A preliminary layout for beam preparation

(and beamlines)

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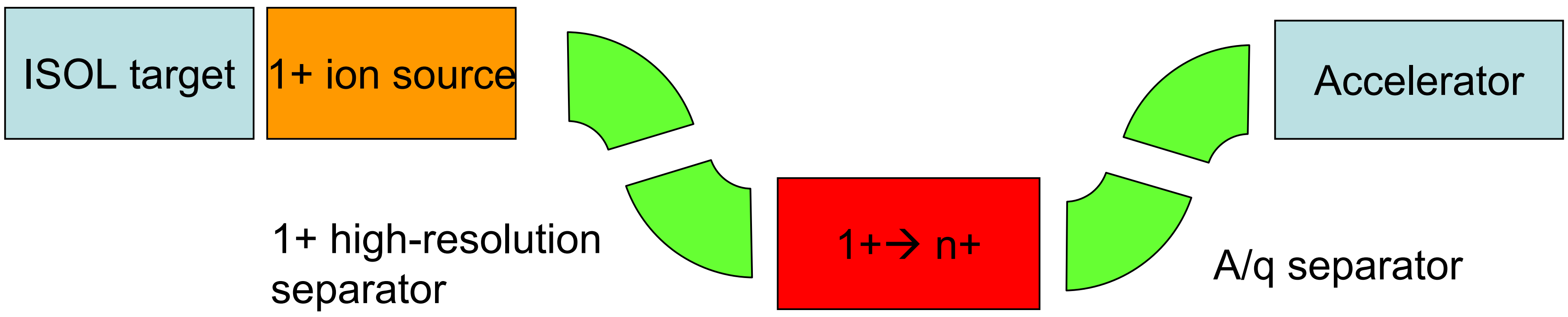
- Task 9 definition
- Basic beam preparation chain
- General EURISOL lay-out
- Summarize on-going discussion 2006, recommendations/decisions and open questions
- Schematic lay-out
- Perspectives (Task 9 and Lay-out issue)

Task Definition

The objective of this task is to study the feasibility of a new generation of devices with orders of magnitude greater capacity and throughput in order to accumulate, cool, bunch and purify the high intensity radioactive ion beams of EURISOL.
+ Construction of the prototype for beta-beams (separate presentation by P. Delahaye on Tuesday morning 8:30)

1+ → n+ scenario for ISOL post-accelerators



Task Definition

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+ Construction of the prototype ion source (ECR) for beta-beams (separate presentation by P. Delahaye on Tuesday morning 8:30)

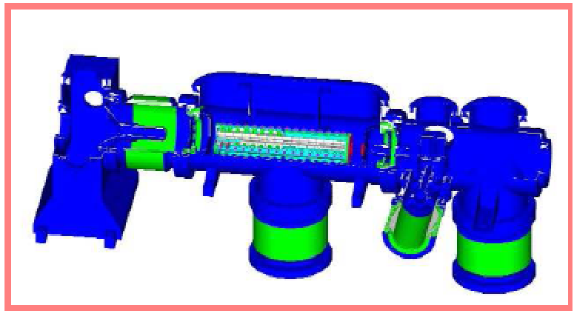
Sub-tasks and responsible scientists:

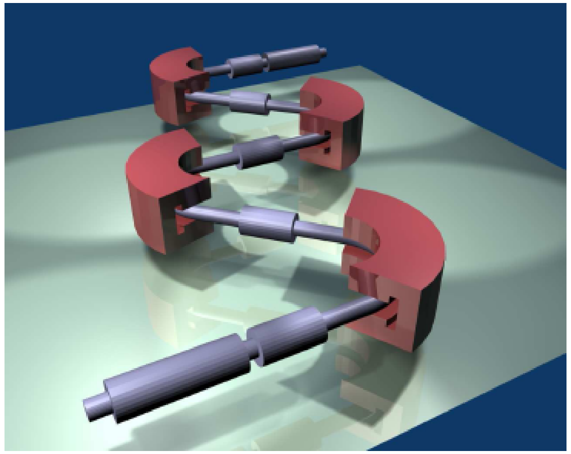
- **Species purification, Tim Giles, CERN-Geneva**
  - Study beam transport and mass separation in the EURISOL complex with its specific boundary conditions and to deliver a dedicated design for mass separation and low-energy beam transport for EURISOL
- **Beam bunching and cooling, David Lunney, CSNSM-Orsay**
  - to propose state-of-the-art techniques for ion cooling and bunching
- **Charge breeding, Oliver Kester, GSI-Darmstad**
  - Test charge-state manipulation methods in order to achieve breeding efficiency of more than 50% in one charge state for a set of isotopes
- **Ion source for β-beams, Thierry Lamy, LPSC-Grenoble**
  - Design a high-intensity pulsed 60 GHz ECR ion source for rapid ionization of light noble gas radioactive ions, especially He and Ne.
  - Realization of a conceptual prototype suitable for the beta-beam project

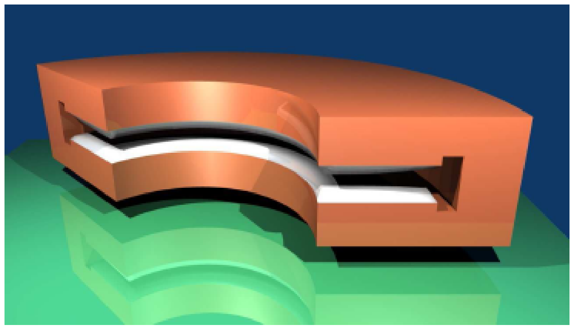
Sub-1: Beam purification by HRS

High resolution requires:

- Low emittance
  - Beam cooler
    - Pre–separator
- Large dispersion
  - Large / multiple magnets
- Correction of distortions
  - Multipolar magnetic field

