Splitting of high power H^- beams: the EURISOL technique

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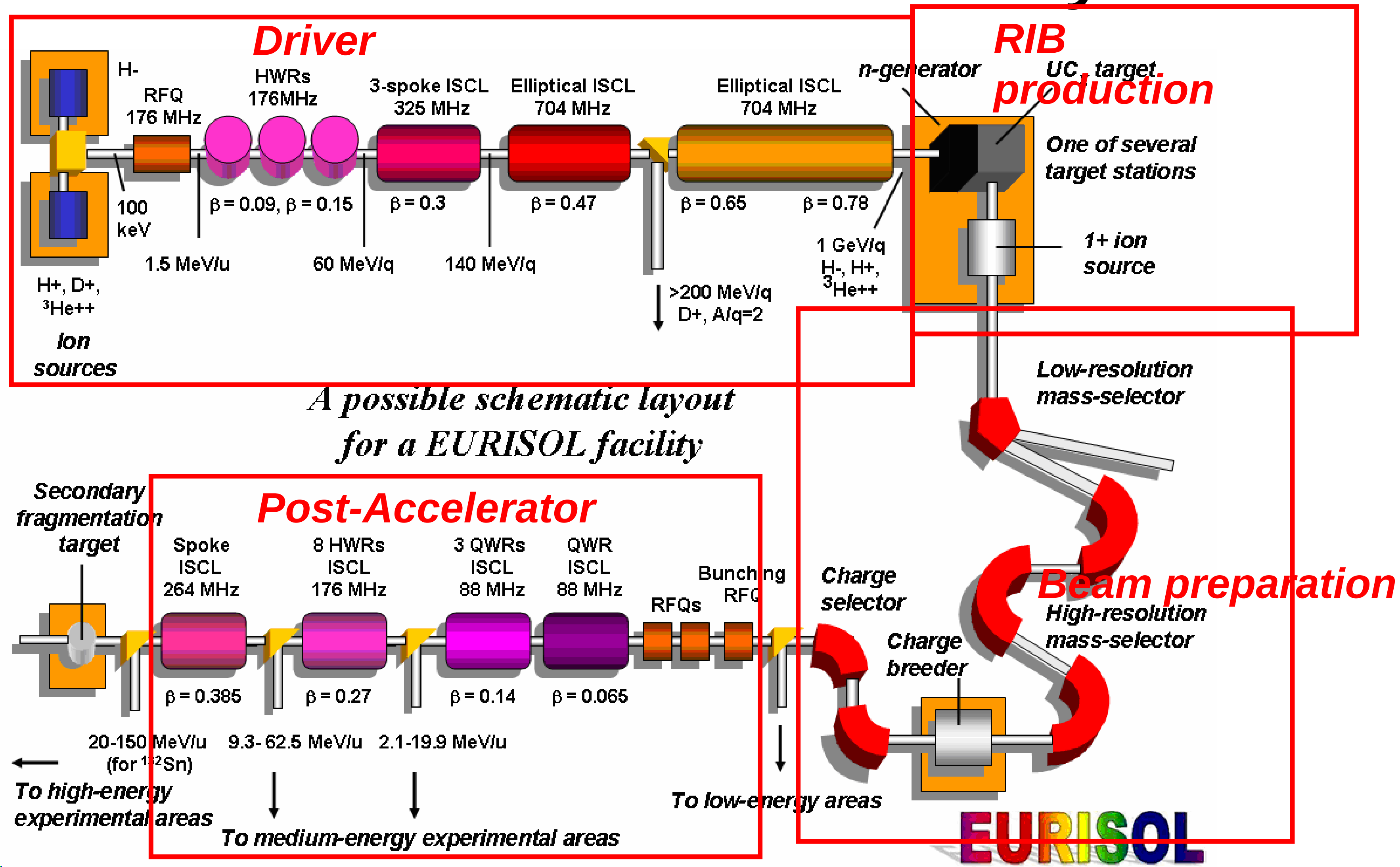
The EURISOL facility



EURISOL driver requirements

- 4 MW H^+ (or H^-) primary beam to a neutron converter
- 3×100 kW H^+ secondary beams to RIB direct targets
- finely tunable beam intensity
- parallel operation in cw mode

