EURISOL DS

Approved EU design study for a next generation ISOL facility and a beta-beam facility

Mats Lindroos
on behalf of
The EURISOL DS

Outline

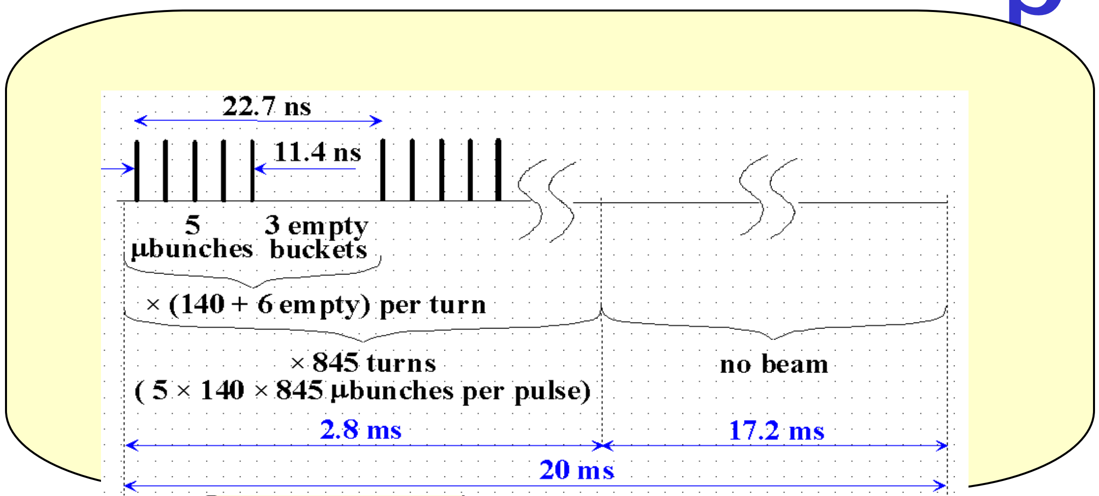
- The SPL
- The beta-beam base line design
- The approved EURISOL(/beta-beam) Design Study

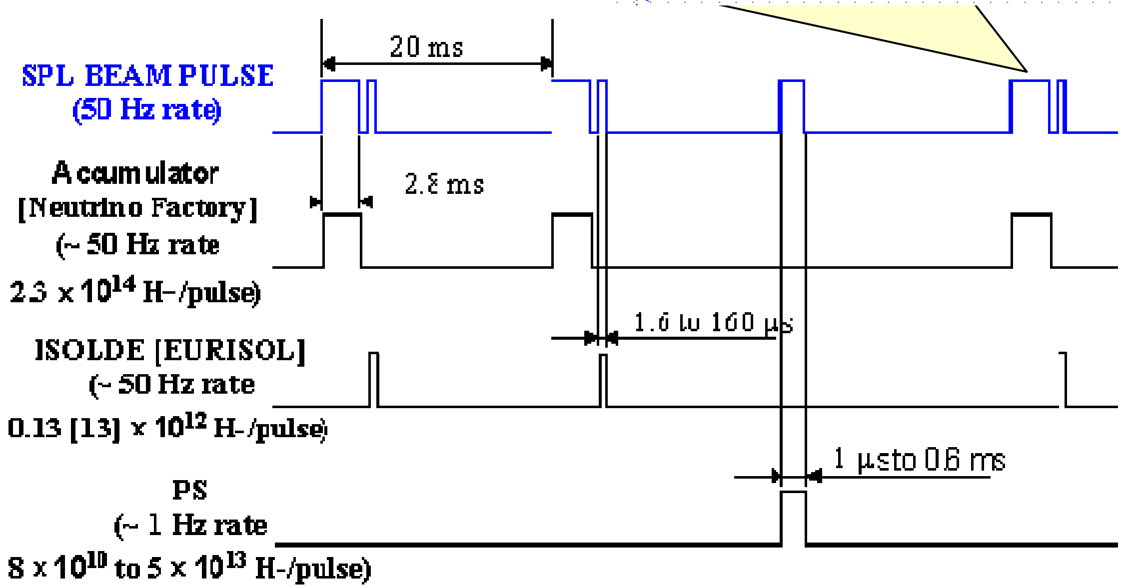
SPL beam characteristics (CDR 1)

Ion species	H^-	
Kinetic energy	2.2	GeV
Mean current during the pulse	13	mA
Duty cycle	14	%
Mean beam power	4	MW
Pulse repetition rate	50	Hz
Pulse duration	2.8	ms
Bunch frequency (minimum distance between bunches)	352.2	MHz
Duty cycle during the pulse (nb. of bunches/nb. of buckets)	62 (5/8)	%
Number of protons per bunch	$4.02\ 10^8$	
Normalized rms transverse emittances	0.4	π mm mrad
Longitudinal rms emittance	0.3	π deg MeV
Bunch length (at accumulator input)	0.5	ns
Energy spread (at accumulator input)	0.5	MeV
Energy jitter during the beam pulse	< ± 0.2	MeV
Energy jitter between pulses	< ± 2	MeV

SPL beam time structure (CDR 1)

Fine time structure (within pulse)





Macro time structure

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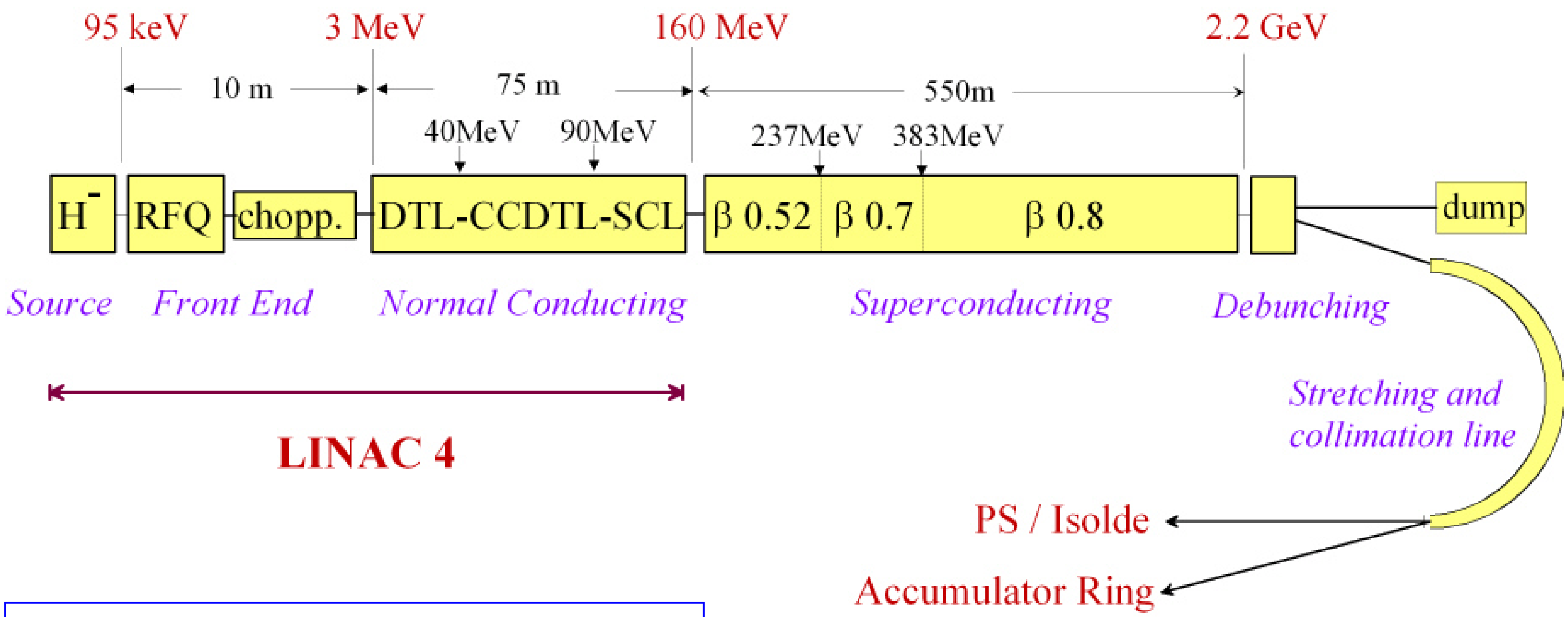
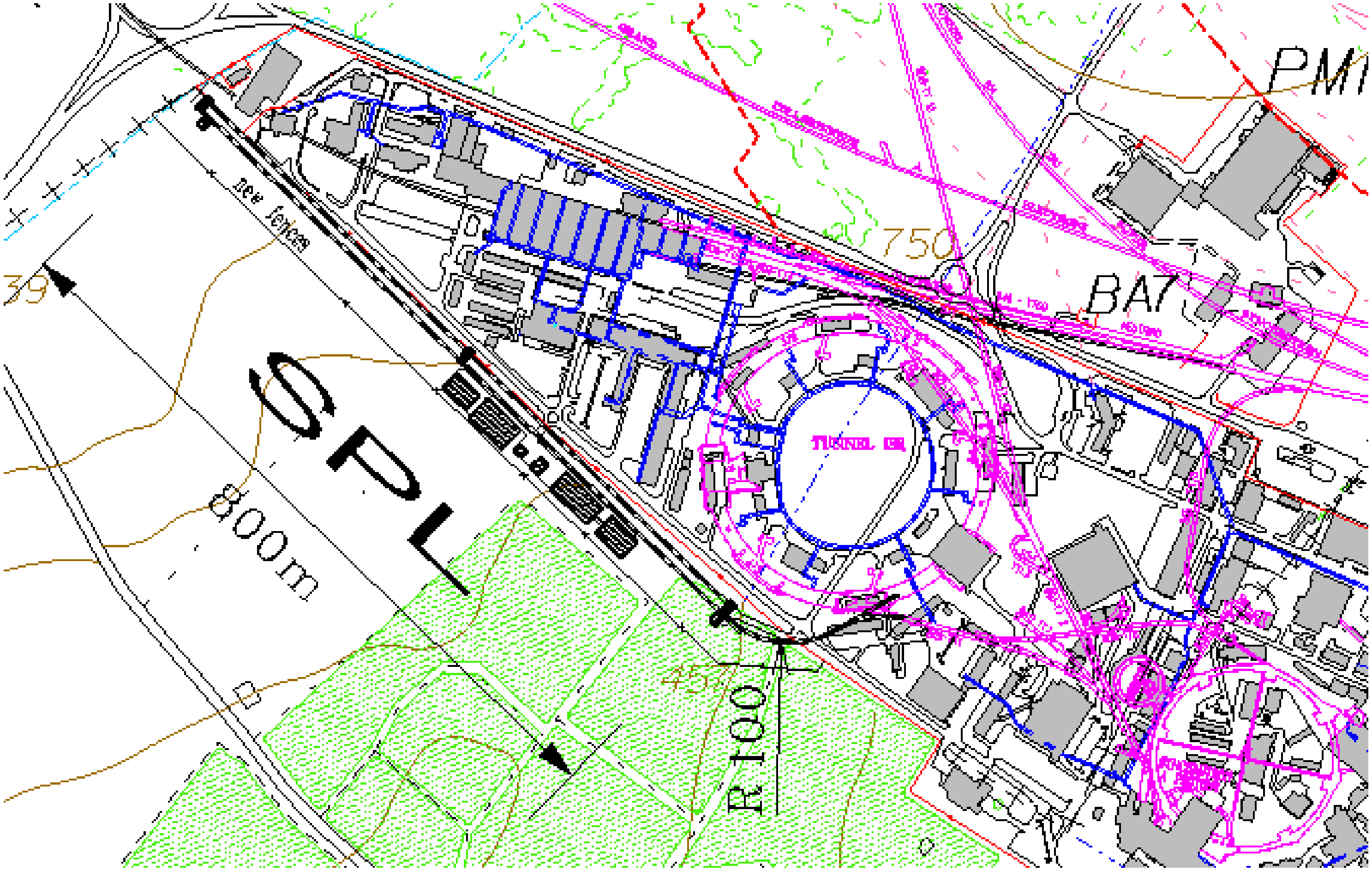
SPL block diagram (CDR 1)