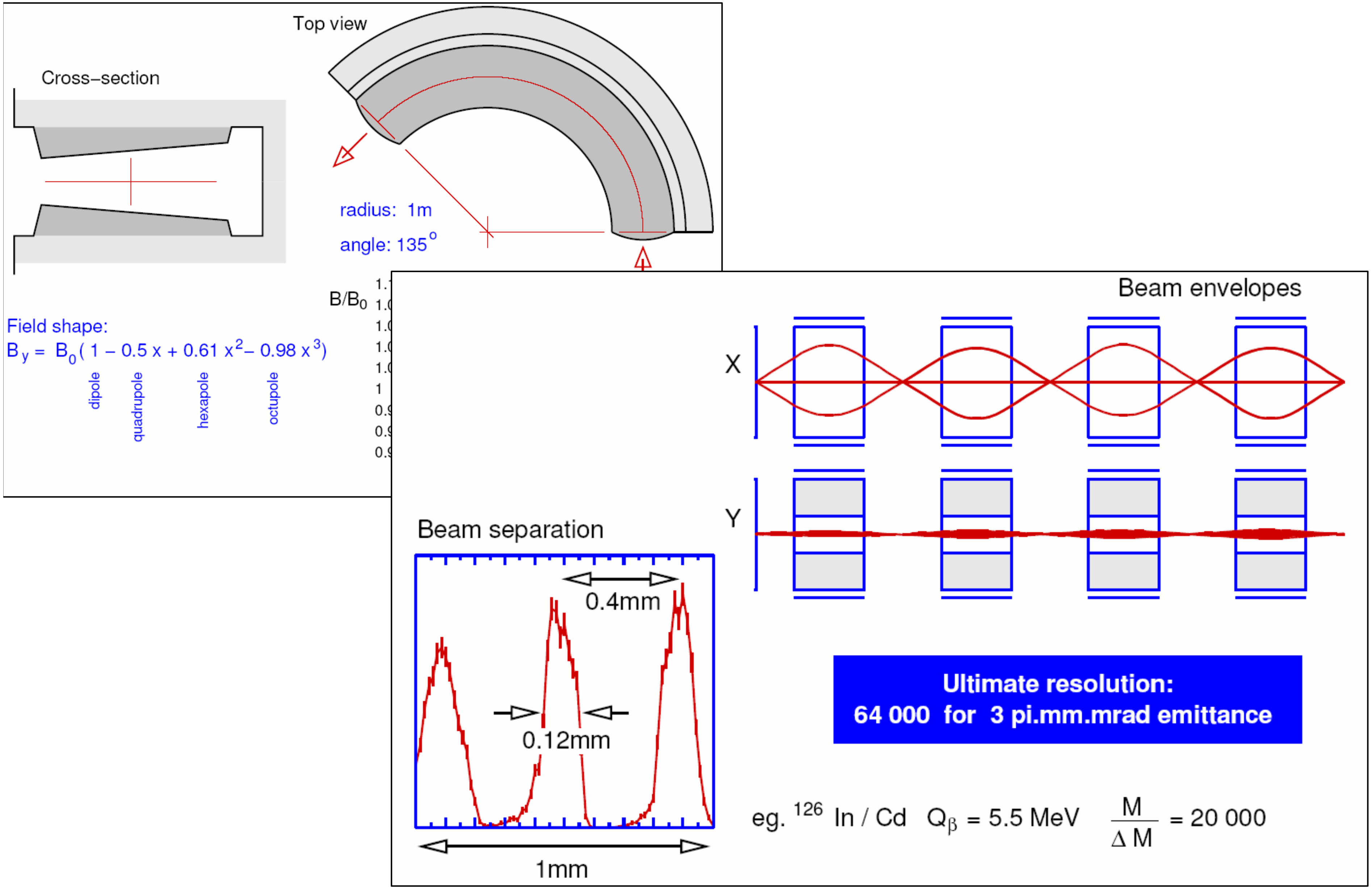






(T. Giles, CERN)

Multiple multipolar EHRS: performance



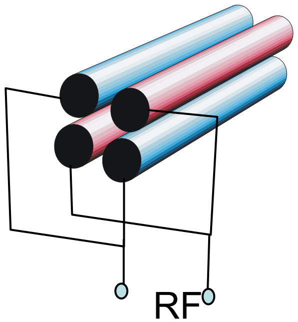
(T. Giles, CERN)

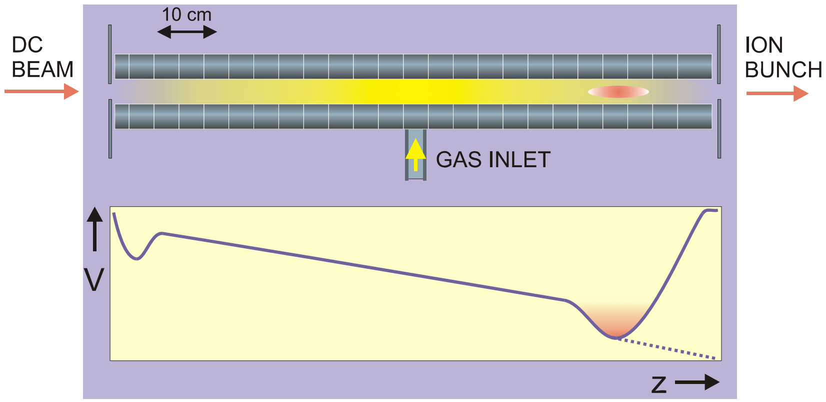
Sub-2: Ion cooling and bunching

Combination of buffer gas cooling and RF-confinement
- To reduce the emittance and the energy spread
- Optional bunching the DC-beam

RF-multipole structure
A. Nieminen, JYFL
F. Herfurth, ISOLTRAP
D. Lunney, MISTRAL cooler