A new kind of beam splitter is required

Splitting methods

1. pulsing the beam, then diverting some of the pulses with rf deflectors

2. changing A/q of some particles, then splitting the two beams by means of a dipole magnet

the second method, with a H^- primary beam, can be used <u>also</u> in cw operation

1° step: changing of the H^- charge state

1. stripper foils:
   - $H^- \rightarrow H^-, H^0, H^+$ // $H^- \rightarrow H^0, H^+$ // $H^- \rightarrow H^+$ (depending on foil thickness)
   - not able to hold MW power
   - impossible to regulate the branching ratio after chosing the foil
   - <u>not usable on the main beam for our purpose</u>

2. laser stripping:
   - $H^- \rightarrow H^-, H^0$; $H^0 \rightarrow H^0, H^+$
   - sufficient laser power density reachable only in pulsed operation
   - sufficient laser-beam interaction reachable only with pulsed beam
   - <u>not easy, high power lasers required</u>

3. magnetic stripping:
   - $H^- \rightarrow H^0$
   - branching ratio finely tunable
   - <u>simple and inexpensive: only small dipoles required</u> ***←ok***

2° step: beams separation

- After the charge changing device: 2 superimposed beams, H^- and H^0

- The beam separation is obtained with a dipole magnet:
  - H^- is transported by the magnet
  - H^0 proceeds straight

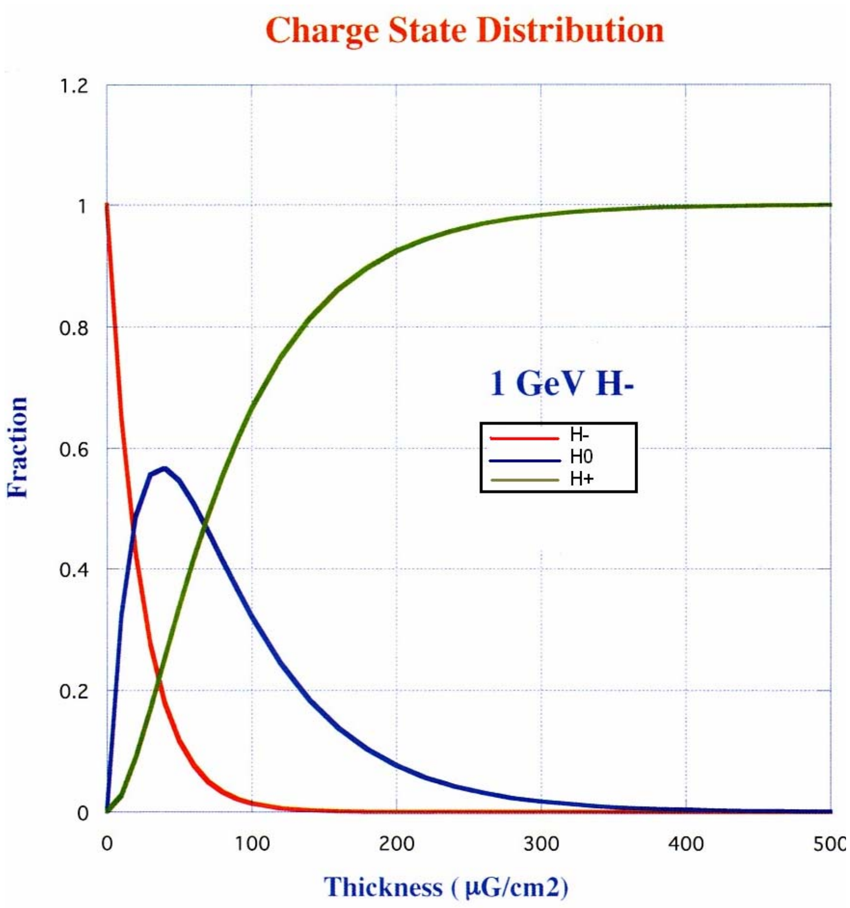
- the magnetic field must be low enough to avoid significant H^- neutralization (thus losses) along the bending magnet (reasonable treshold: below 1 W/m)

- After leaving the dipole, H^0 must be transformed in H^+ to be further transported

