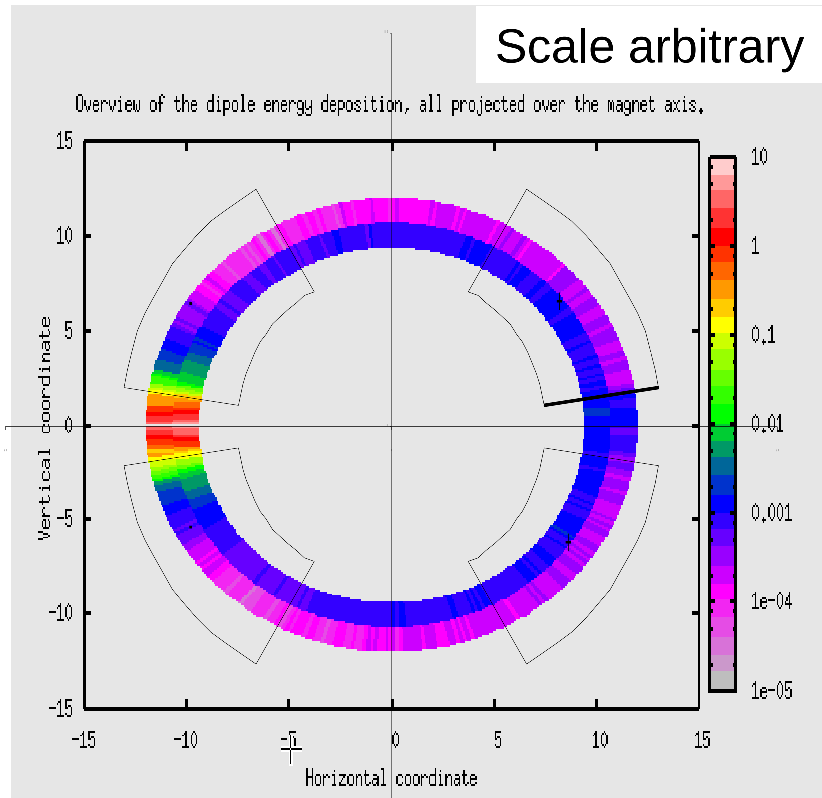
Filling of decay ring using barrier buckets

Start 01/08/09





Open midplane superconducting magnets for decay ring



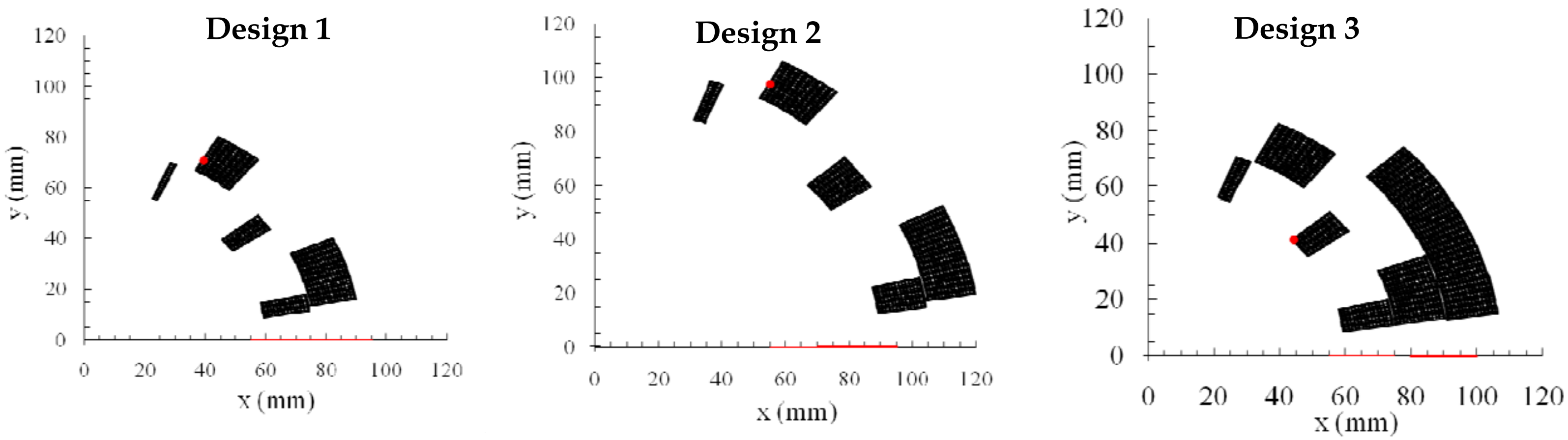
- Design ok for the present layout of the decay ring
- check for energy deposition
- radio protection (B and Li)
- check if larger apertures with liner a better option