Emittance 3 π mm mrad
Energy spread 0.5 eV
Bunch width 10 µs
Transmission 70 %

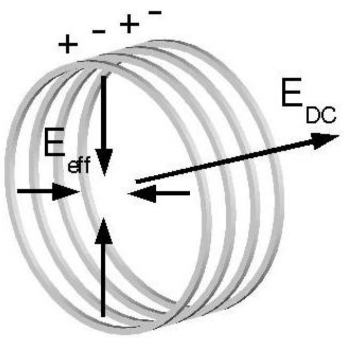


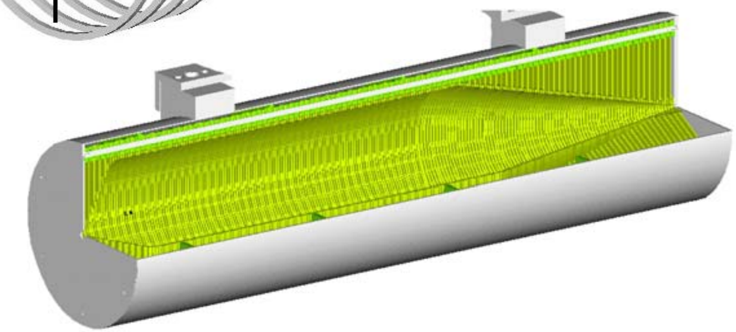


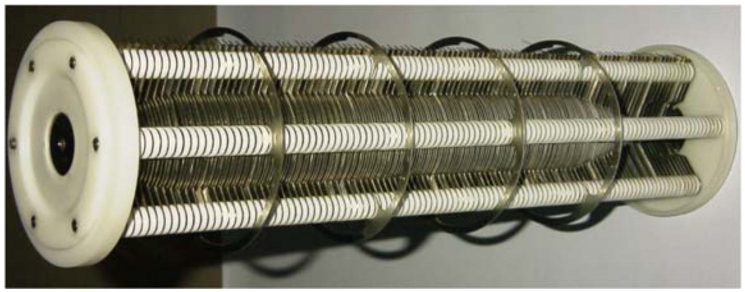
D.Lunney, CSNSM-Orsay

RF-wall with the funnel
S. Heinz, LMU

Tested on-line at JYFL





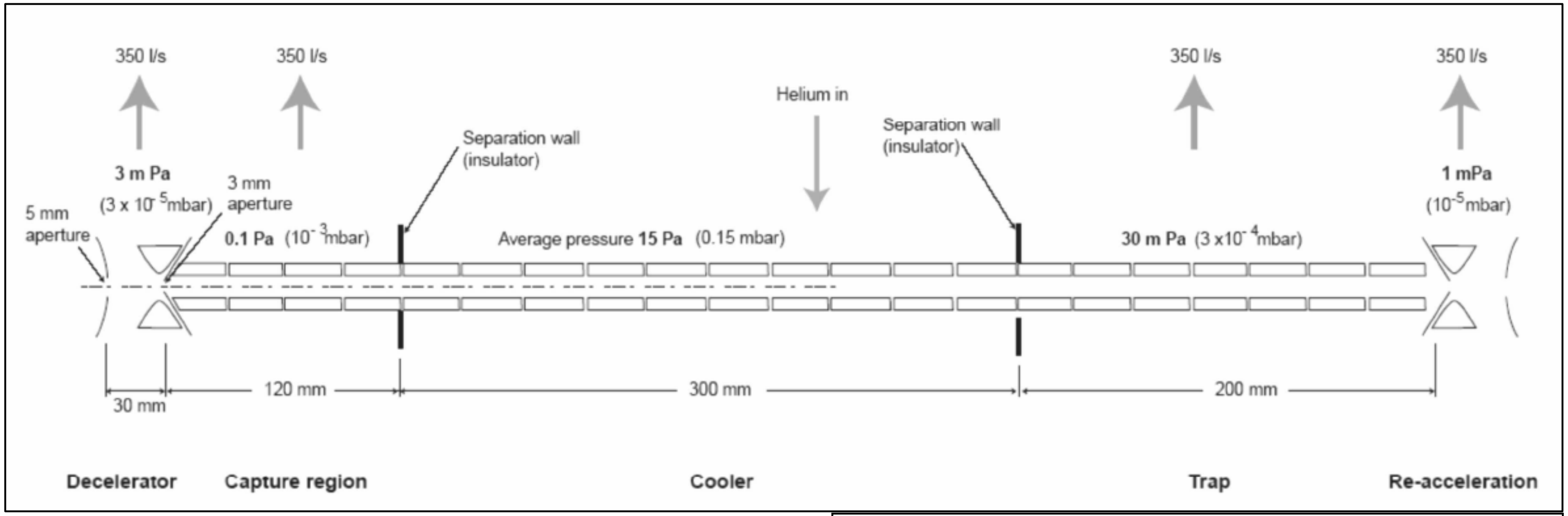


Next-generation RFQ for EURISOL

(in terms of an ion beam/cloud capacity)

$$D = \frac{eV^2}{4mr_0^2\omega_{RF}^2} = \frac{q_{Mathieu}V}{8}$$

10-fold increase in the capacity based on the increasing of the pseudopotential depth D



Technical proposal, see poster by O. Gianfrancesco

Technical challenge to be solved: 20-30 MHz at 10 kV !

➔10 μA beam or cooled bunches of 6×10^9 ions at 100 Hz rate

(D. Lunney, Orsay)

Sub-3: Charge Breeding (Objectives and Tasks)

1. Set-up of the Frankfurt MAXEBIS at GSI and test of breeding with intense electron beam current (>1 A) (LMU, GSI)

   a) Installation of the MAXEBIS at GSI and first test operation ✔
   b) First injection tests with Ba ions from a surface ion source
   c) Test of the MAXEBIS with electron beam currents above 1 A → measurements at the BNL Test-EBIS (10 A electron beam)

2. Measurement to test charge state manipulation methods (ISOLDE, LMU, MSL, GSI, Bari)

   a) Breeding at shell closures
   b) Injection into partially neutralized beam and test of accu-mode
   c) New more reliable and intense electrode gun (new cathode) at REX-EBIS ✔
   d) Influence of rf-exitation on the charge state distribution

3. Measurements at the ISOLDE PHOENIX ECRIS for charge breeding to explore properties of an ECRIS based system and the beam separation (LPSC, ISOLDE)

   a) Breeding measurements of metallic and noble gas elements such as Cs, Ar, Kr, Xe, Sn, Sr and comparison with REXEBIS performances
   b) Reduce background contamination of the Phoenix ECRIS at ISOLDE
   c) Extension of breeding tests to light elements like Na and K
   d) 60 kV operation of the Daresbury PHOENIX ✔