Linac 4: up-to-date design
Superconducting linac: CDR 1

Layout (CDR 1)



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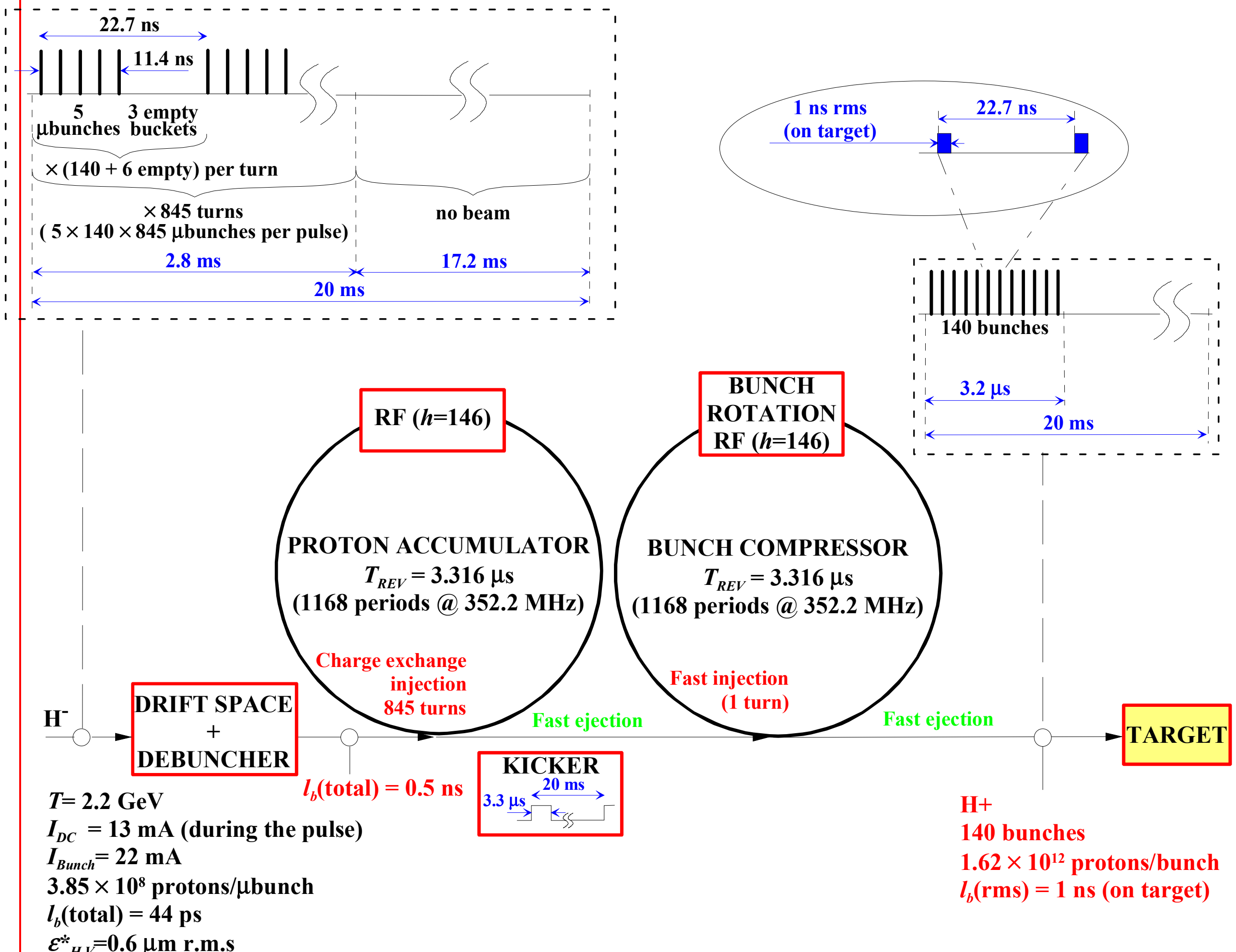
Accumulator and Compressor



Parameter	Value	Unit
Mean beam power	**4**	MW
Kinetic energy	**2.2**	GeV
Repetiton rate	**50**	Hz
Pulse duration	**3.3**	µs
Number of bunches	**140**	
Pulse intensity	**2.27 $\times 10^{14}$**	p/pulse
Bunch spacing (Bunch frequency)	**22.7 (44)**	ns (MHz)
Bunch length (σ)	**1**	ns
Relative momentum spread (σ)	**5×10^{-3}**	
Norm. horizontal emittance (σ)	**50**	µm.rad

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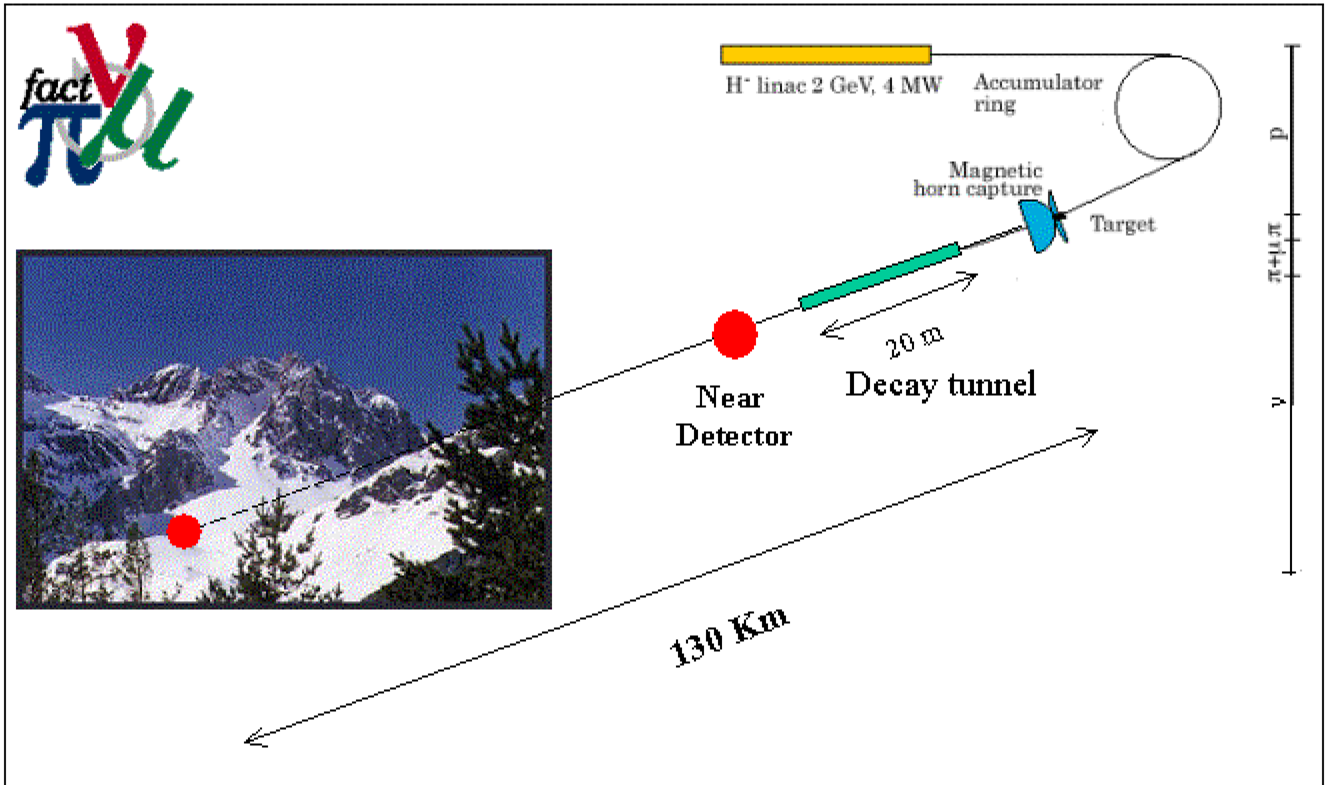
The Super Beam