Acknowledgments (magnet design, cryostating, cryogenics):
Jens Bruer, F Borgnolutti, P. Fessia, R. van Weelderen , L. Williams and E. Todesco (CERN)

Three designs, Decay Ring Dipole

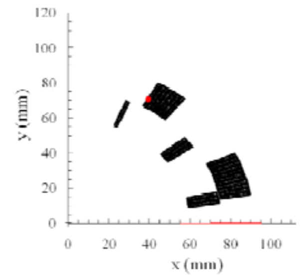
Design	1	2	3
Aperture radius (mm)	60	90	60
B_{ss} at 1.9 K (T)	6.5	6.8	8.7
Operational field at 1.9 K (T)	5.2	5.5	7.0
B_{ss} at 4.2 K (T)	4.9	5.3	6.7
Operational field at 4.2 K (T)	4.0	4.2	5.4
Gap in midplane (mm)	8.9	12.5	8.7
Yoke (mm)	180	270	240

Courtesy Jens Bruer

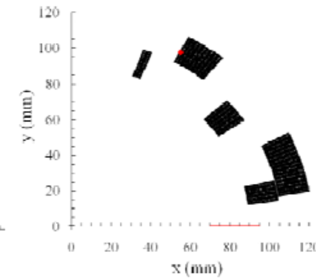


Cost estimation, Decay Ring Dipole

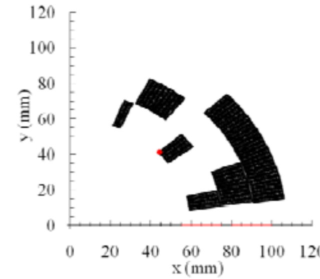
- For magnet fabrication and assembling, calculated for a 13 m long dipole



Design 1



Design 2



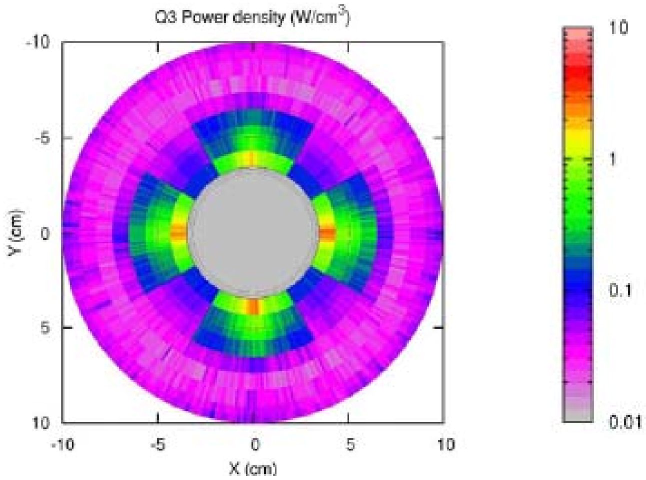
Design 3

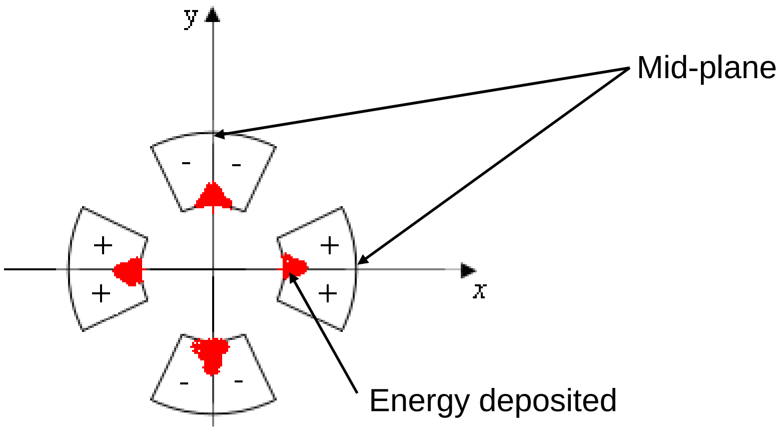
Requires 1.9K !!

