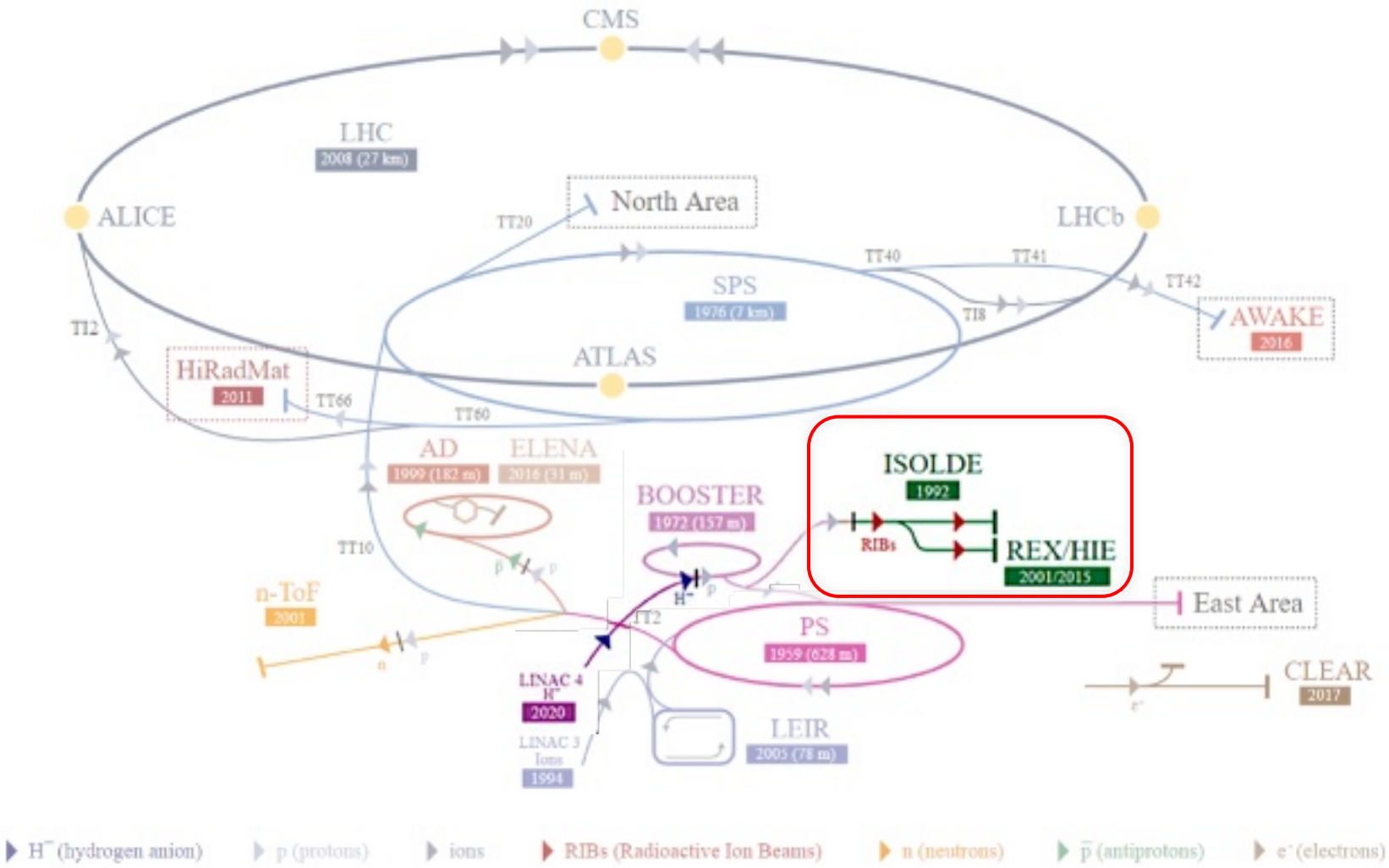
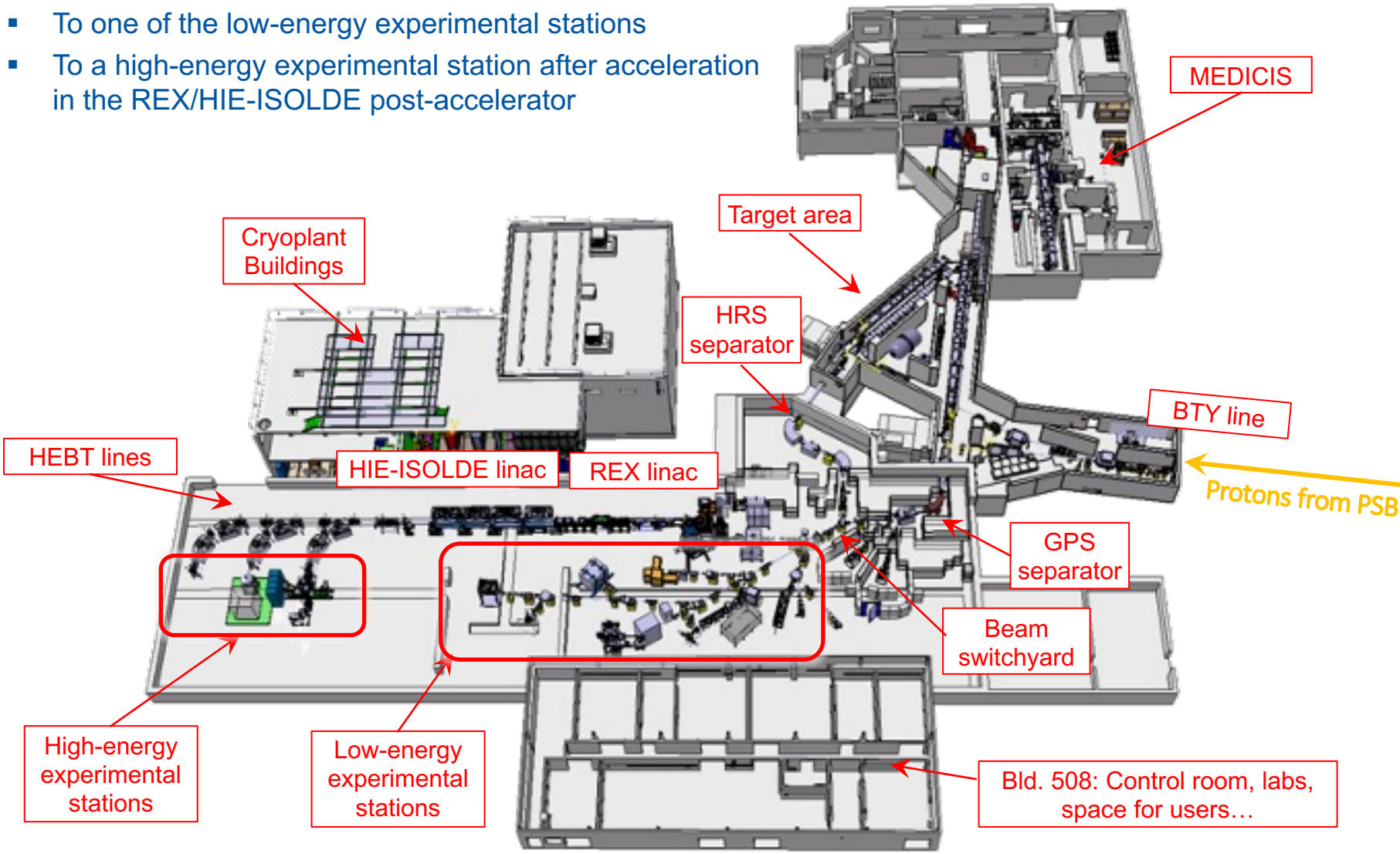
The ISOLDE Facility:

- ISOLDE is a Radioactive Ion Beams (RIBs) production facility located at CERN
- ISOLDE is the destination of around 50% of the