A possible layout of a Low Energy Neutrino Super Beam

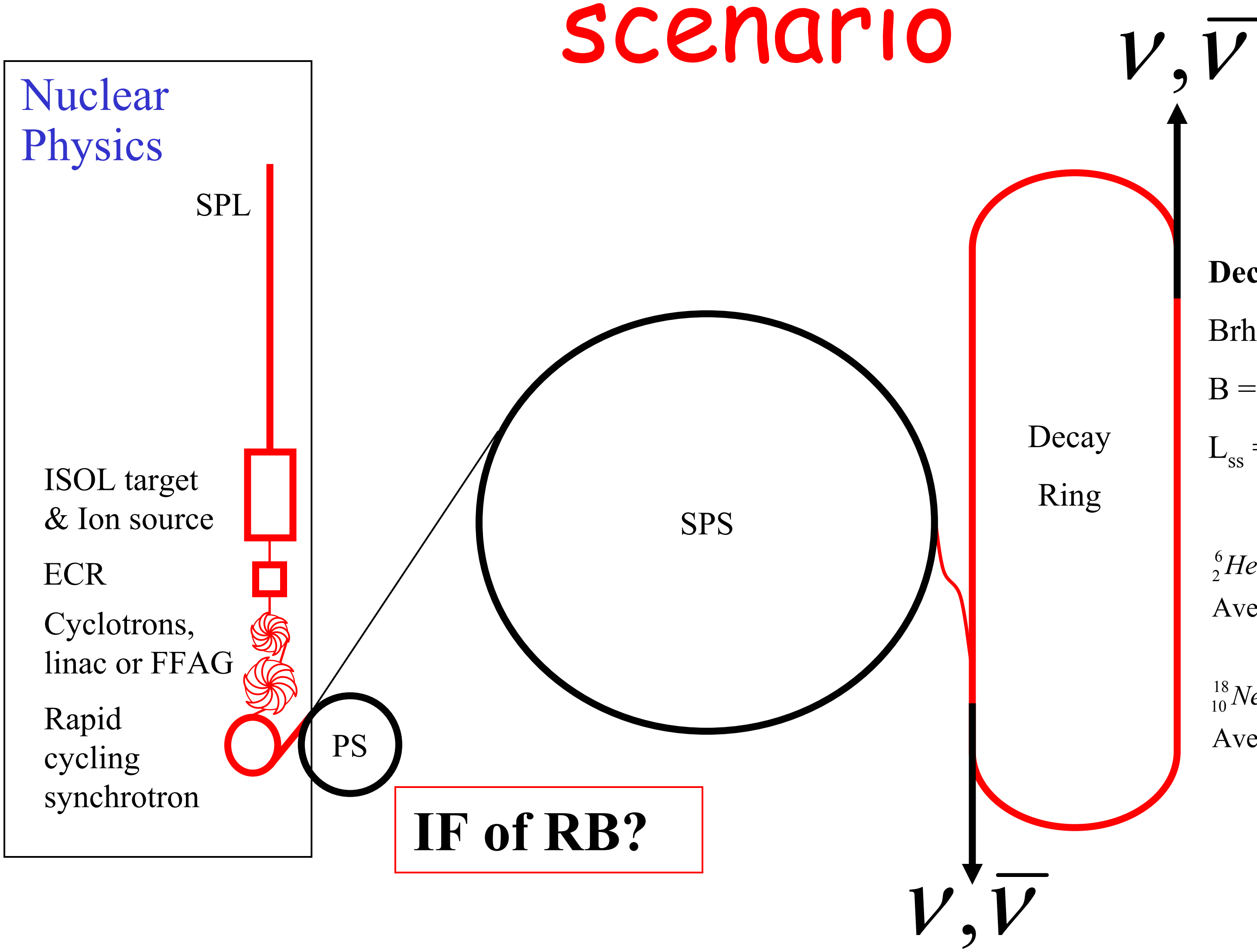
The beta-beam

- Idea by Piero Zucchelli
  - *A novel concept for a neutrino factory: the beta-beam*, Phys. Let. B, 532 (2002) 166-172
- The CERN base line scenario
  - Avoid anything that requires a "technology jump" which would cost time and money (and be risky)
  - Make use of a maximum of the existing infrastructure
  - If possible find an "existing" detector site

Collaborators

- The beta-beam study group:
  - **CEA, France:** Jacques Bouchez, Saclay, Paris Olivier Napoly, Saclay, Paris Jacques Payet, Saclay, Paris
  - **CERN, Switzerland:** Michael Benedikt, Peter Butler, Roland Garoby, Steven Hancock, Ulli Koester, Mats Lindroos, Matteo Magistris, Thomas Nilsson, Fredrik Wenander
  - **Geneva University, Switzerland:** Alain Blondel Simone Gilardoni
  - **GSI, Germany:** Oliver Boine-Frankenheim B. Franzke R. Hollinger Markus Steck Peter Spiller Helmuth Weick
  - **IFIC, Valencia:** Jordi Burguet, Juan-Jose Gomez-Cadenas, Pilar Hernandez, Jose Bernabeu
  - **IN2P3, France:** Bernard Laune, Orsay, Paris Alex Mueller, Orsay, Paris Pascal Sortais, Grenoble Antonio Villari, GANIL, CAEN Cristina Volpe, Orsay, Paris
  - **INFN, Italy:** Alberto Facco, Legnaro Mauro Mezzetto, Padua Vittorio Palladino, Napoli Andrea Pisent, Legnaro Piero Zucchelli, Sezione di Ferrara
  - **Louvain-la-neuve, Belgium:** Thierry Delbar Guido Ryckewaert
  - **UK:** Marielle Chartier, Liverpool university Chris Prior, RAL and Oxford university
  - **Uppsala university, The Svedberg laboratory, Sweden:** Dag Reistad
  - **Associate:** Rick Baartman, TRIUMF, Vancouver, Canada Andreas Jansson, Fermi lab, USA, Mike Zisman, LBL, USA

CERN: β-beam baseline scenario



Decay ring

Brho = 1500 Tm

B = 5 T

L_{ss} = 2500 m

${}^{6}_{2}He \rightarrow {}^{6}_{3}Li\, e^{-} \overline{\nu}$

Average $E_{cms} = 1.937$ MeV

${}^{18}_{10}Ne \rightarrow {}^{18}_{9}Fe\, e^{+} \nu$

Average $E_{cms} = 1.86$ MeV

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Target values for the decay ring

^{6}Helium^{2+}

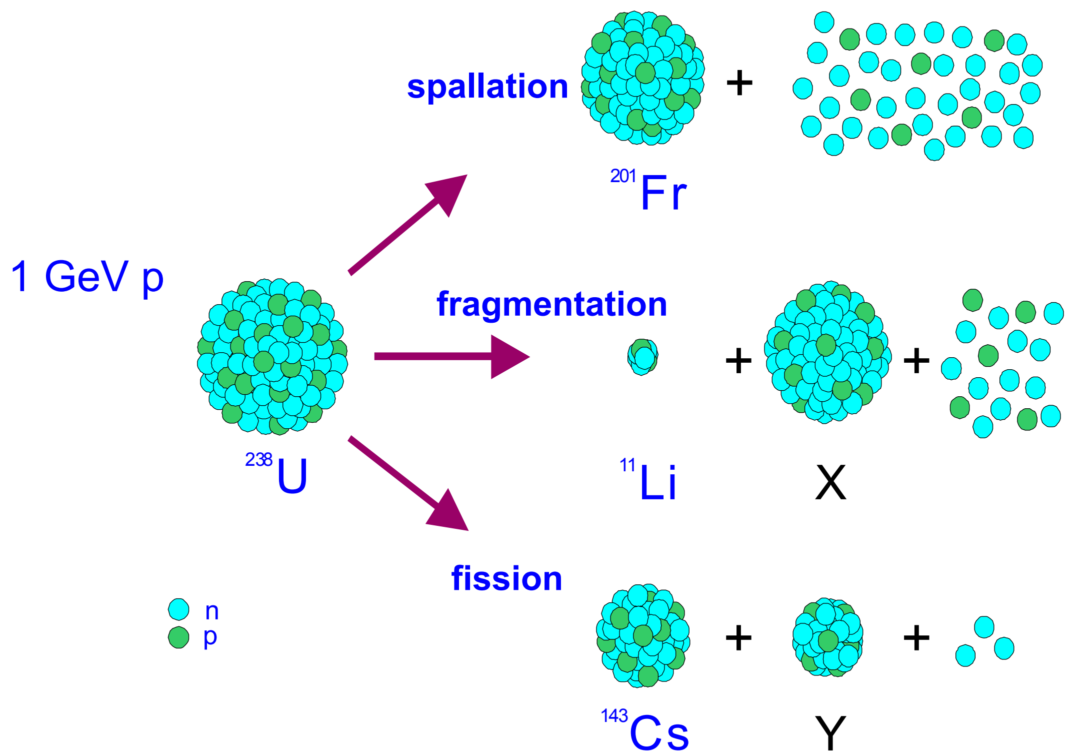
- In Decay ring: 1.0x10^{14} ions
- Energy: 139 GeV/u
- Rel. gamma: 150
- Rigidity: 1500 Tm