Cost (MCHF per unit)	Design 1	Design 2	Design 3
Magnet (material + fabrication)	0.71	0.76	0.82
Cryostat	0.1	0.1	0.1
Cryoplants at 1.9 K	0.3	0.3	0.3
Cryoplants at 4.5 K	0.2	0.2	0.2
Total at 4.5 K	1.01	1.06	1.12
Total at 1.9 K	1.11	1.16	1.22

Decay ring quadrupole

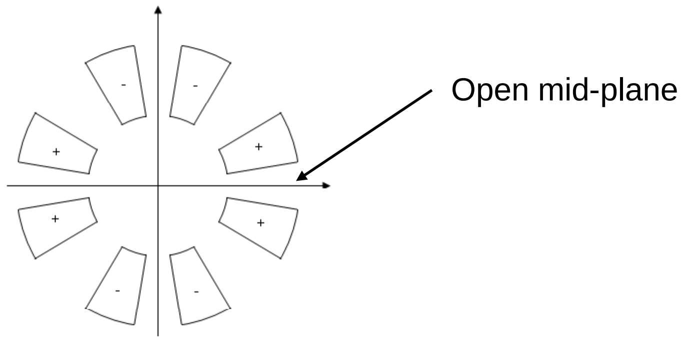
- In a quadrupole beam losses are mainly located in the mid-plane:
  - Damage the superconducting cable
  - Might lead to a quench





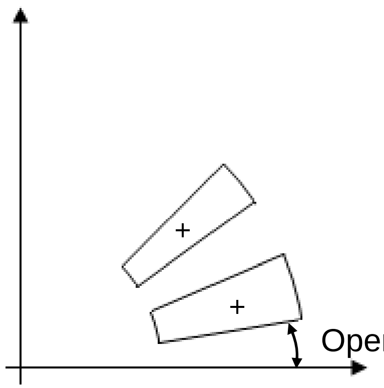
- To avoid the peak of the heat deposition an open mid-plane can be inserted
  - How is the field strength affected by insertion of an open mid-plane?

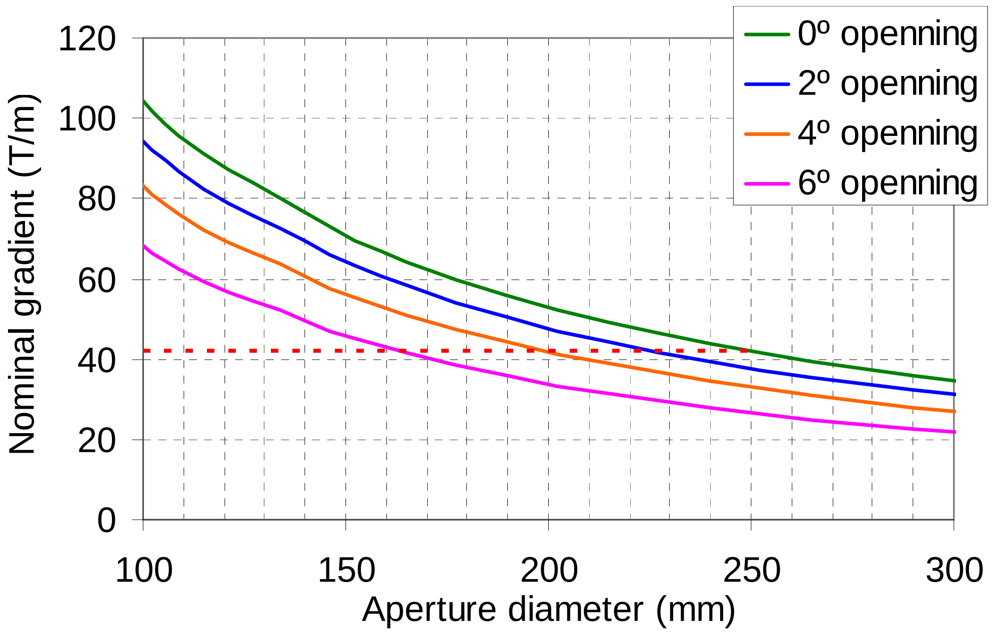
Courtesy Franck Borgnolutti



Open mid-plane quadrupole

- We consider a quadrupole made of 2 pure sector blocks of the LHC main dipole cable.
- Ironless coil is assumed.