(O. Kester, GSI)

EURISOL: Comparison EBIS v. ECRIS

	ECRIS	EBIS/T
Single charge state breeding efficiencies	< 20%	<30% <70% in principle
Beam purity	Support gas and rest gas In between peaks ~0.5-10 nA	Rest gas peaks 10-100 pA; In between peaks <<<1 pA (not detectable)
Beam particle rate limitations	> 1e12/s	<1e9/s with pre-bunching <1e11/s with continuous injection
Breeding times	50 ms	10 ms
Typical A/q	A/Q >5-6	A/Q > 2.6
Breakup of molecules	Possible	Possible
CS optimization	Partially possible	Well suited
Energy spread of ions	negligible	Up to 0.5% for high current devices
Ion beam acceptance	Large	Small

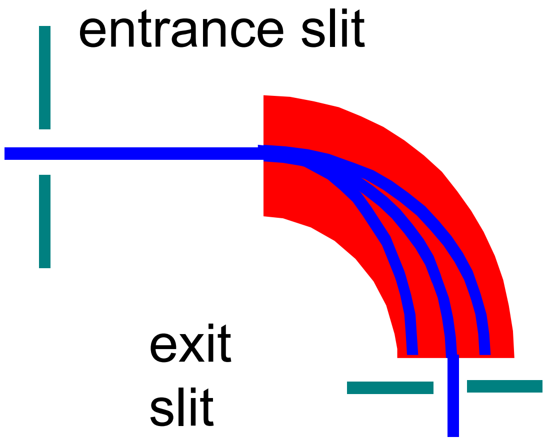
Complementary devices !!

(O. Kester, GSI)

Separator after the charge breeder (CB)

$$A = \frac{2R}{x_S\left[1 - 1/M\right]}$$

A = Resolution, R = bending radius, x_s = slit size or beam size
M = magnification



Double focusing magnet and slit distance = 2R → M = -1
bending radius < 0.5 m
(highly charged ions, low energy)

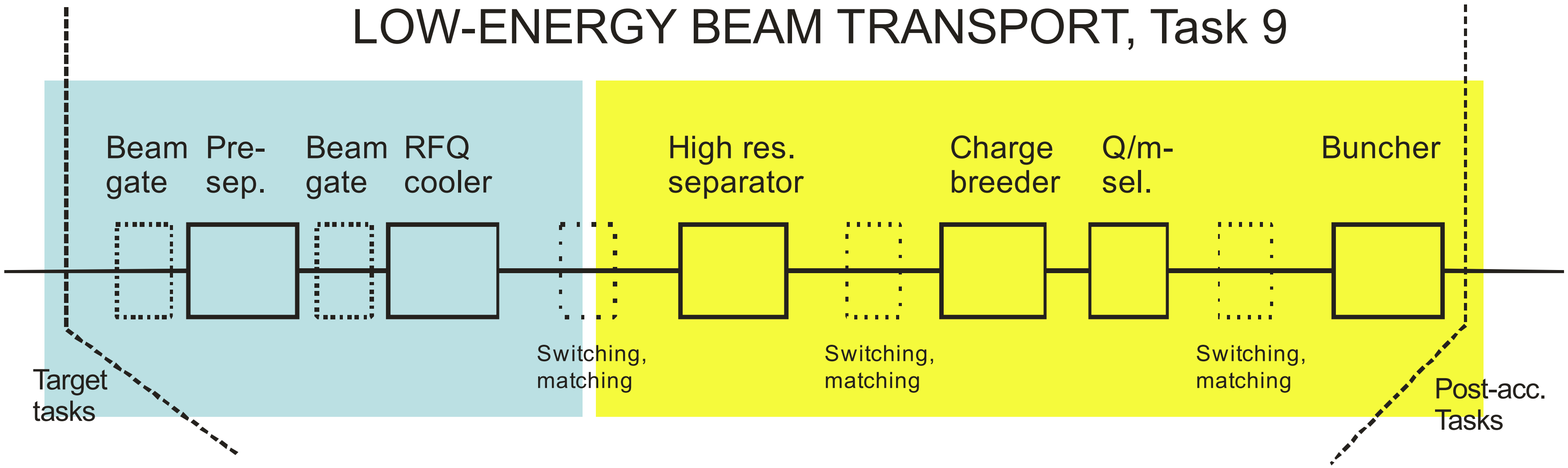
In case of high current EBIS device:
deep space charge potential well
→ achromatic separator (Nier type) required due to the energy spread of the ions

Aperture of magnet:
small in case of EBIS (20-30 mm)
larger in case of ECRIS (space charge, 40-60 mm)

(O. Kester, GSI)