3° step: Carbon foil stripping

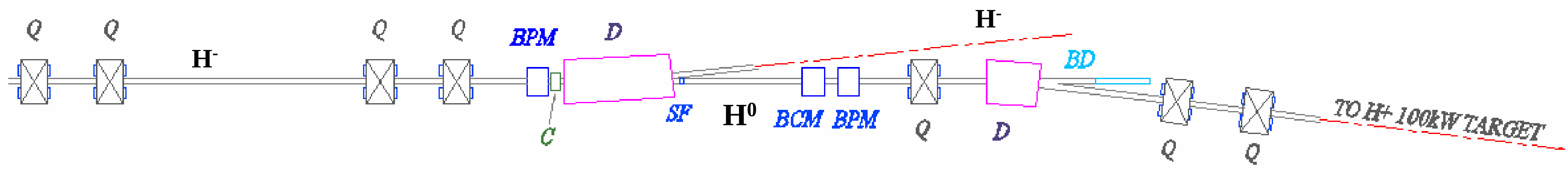
– the stripping efficiency depends on the foil thickness: a nearly full stripping can be obtained

– long foil lifetime is possible for ~100 kW beams



EURISOL Splitter Layout

Primary beam: 1 GeV, 4 MW
Secondary beams: 100 kW

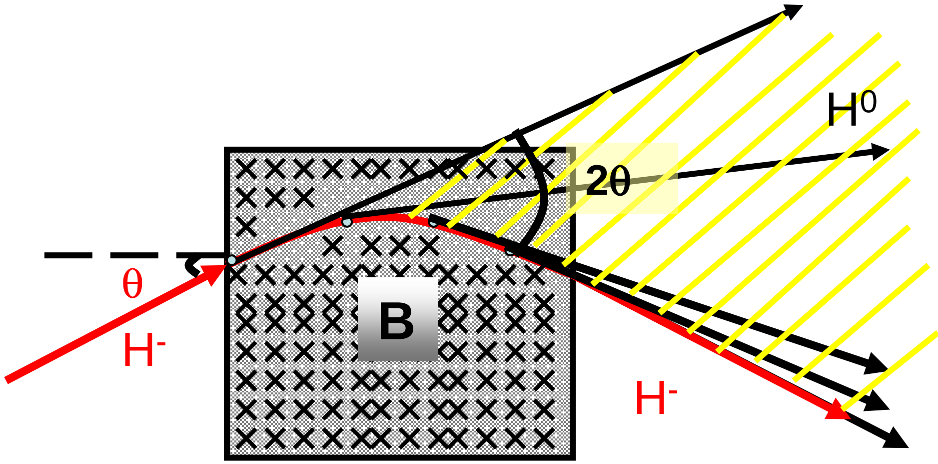


- 3-step splitting scheme:
  - (*C*) Magnetic neutralizer to extract H^0 beam
  - (*D*) 1° bending magnet to separate H^0 from H^-
  - (*SF*) stripper foil on the H^0 line to strip H^0 into H^+
  - 2° bending magnet to send H^+ to target and residual H^0 (~50 W) to a beam dump (*BD*)

EURISOL Design Study

Emittance growth in Lorentz Stripping

Ions travel a finite distance before being stripped
⇒angular spread
⇒emittance growth for the H^0 beam



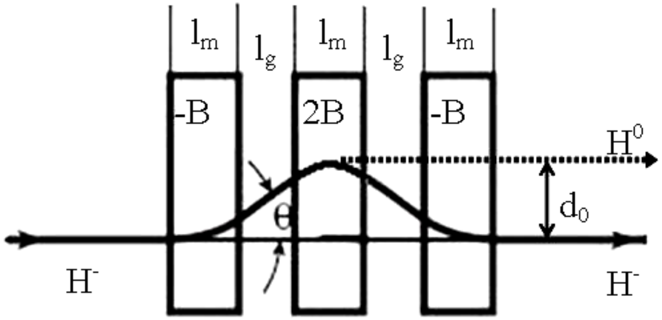
- the shorter the beam path along B above the stripping threshold, the less is the emittance growth of H^0

→ a short dipole is required

- a system that does not modify the output beams trajectories while changing B (thus the the stripping efficiency) is also desirable

How to limit emittance growth?