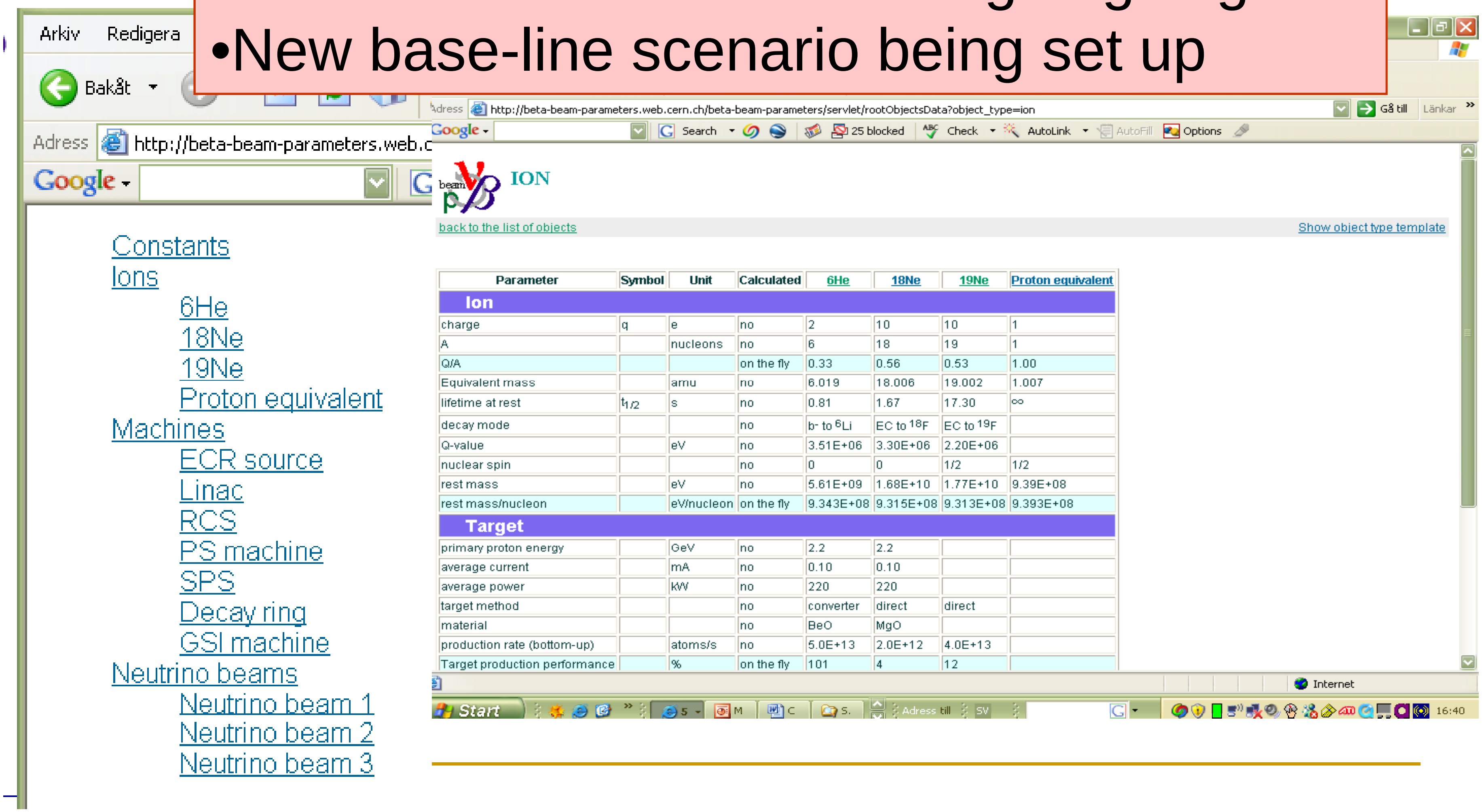




- Aperture diameter corresponding to a nominal gradient of 42 T/m with 20 % margin from the quench:
  - 2º opening : 230 mm
  - 4º opening : 200 mm
  - 6º opening : 160 mm
- Alternative to open mid-plane: thick liners

Parameters on the Web for 8B and 8Li

- Data Base creation and filling ongoing
- New base-line scenario being set up



Parameter	Symbol	Unit	Calculated	6He	18Ne	19Ne	Proton equivalent
Ion							
charge	q	e	no	2	10	10	1
A		nucleons	no	6	18	19	1
Q/A			on the fly	0.33	0.56	0.53	1.00
Equivalent mass		amu	no	6.019	18.006	19.002	1.007
lifetime at rest	$t_{1/2}$	s	no	0.81	1.67	17.30	∞
decay mode			no	b^- to ^{6}Li	EC to ^{18}F	EC to ^{19}F	
Q-value		eV	no	3.51E+06	3.30E+06	2.20E+06	
nuclear spin			no	0	0	1/2	1/2
rest mass		eV	no	5.61E+09	1.68E+10	1.77E+10	9.39E+08
rest mass/nucleon		eV/nucleon	on the fly	9.343E+08	9.315E+08	9.313E+08	9.393E+08
Target							
primary proton energy		GeV	no	2.2	2.2		
average current		mA	no	0.10	0.10		
average power		kW	no	220	220		
target method			no	converter	direct	direct	
material			no	BeO	MgO		
production rate (bottom-up)		atoms/s	no	5.0E+13	2.0E+12	4.0E+13	
Target production performance		%	on the fly	101	4	12	

Conclusion

- For deliverables and milestones we have no immediate risks
  - UCL has some delay (see presentation by Semen Mitrofanov)
  - CERN has to deliver baseline scenario fall of this year