Beam preparation task 9

1+→n+ reference design, 2006



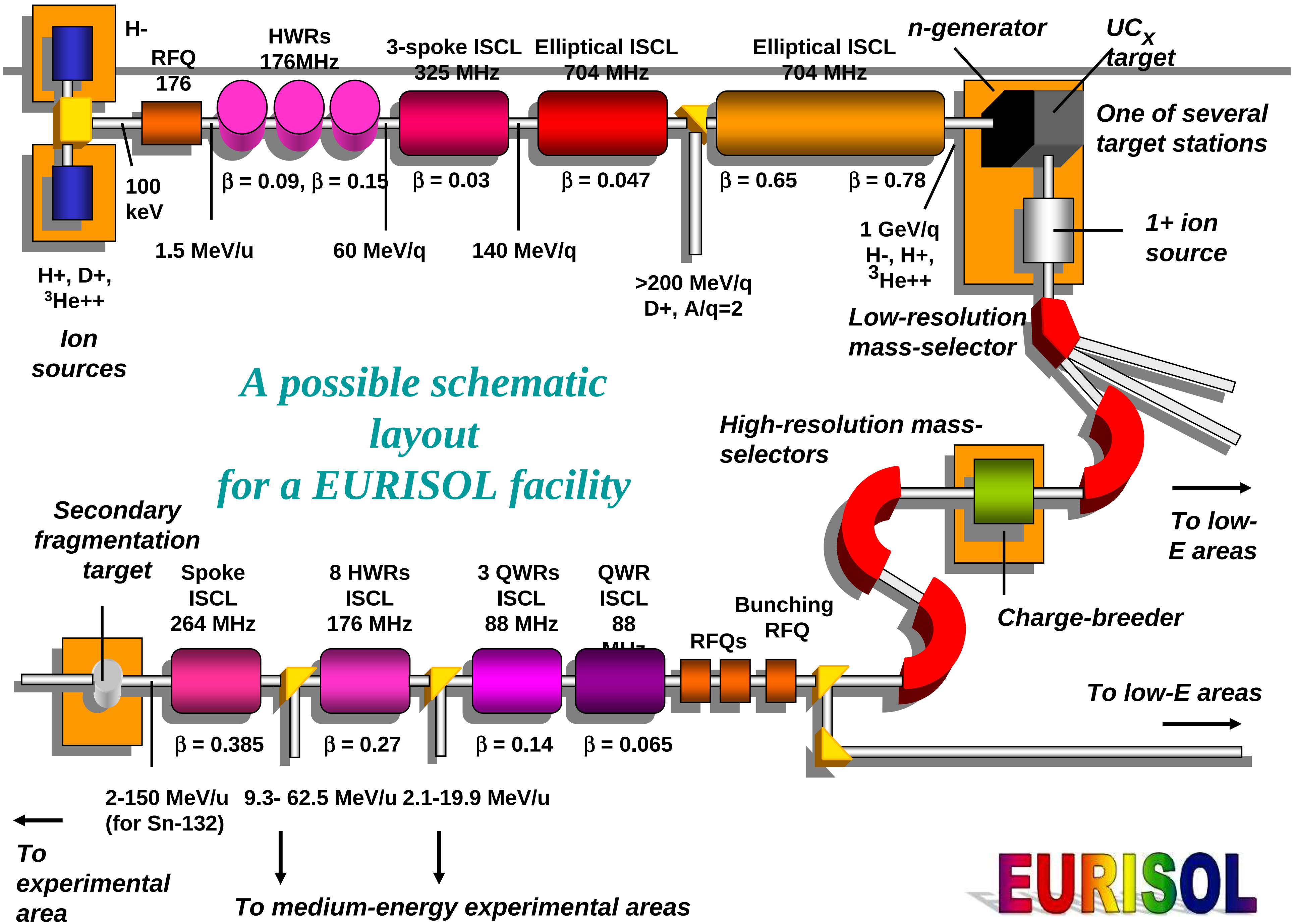
Basic chain of devices is well established and individual components are further developed in sub-tasks

Drift sections, switching and matching optics:

- Conventional ion optics
- Electrostatic elements (mass independent optimization)
- IAP recommendation: acceptance >> emittance

Development end of 2005 - 2006

- Physics workshop, Trento, January-06,
- Combined task 6, 9 and 10 meeting, Orsay May-06
- Coordination Board meeting, PSI, June-06
- Discussion on key experiments → recommendations
- Discussion on parallel operation
- Feasibility of the EURISOL-CS layout



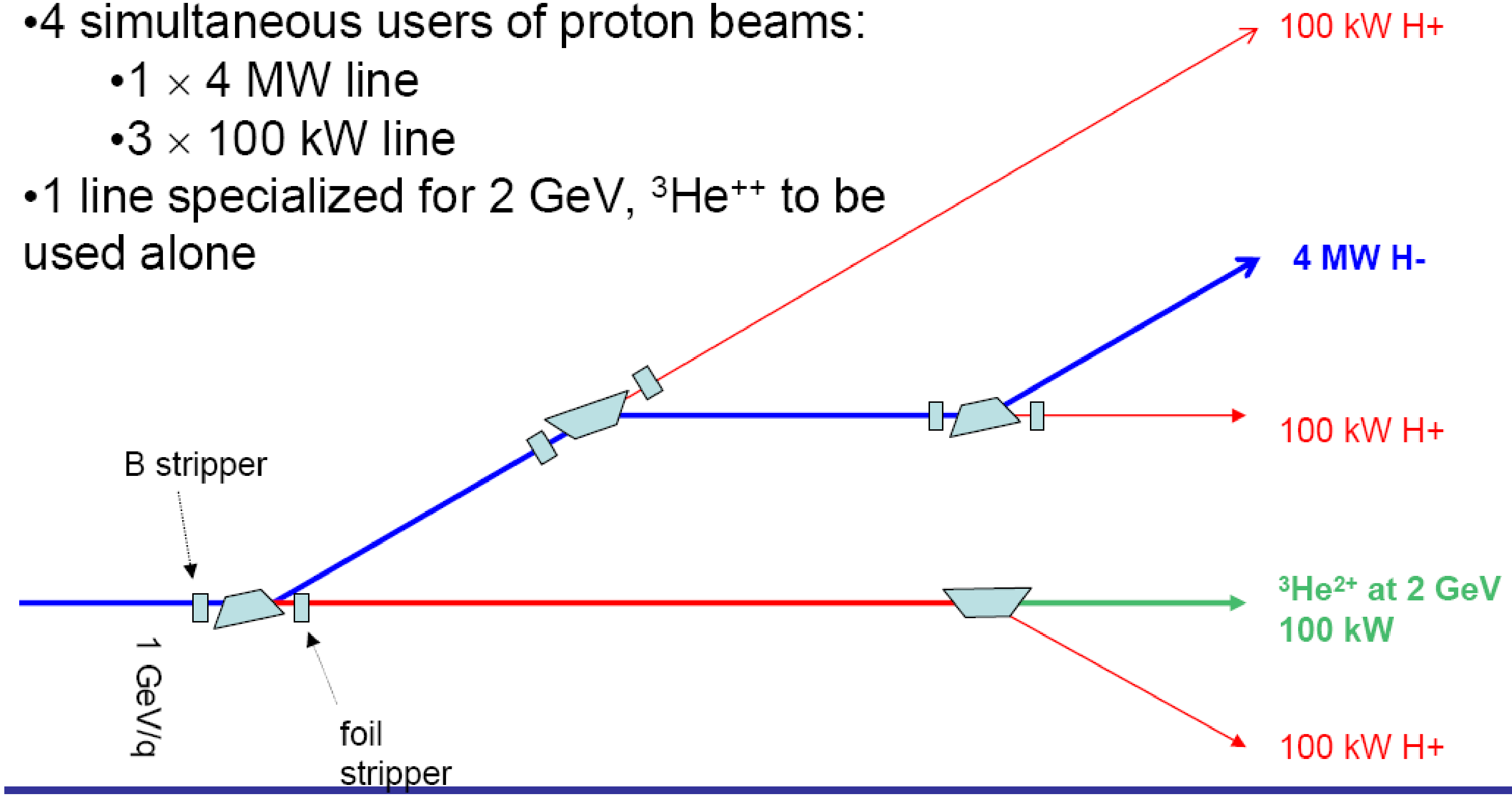
Eurisol Town Meeting, CERN, 28.11.2006, A. Jokinen