- neutralising chicane with 3 short dipoles
- magnetic fields:
  - 1° dipole: -B
  - 2° dipole: +2B
  - 3° dipole: -B
- the B dependence of Lorentz neutralization is very steep:
  → with this scheme the H^0 beam is formed only in the short center magnet
- the H^- output beam trajectory is independent from the B value

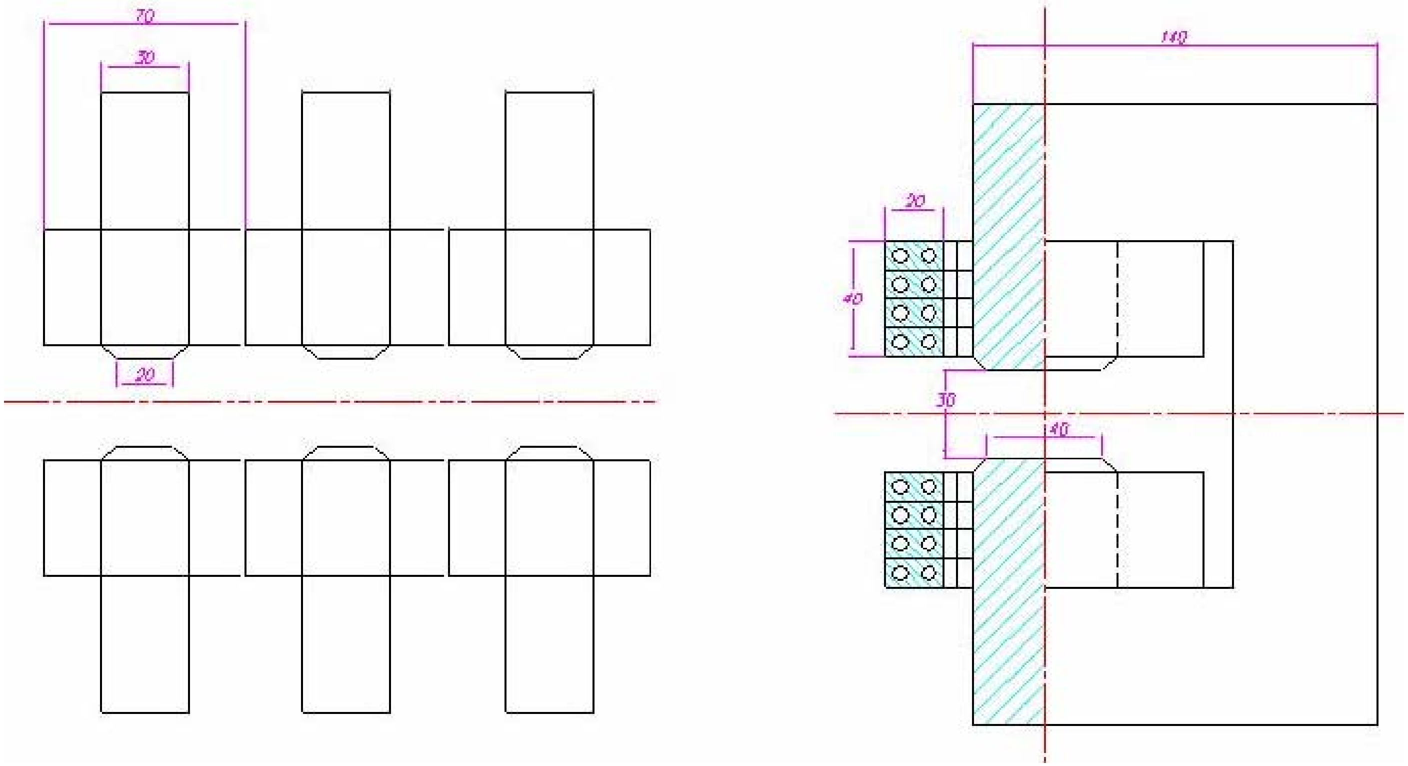


Magnetic length	30 mm
Separation for house coils	40 mm
Magnetic fields [T]	0.33; 0.66; 0.33
θ, deflection angle	~ 0.1 °
d_0, H^0 displacement	0.11 mm