^{18}Neon^{10+} (single target)

- In decay ring: 4.5x10^{12} ions
- Energy: 55 GeV/u
- Rel. gamma: 60
- Rigidity: 335 Tm

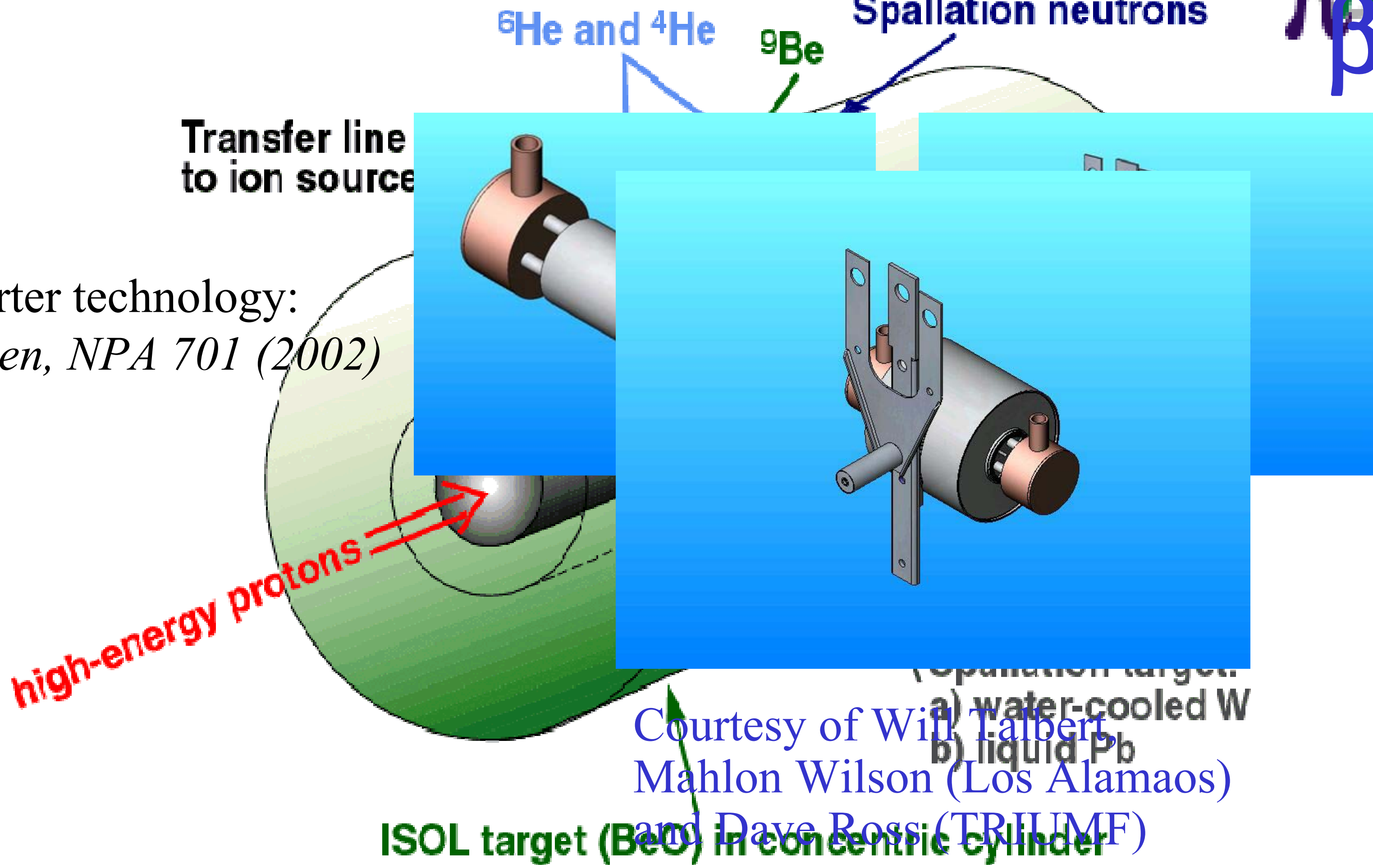
- The neutrino beam at the experiment should have the "time stamp" of the circulating beam in the decay ring.
- The beam has to be concentrated to as few and as short bunches as possible to maximize the number of ions/nanosecond. (background suppression), aim for a duty factor of 10^{-4}

ISOL production



^{6}He production by ^{9}Be(n,α)

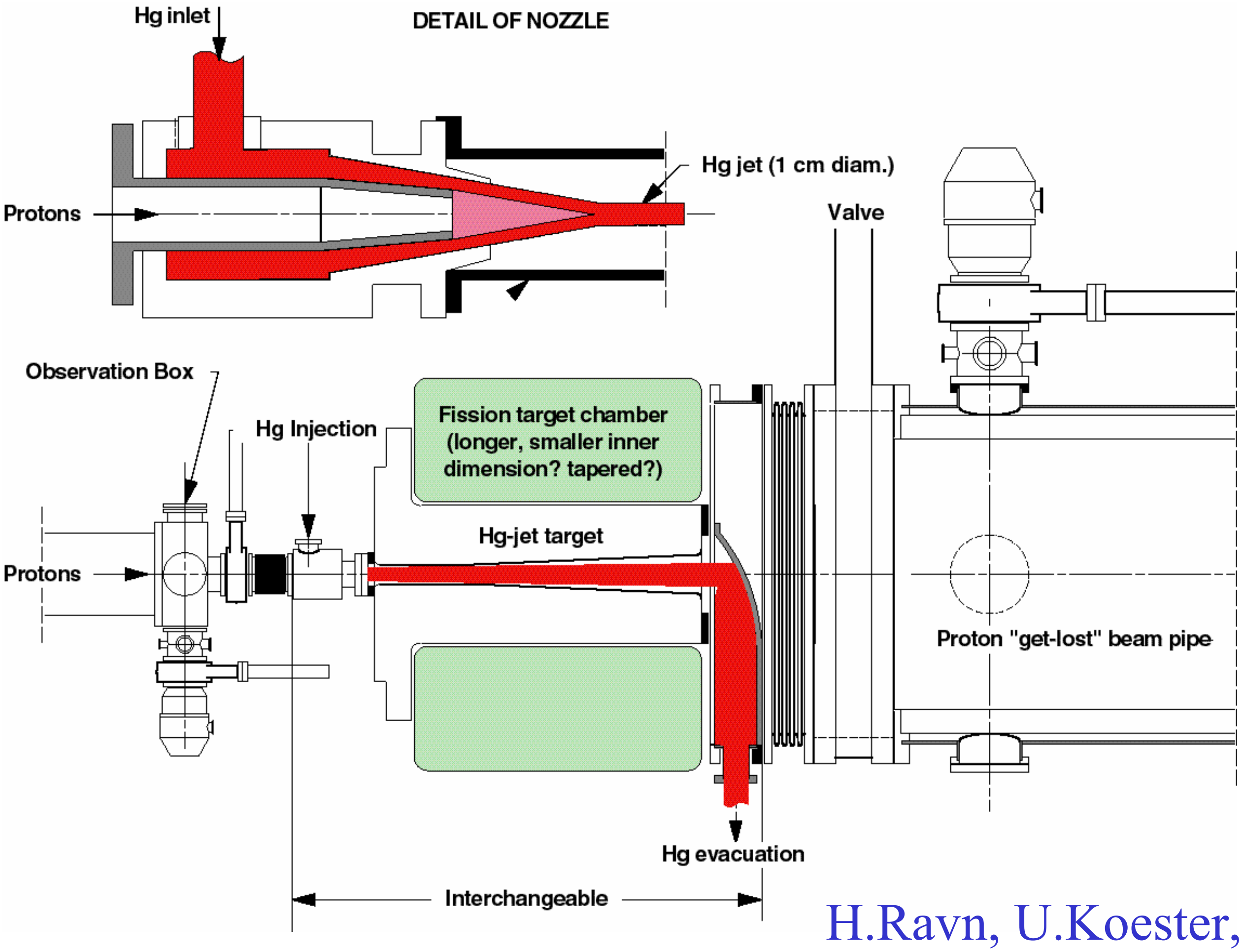
Converter technology:
(J. Nolen, NPA 701 (2002) 312c)



Courtesy of Will Talbert, Mahlon Wilson (Los Alamaos) and Dave Ross (TRIUMF)

Layout very similar to planned EURISOL converter target aiming for 10^{15} fissions per s.