General lay-out and parallel operation

Parallel operation of different target stations	
Geometries and ion beam characteristics of the target and ion source combinations	
Extraction of the different energies from one post-accelerator	
Number of parallel beams	
Experimental areas	

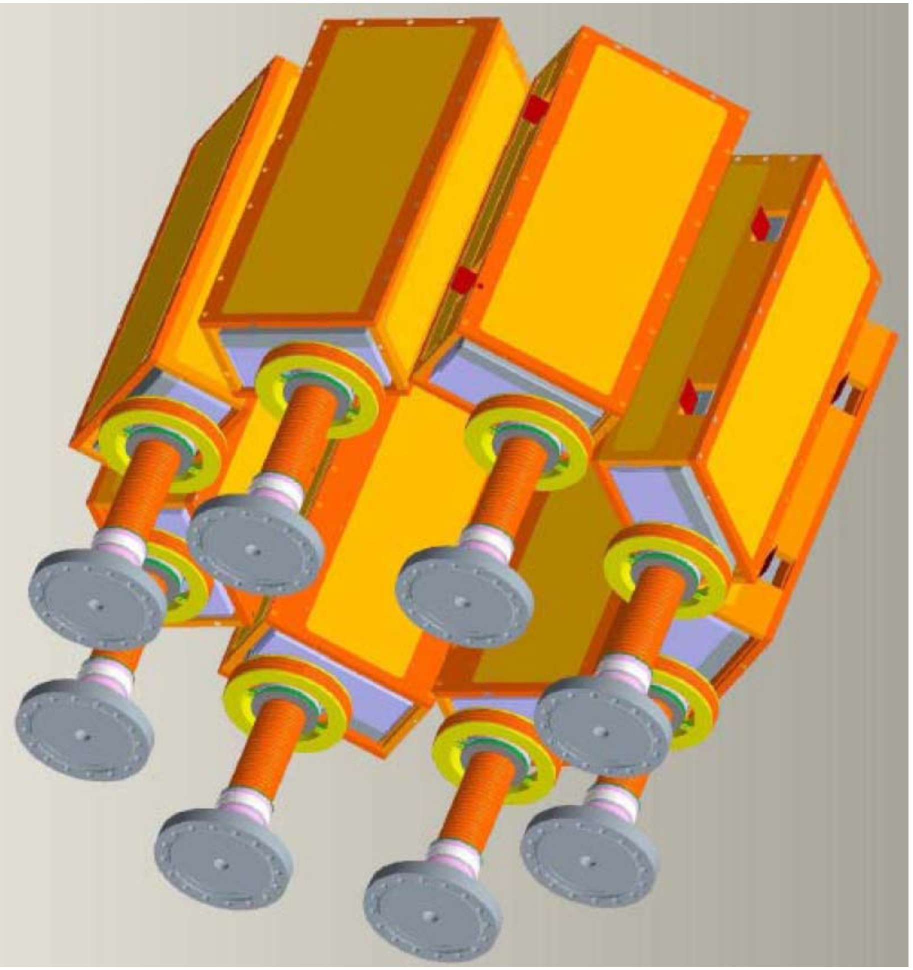
1 GeV extraction scheme

- 3 splitting stations
- 4 simultaneous users of proton beams:
  - 1 × 4 MW line
  - 3 × 100 kW line
- 1 line specialized for 2 GeV, $^3He^{++}$ to be used alone



A. Facco, Driver Task 7

Target-ion source geometries: Fission target



Hg-jet target surrounded by the bulky converter

→ multiple ion-source system (type not yet decided)
OR
Multiple transfer lines

→ complicated coupling to the beam preparation phase – not solved

(Don't forget radiation issues)

(L. Tecchio)

Baseline parameters – 100 kW

Baseline parameters – 05/27/2005   Eurisol-DS task #3 "100kW direct target station"

Parameter	Symbol	Units	Nval	Range
Target material	Z_{targ}	-	SiC, Ta, BeO, Pb (molten)	UC_x, MgO
Beam particles	Z_{beam}	-	Proton	Deuterium – ^{12}C
Beam particle energy	E_{beam}	GeV	1	0.5 – 3
Beam current	I_{beam}	µA	100	100 – 1000
Beam time structure	-	-	dc	Ac 50Hz 1ms pulse
Gaussian beam geometry	σ_{beam}	mm	7	3 – 20
Beam power	P_{beam}	kW	100	100-1000
Target thickness	X	g/cm^2	200	10 – 250
Target radius (cylinder)	r_{targ}	mm	$3\sigma_{beam}$	$3\sigma_{beam} - 5\sigma_{beam}$
Target temperature	T_{targ}	ºC	2000	500-2500
Number of target containers	j_{targ}	-	4	1 – 10
Plasma ionization outlet diameter	$Ø_{out}$	mm	3	2 – 6

Edited by T. Stora for the EurisolDS-T3 CERN work group.