•EURISOL case:
•2.5%, neutralization, finely adjustable

Chicane Fringe Fields

Short rectangular magnets, small bending angle

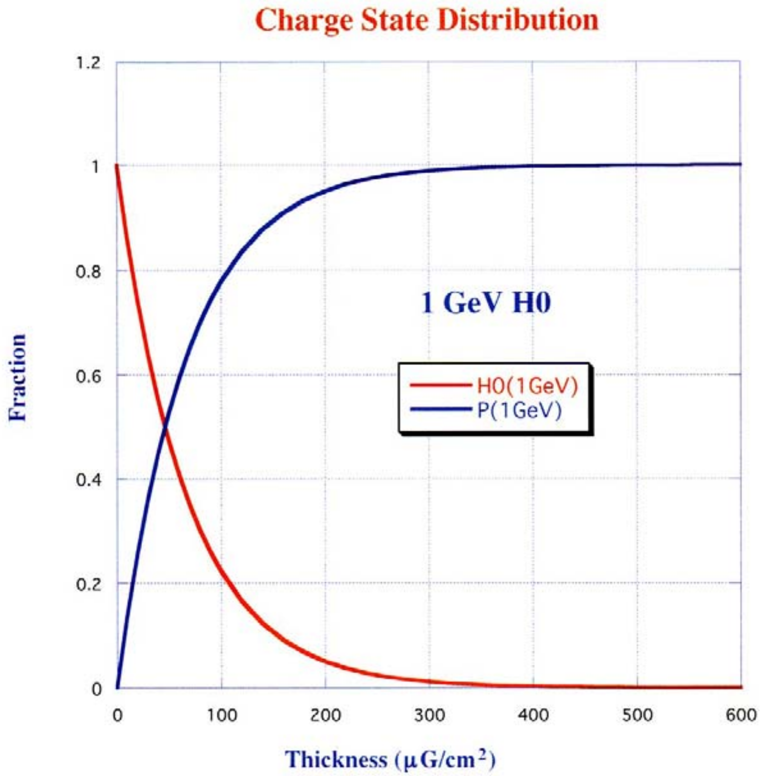


Very weak focusing in both horizontal and vertical planes ⇒

Chicane beam optics insensitive to dipoles fringe field shape

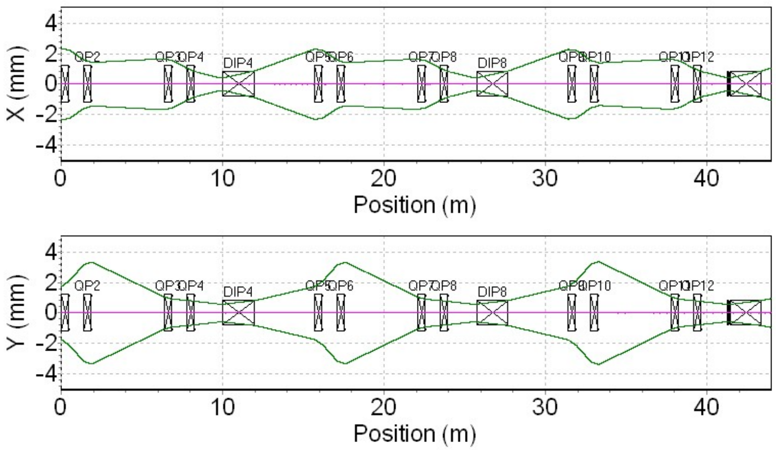
Stripper Foil for 1 GeV H^0

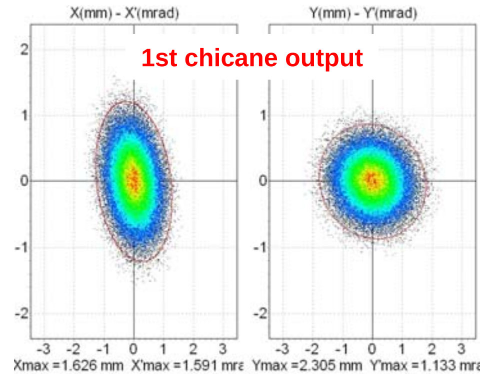
- Necessary thickness for nearly full stripping (unconverted H^0 beam ~50 W): 500 $\mu g/cm^2$
- 1 GeV - 100 μA $H^0 \Rightarrow$ the heat load is estimated 0.1 W $\Rightarrow$ not critical
- Expected foil lifetime of several weeks