Mercury jet converter

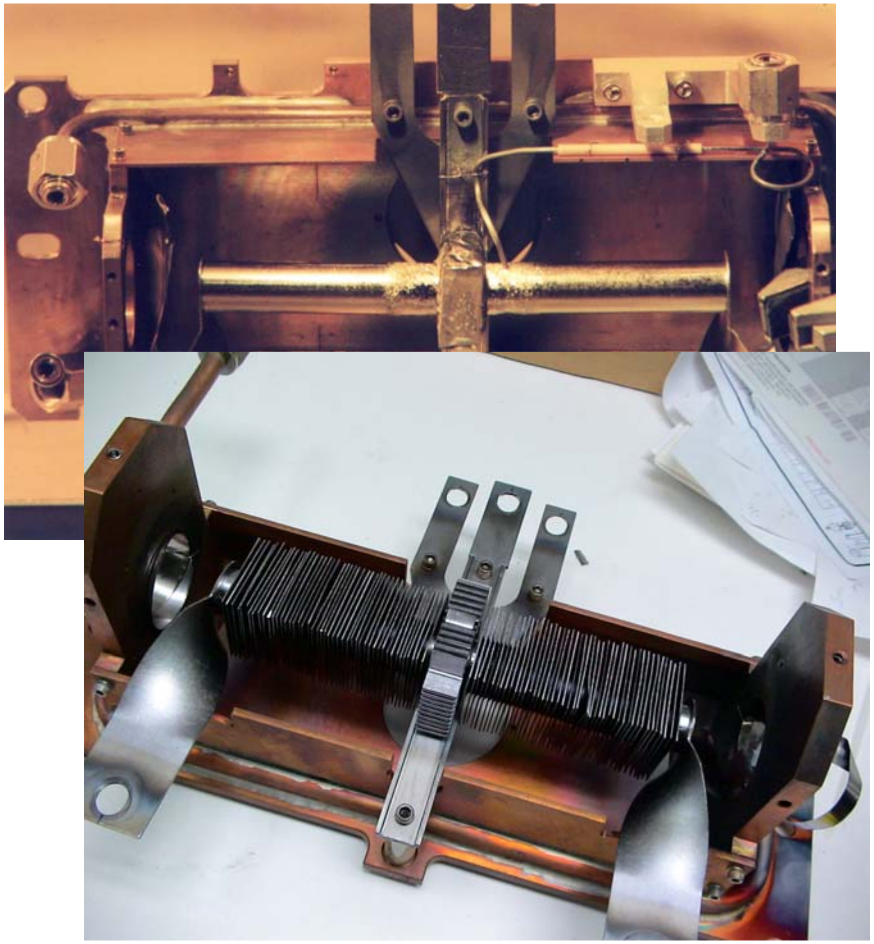


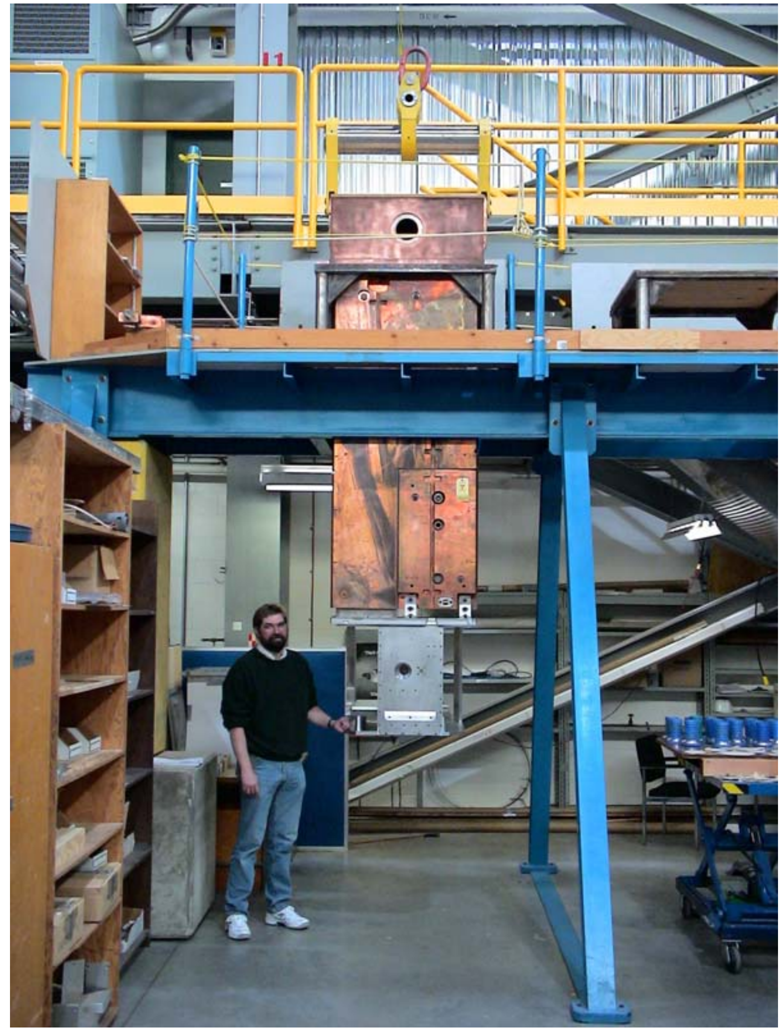
H.Ravn, U.Koester, J.Lettry, S.Gardoni, A.Fabich

Production of β^+ emitters

- Spallation of close-by target nuclides: $^{18,19}Ne$ from MgO and $^{34,35}Ar$ in CaO
  - Production rate for ^{18}Ne is $1x10^{12}$ s^{-1} (with 2.2 GeV 100 µA proton beam, cross-sections of some mb and a 1 m long oxide target of 10% theoretical density)

High power target





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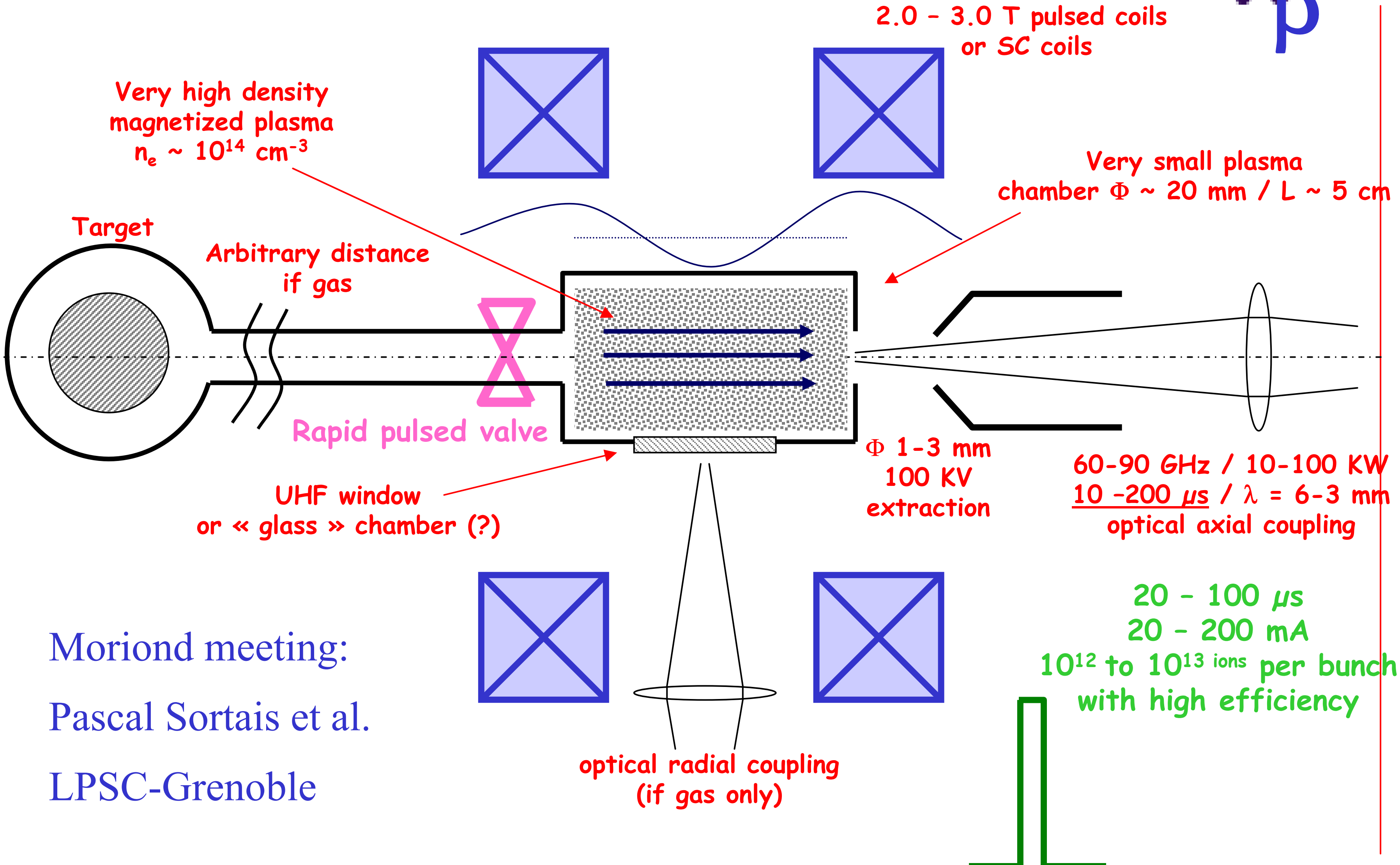
60-90 GHz « ECR Duoplasmatron » for pre-bunching of gaseous RIB



Moriond meeting:

Pascal Sortais et al.