However, no parameters defining the properties of the extracted ion beam (emittance, energy spread, $I_{interest}/I_{total}$, …)

Post-acceleration scheme

From:
a) "Experimental requirements", N. Orr, April 2006
b) EURISOL joint meeting of tasks 6,9,10, May 2nd, 2006, Orsay

- **3 separate post-accelerators: VLE (<1 MeV/u), LE (1-5 MeV/u), and HE (150 MeV/u). Task 6 study concerns only LE & HE accelerators**
- **Beta-beam injector will be a separate machine, studied outside of the Task 6**
- **For normal use, the linac post-accelerators should NOT employ stripping foils because of safety, beam loss, and beam quality considerations. However, the provision of strippers as an option is desirable for physics applications requiring short-lived radionuclides or high-energy high-A beams**
- **The most flexible scheme has to be found concerning beam sharing**

Jean-Luc Biarrotte, EURISOL Task 6 meeting, Frankfurt, 26/09/2006

Will be discussed in detail in the following presentation by M.-H. Moscatello

Experimental areas and # of parallel beams

- Low-energy area (few tens of keV)
- Astrophysics (0.1-1 MeV/u)
- Coulomb barrier (1-5 MeV/u)
- High-energy area (up to 150 MeV/u)

Task 10 (Low-energy area, Astrophysics)

Task 6 (Coulomb barrier, High-energy area)

Based on the
Nigel Orr, Summary report HI-beam parameters (updated Nov 06)
Minutes of the Coordination Board Meeting June 2006

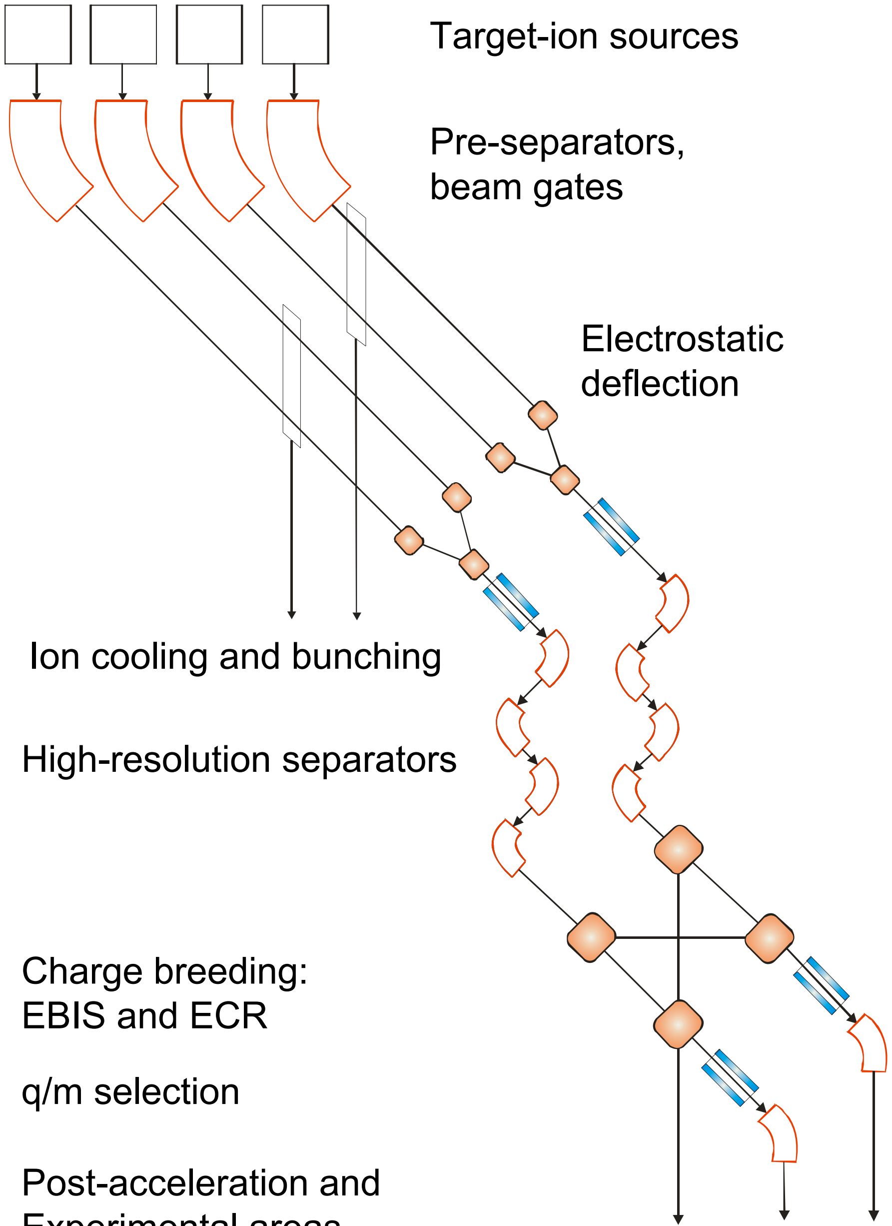
A) The lifetime of the individual targets and required time for the change of the target
B) Realistic proposal (in terms of complexity and costs)

→ two parallel beams (variation in Z,E)

General lay-out and parallel operation

Parallel operation of different target stations	~solved. Minor practical considerations to be studied but proposed scheme should be used (A. Facco Task-7). 4 target stations assumed.
Geometries and ion beam characteristics of the target and ion source combinations	Open (Presentations on Monday by L. Tecchio, C. Lau and T. Stora)
Extraction of the different energies from one post-accelerator	Less interesting and technically complicated → three post-accelerators (physics requirements, R. Page and N. Orr and post-accelerator task, M.-H. Moscatello)
Number of parallel beams	Simplification to old ideas: Goal is to have two parallel beams: different isotopes at different final energy (Coordination Board, June 2006)
Experimental areas	4 areas proposed (physics requirements, R. Page and N. Orr). Lay-out and necessary instrumentation to be defined in Physics Task