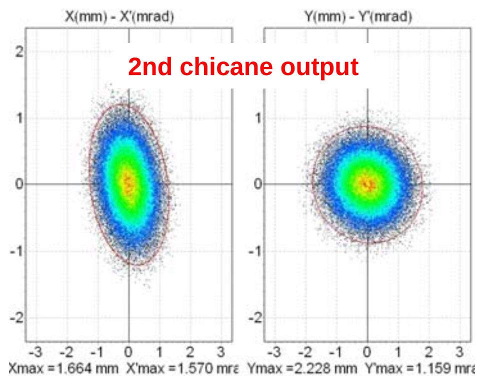


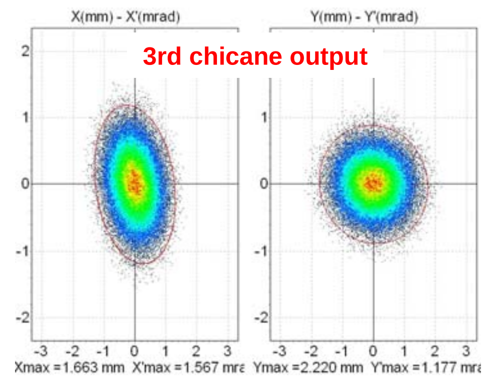
H^- Transport Along 3 Splitters

The line can be designed in order to repeat splitting without changing the primary H^- beam characteristics



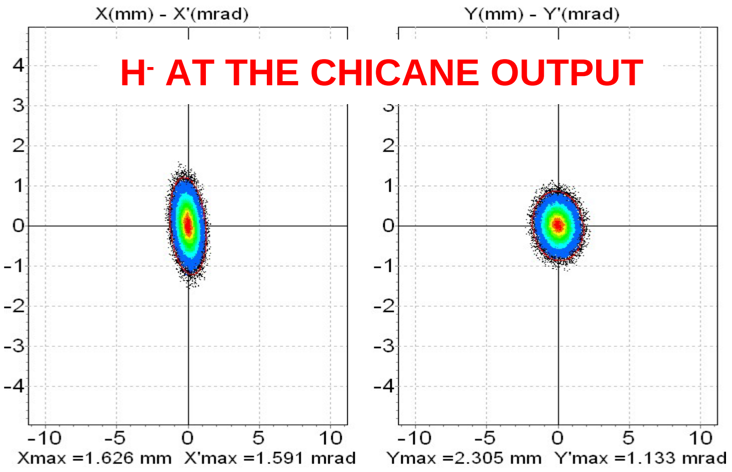




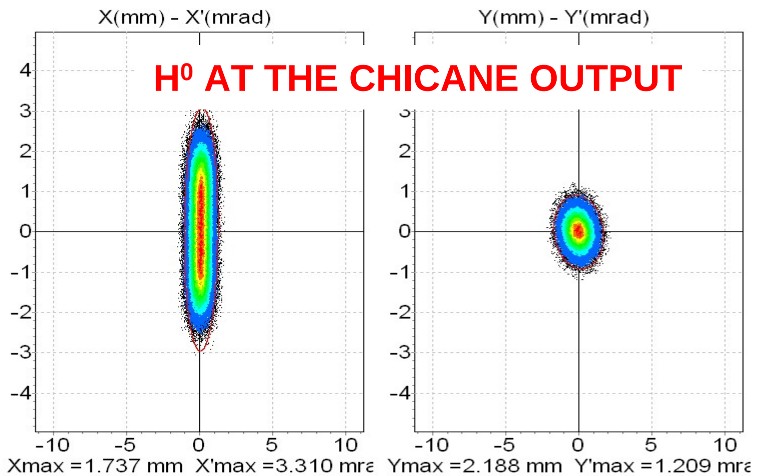


EURISOL Design Study

H^- - H^0 Phase Spaces



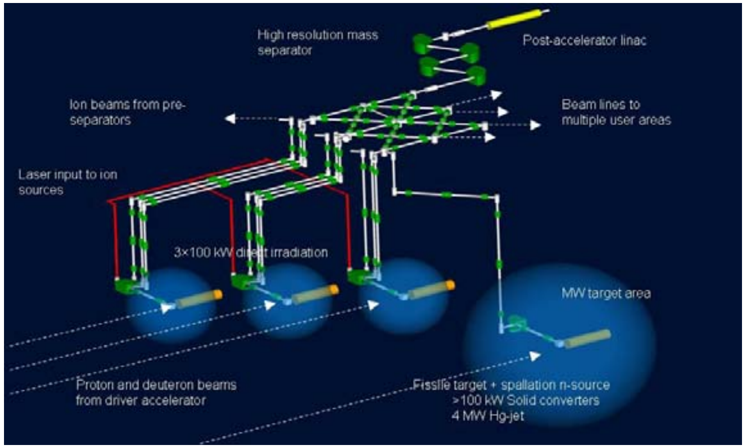
- H^- main beam not perturbed by the chicane
- emittance unchanged
- the primary beam can be used for any application (synchrotron injection, etc.)
- splitting can be repeated many times