LPSC-Grenoble

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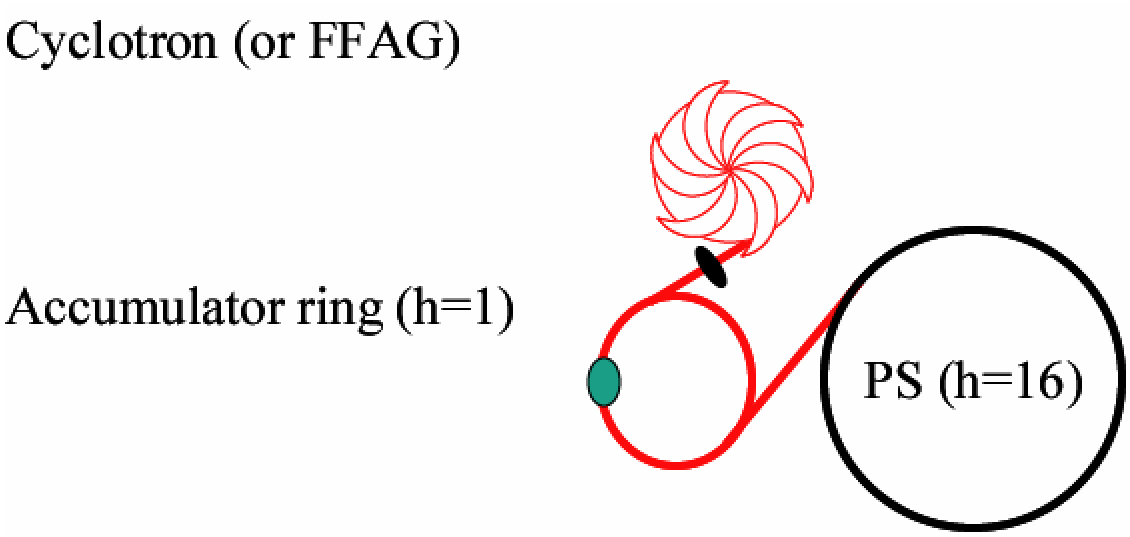
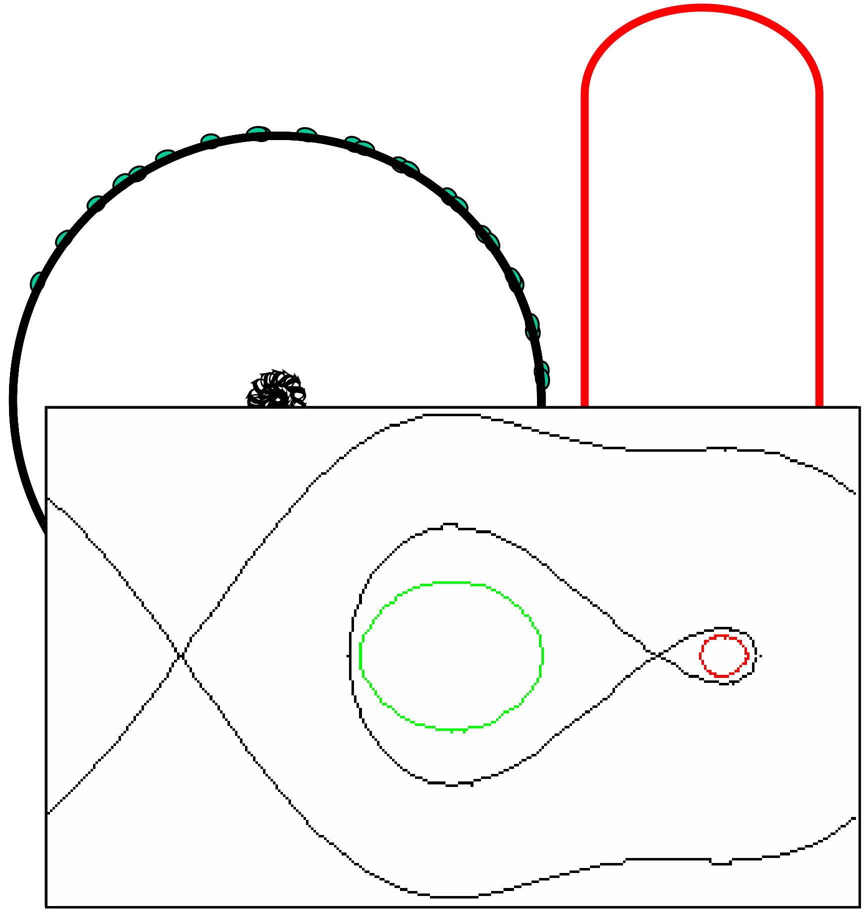
Overview: Accumulation



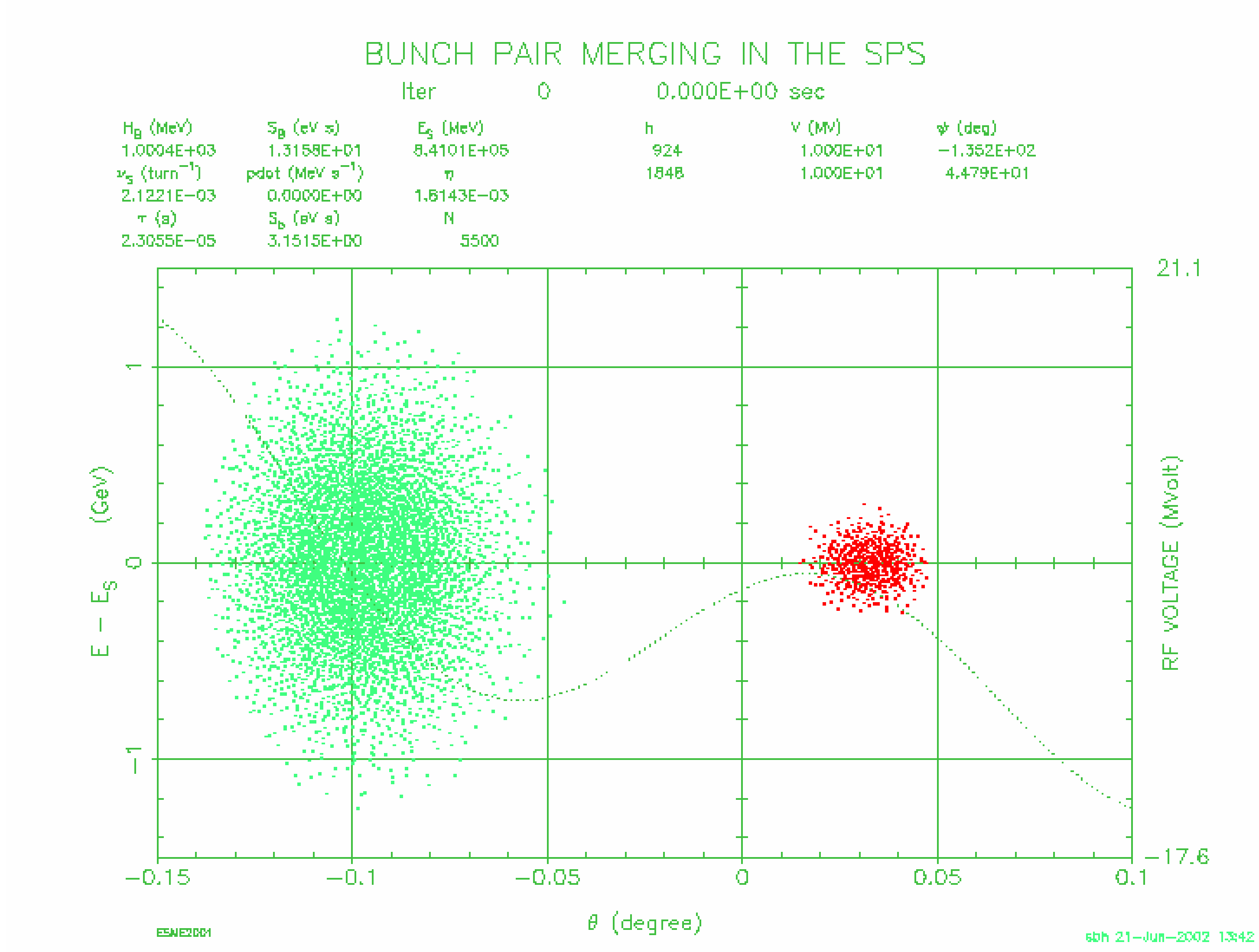
- Sequential filling of 16 buckets in the PS from the storage ring