Schematic lay-out and an outlook

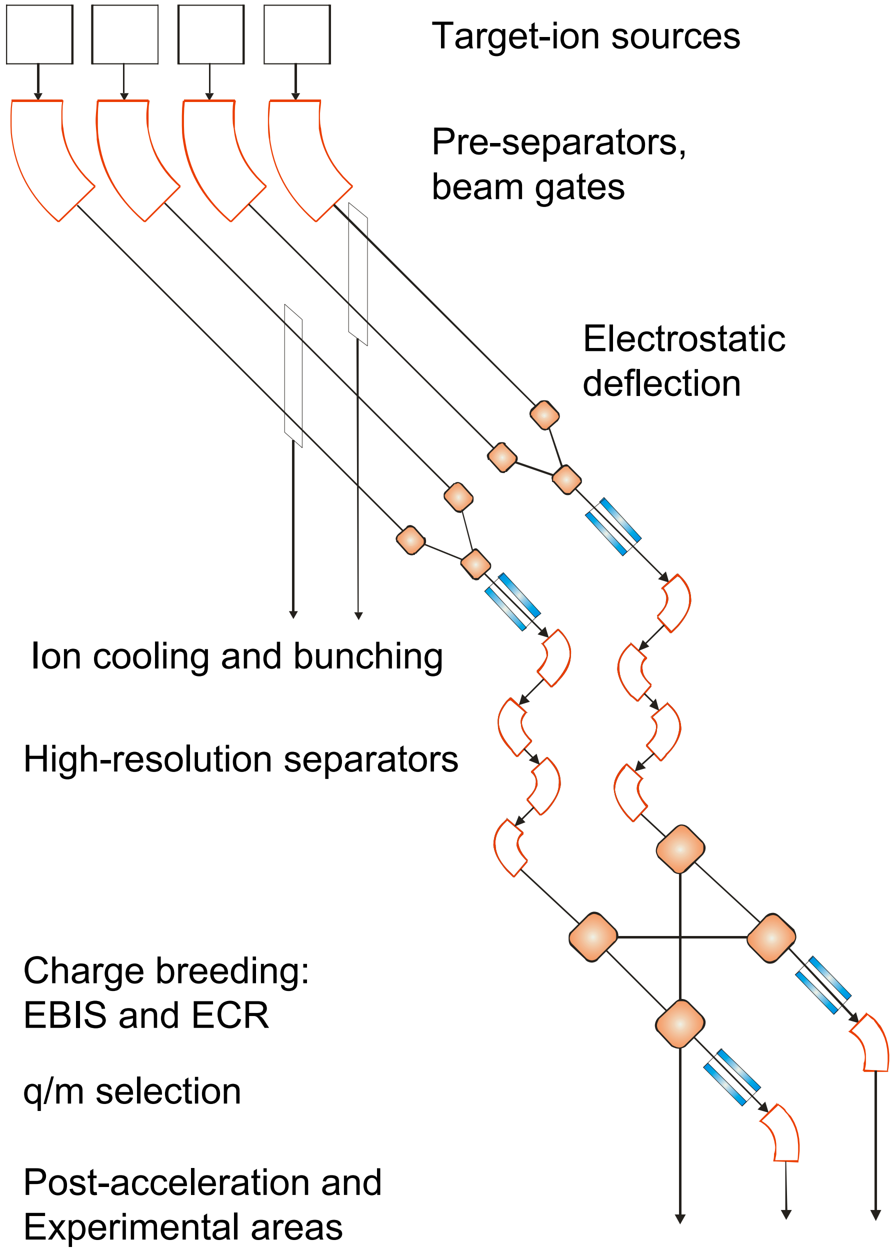


Beam preparation lay-out:
- Two complete beam preparation chains:
- 2 parallel mass-purified beams for on-line experiments
- 2 charge breeders:
  - EBIS (fast, low capacity, low background, narrower charge state distribution)
  - ECR (slow, high capacity, high background)
- Modular (easy to expand)
- Robust (electrostatic deflectors without moving parts)

Task 9 perspective:
- Development of high capacity cooler
- Continuation of HRS calculations (2 magnets instead of 4?)
- ECR and EBIS R&D in progress (within EURISOL Task 9 and EURONS Jra's)
- Interim reports 2007

Lay-out perspective:
- Target-ion source geometries and ion beam paramaters and composition have to be defined
- Site-related boundary conditions
- Radiation issues
- Physics and post-acceleration requirements
- Target Tasks (2,3,4), Radiation Safety Task (5), Post-accelerator Task (6), Beam Preparation Task (9) and Physics Task (10)
- Parameter database: Necessary (but not enough)

Schematic lay-out



Beam preparation lay-out:

- Two complete beam preparation chains
- Two parallel mass-purified beams for on-line experiments
- Two charge breeders:
  - EBIS (fast, low capacity, low background, narrower charge state distribution, provides intensity also for light elements)
  - ECR (slow, high capacity, high background, access to intense beams including stable ones)
- Modular (easy to expand)
- Robust (electrostatic deflectors without moving parts)

Outlook

Beam Preparation Task 9:
- Development of high capacity cooler
- Continuation of HRS calculations (2 magnets instead of 4?)
- ECR and EBIS R&D in progress (within EURISOL Task 9 and EURONS Jra's)
- Good progress in beta-beam source sub-task (report by P. Delahaye)
- Interim reports 2007

General lay-out:
- Target-ion source geometries and ion beam paramaters and composition have to be defined
- Site-related boundary conditions
- Radiation issues
- Physics and post-acceleration requirements
- Target Tasks (2,3,4), Radiation Safety Task (5), Post-accelerator Task (6), Beam Preparation Task (9) and Physics Task (10)
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END

Brief Summary Shutdown 2006

	REXEBIS+REXTRAP	PHOENIX booster
Efficiency	15→2%	7→ 2% ≈ for same Z
τ_{cb}	From 13 to 300ms depending on A	100 ms ~ Confinement time <300ms
A/q	3.5 - 5	4 – 8
A	No real limitation	Injection difficult A<40
Mode	Pulsed	Continuous or pulsed
Imax	A few 10nA	> 1 μA
Backgrd	If no gas peak <0.1pA	Usually >2nA
Reliability	Cathode is fragile	Robust

P. Delahaye, CB06 workshop, Darmstadt 22/05/2006