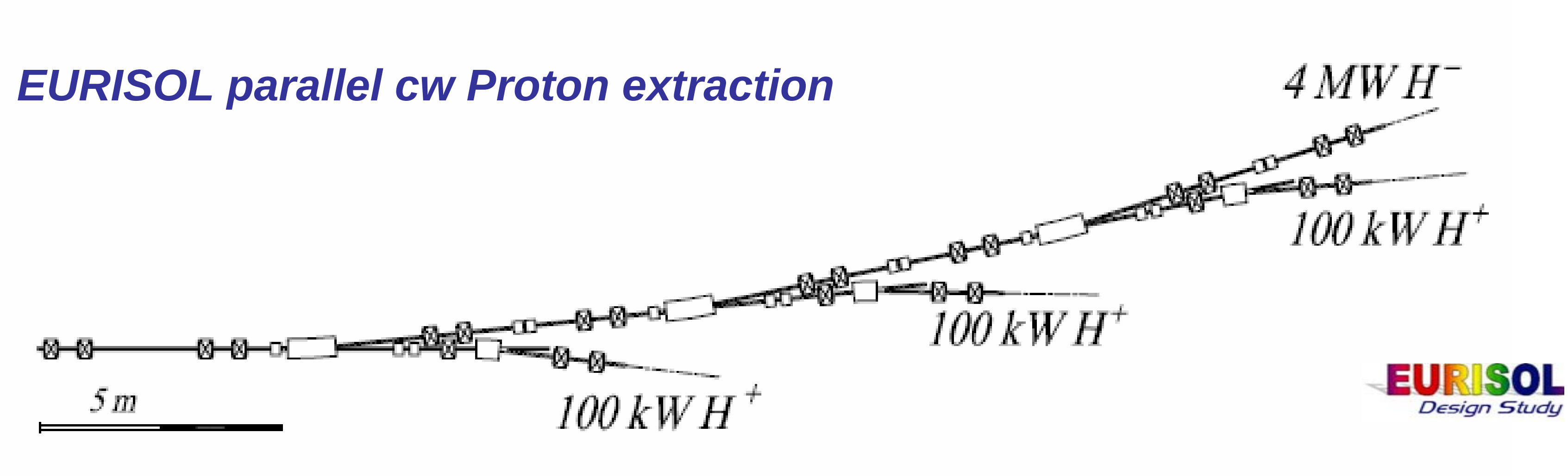


- H^0 emittance increased by Lorentz stripping (~ 3) on the bending plane
- not critical in a beam directed to a RIB target

EURISOL 1 GeV Multiple Extraction

- 3 splitting stations for cw proton beams
- 4 simultaneous users :
  - 1 × 4 MW
  - 3 × 0÷100 kW finely tunable





- for more information, see paper on PRST-AB

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Splitting of high power, cw proton beams

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A simple method for splitting a high power, continuous wave (cw) proton beam in two or more branches with low losses has been developed in the framework of the EURISOL (European Isotope Separation On-Line Radioactive Ion Beam Facility) design study. The aim of the system is to deliver up to 4 MW of H^- beam to the main radioactive ion beam production target, and up to 100 kW of proton beams to three more targets, simultaneously. A three-step method is used, which includes magnetic neutralization of a fraction of the main H^- beam, magnetic splitting of H^- and H^0, and stripping of H^0 to H^+. The method allows slow raising and individual fine adjustment of the beam intensity in each branch.

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Summary and Conclusions

- A new high power beam splitter design has been developed
- Relatively simple and reliable technology, suitable for cw and pulsed beams
- Allowing elimination of high power kickers and lasers
- Fine regulation of the secondary beam intensity without perturbing the primary beam
- Low beam losses expected
- Primary H^- beam emittance unchanged
- Secondary beam emittance suitable for lossless transport to ~100 KW RIB targets
- Splitting can be repeated many times

The 3-step proposed splitter could be profitably used in SPL for parallel feeding of different users, like synchrotron and RIB targets