Stacking in the Decay ring

- Ejection to matched dispersion trajectory
- Asymmetric bunch merging



Asymmetric bunch merging



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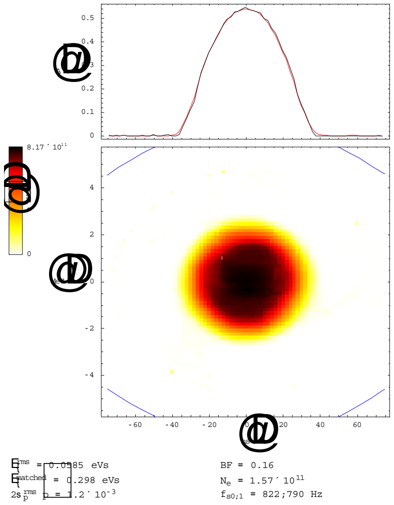
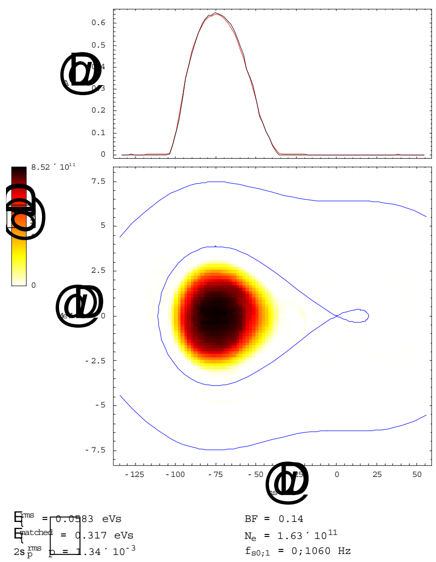
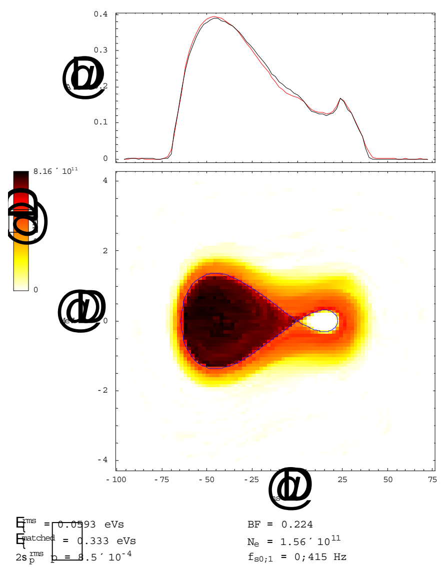
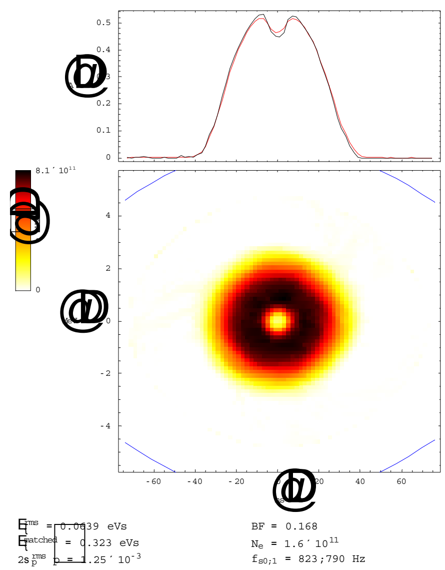
Asymmetric bunch merging









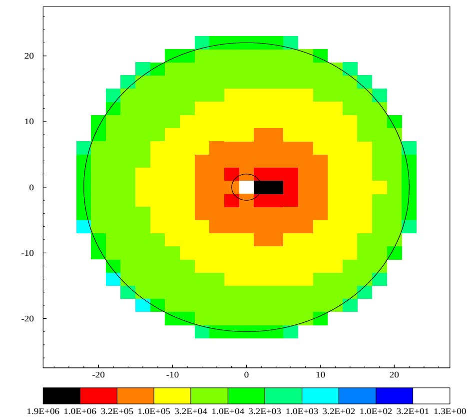
(S. Hancock, M. Benedikt and J,-L.Vallet, *A proof of principle of asymmteric bunch pair merging*, AB-note-2003-080 MD)

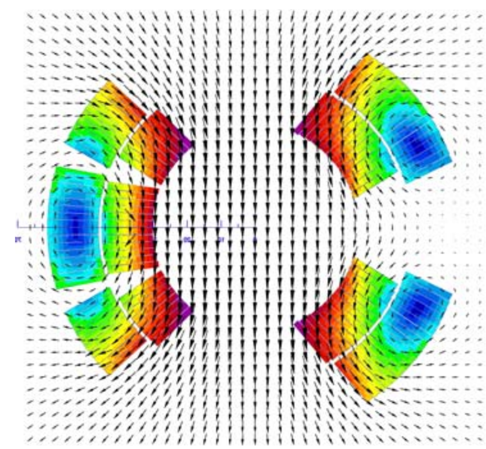
Decay losses

- Losses during acceleration are being studied:
  - Full FLUKA simulations in progress for all stages (M. Magistris and M. Silari, *Parameters of radiological interest for a beta-beam decay ring*, TIS-2003-017-RP-TN)
  - Preliminary results:
    - Can be managed in low energy part
    - PS will be heavily activated
      - New fast cycling PS?
    - SPS OK!
    - Full FLUKA simulations of decay ring losses:
      - Tritium and Sodium production surrounding rock well below national limits
      - Reasonable requirements of concreting of tunnel walls to enable decommissioning of the tunnel and fixation of Tritium and Sodium

SC magnets

- Dipoles can be built with no coils in the path of the decaying particles to minimize peak power density in superconductor
  - The losses have been simulated and one possible dipole design has been proposed

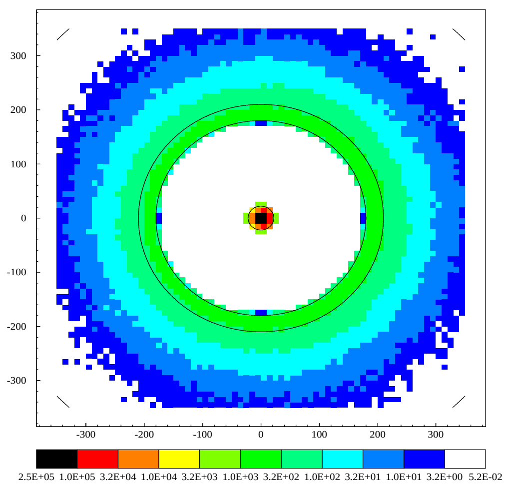




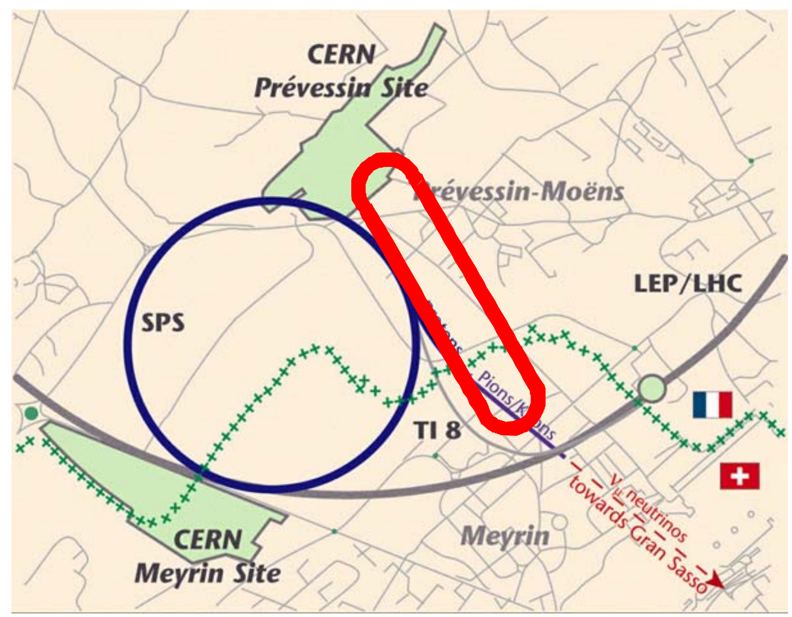
S. Russenschuck, CERN

Tunnels and Magnets

- Civil engineering costs: Estimate of 400 MCHF for 1.3% incline (13.9 mrad)
  - Ringlenth: 6850 m, Radius=300 m, Straight sections=2500 m
- Magnet cost: First estimate at 100 MCHF



FLUKA simulated losses in surrounding rock (no public health implications)

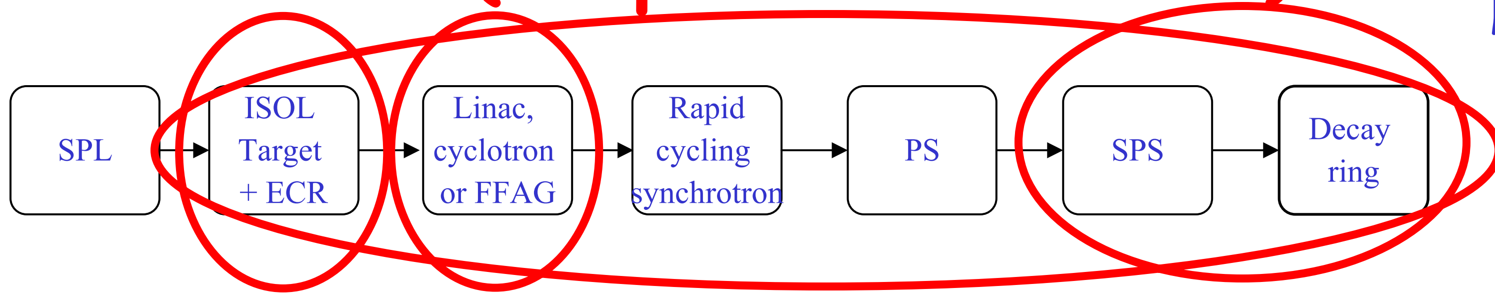


Intensities

Stage	^{6}He	^{18}Ne (single target)
From ECR source:	2.0×10^{13} ions per second	0.8×10^{11} ions per second
Storage ring:	1.0×10^{12} ions per bunch	4.1×10^{10} ions per bunch
Fast cycling synch:	1.0×10^{12} ion per bunch	4.1×10^{10} ion per bunch
PS after acceleration:	1.0×10^{13} ions per batch	5.2×10^{11} ions per batch
SPS after acceleration:	0.9×10^{13} ions per batch	4.9×10^{11} ions per batch
Decay ring:	2.0×10^{14} ions in four 10 ns long bunch	9.1×10^{12} ions in four 10 ns long bunch

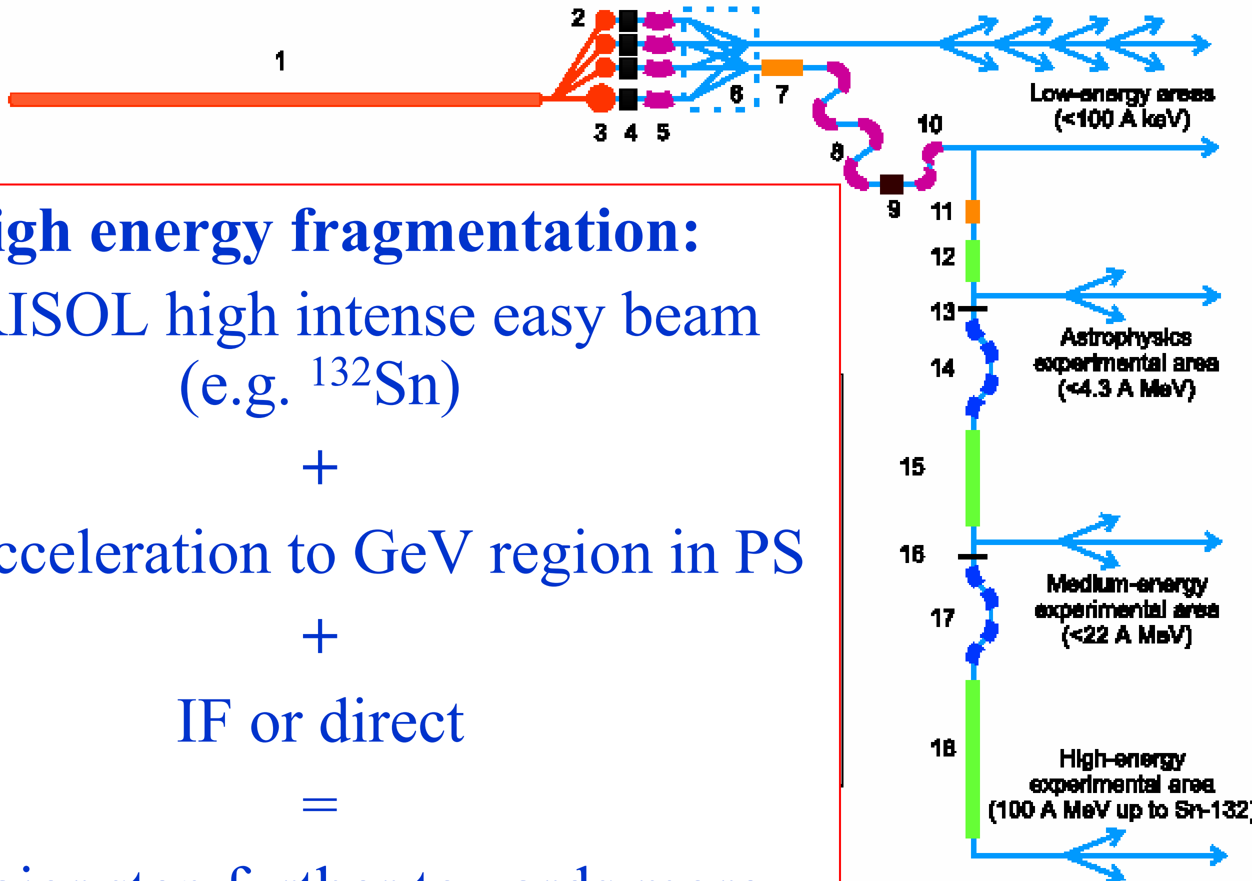
Only β-decay losses accounted for, add efficiency losses (50%)

R&D (improvements)



- Production of RIB (intensity)
  - Simulations (GEANT, FLUKA)
  - Target design, only 100 kW primary proton beam in present design
- Acceleration (cost)
  - FFAG versa linac/storage ring/RCS
- Tracking studies (intensity)
  - Loss management
- Superconducting dipoles (γ of neutrinos)
  - Pulsed for new PS/SPS/Decay ring (GSI FAIR)
  - High field dipoles for higher gamma in the decay ring and/or accelerating decay ring
  - Radiation hardness (Super FRS)

EURISOL



High energy fragmentation:

EURISOL high intense easy beam (e.g. ^{132}Sn)

+

post-acceleration to GeV region in PS

+

IF or direct

=

A major step further towards more exotic nuclei

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EURISOL Design Study

- **Total budget is 33293300 (9161900 from EU)**
- **Start date:** 1 January 2005
- **Objective:** TDR for end of 2008
- **Objective: TDR enabling the Nuclear physics and Neutrino physics communities to take a decision about a future facility**
- **2009:** Fix site and apply for EU construction project

Stake holders

USERS
Frejus
Gran Sasso
High Gamma
Astro-Physics
Nuclear Physics
(γ, intensity and duty factor)

EURISOL
Beta-beam Coordination
Beta-beam parameter group
Above 100 MeV/u
Targets
60 GHz ECR
Low energy beta-beam
And many more…

OTHER LABS
TRIUMF
FFAG
Tracking
Collimators
US study
Neutrino Factory DS

Conceptual Design # with price ### M€

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Beta-beam task

- **Objective:** Study all components of a beta-beam facility above 100 MeV/u
- **Deliverable:** Conceptual Design Report (CDR) for a beta-beam facility
- **Participating institutes:** CERN, CEA, IN2P3, CLRC-RAL, GSI, MSL-Stockholm
- **Parameter group to define the conceptual design and follow the evolution of the beta-beam facility:** Higher intensities and higher gamma

Work Units (WU) in beta-beam task

- **Low energy ring and RCS**: CERN leads the WU
- **PS and SPS**: CERN leads the WU
- **Replacements for PS and SPS**: GSI will be asked to lead WU
- **Design of decay ring**: CEA leads the WU
- **Collimation and machine protection (simulation of decay losses)**: CERN leads the WU
- **Low energy ring, study of critical components**: MSL leads the WU
- **Longitudinal simulations and stacking**: CERN leads the WU
- **Parameter group**: Chaired by Steve Hancock, CERN
- **Synergies to nufact**: RAL will be asked to lead the WU

Present CERN commitement (including EU): 17 FTE over 4 years

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General: beta-beam

- **Driver:** LNL leading task, CERN participates through HIPPI (SPL)
- **Target tasks:** CERN leads the tasks for 100 kW and MW targets
- **Beam preparation:** Jyväskylä Univ. leads the task, IN2P3 leads the work unit for 60 GHz ECR source for stripping and bunching
- **Heavy-ion accelerator:** GANIL leads the task for acceleration up to 100 MeV/u
- **Physics:** Liverpool leads the task, IN2P3-Orsay leads the work unit on the Low energy beta-beam
- *And more…*

Beta-beam

CERN Job descriptions

- **Title: Accelerator physicist**
  - Name: Mats Lindroos
  - Availability: 0.5 FTE/year
- **Title: Accelerator physicist**
  - Name: Michael Benedikt
  - Availability: 0.5 FTE/year
- **Title: Accelerator physicist**
  - Name: Steven Hancock
  - Availability: 0.5 FTE/year
- **Title: Accelerator physicist**
  - Name: New staff, To be advertised autumn 2004
  - Availability: 1 FTE/year
- **Title: Physicist or engineer**
  - Name: New fellow (3 years), To be advertised autumn 2004
  - Availability: 1 FTE/year
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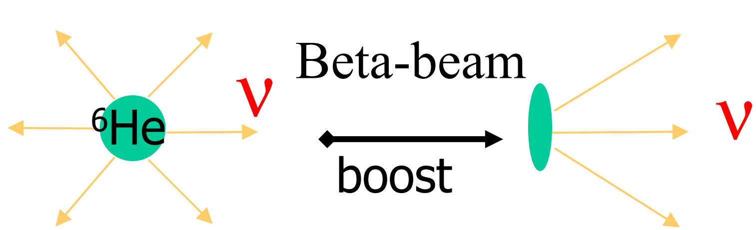

The EURISOL/beta-beam DS!

- A boost for radioactive nuclear beams
    - A boost for neutrino physics

- **A lot of work but it is time for action (and not only talking)!**