protons accelerated by the PS Booster (~ 2 uA at 1.4 GeV)
- Proton pulses arrive to ISOLDE every 1.2 seconds or a multiple (2.4, 3.6… seconds)



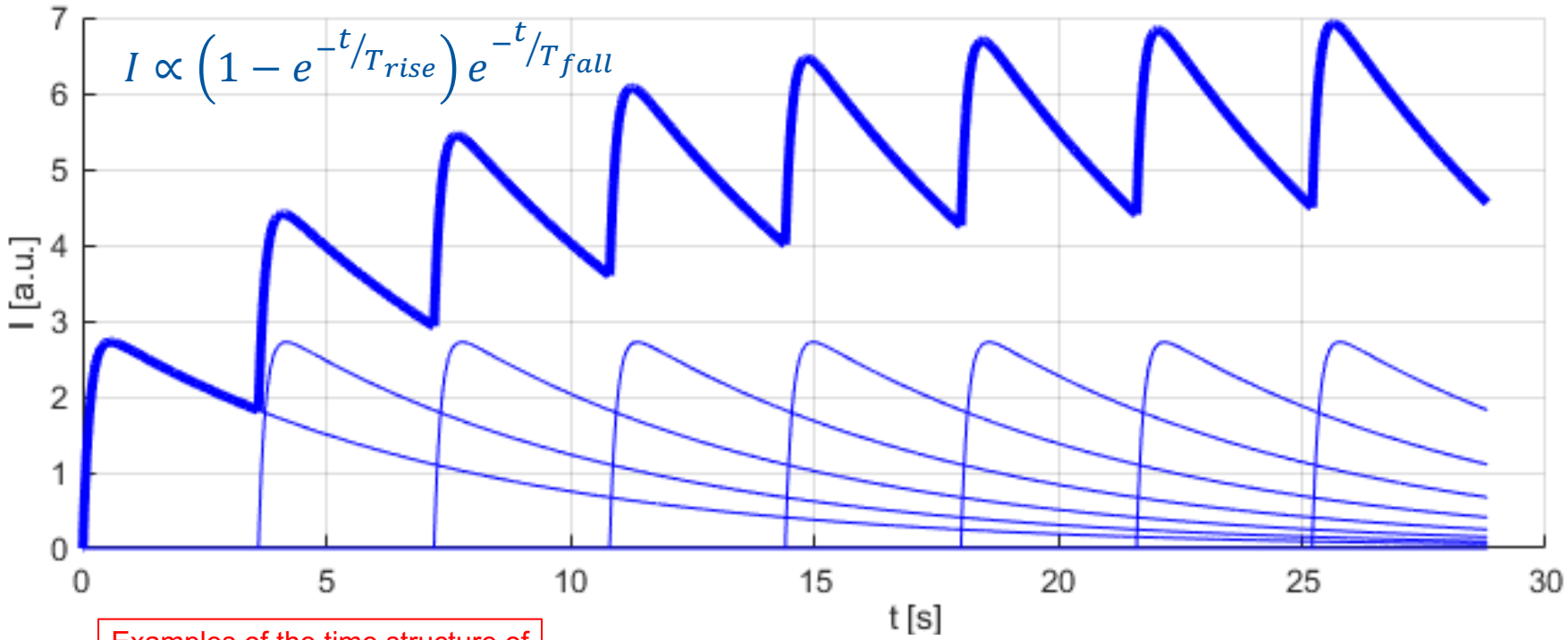
The ISOLDE Facility:

- RIBs are created in one of the two available target stations
- The RIBs are mass-separated and transported:
  - To one of the low-energy experimental stations
  - To a high-energy experimental station after acceleration in the REX/HIE-ISOLDE post-accelerator

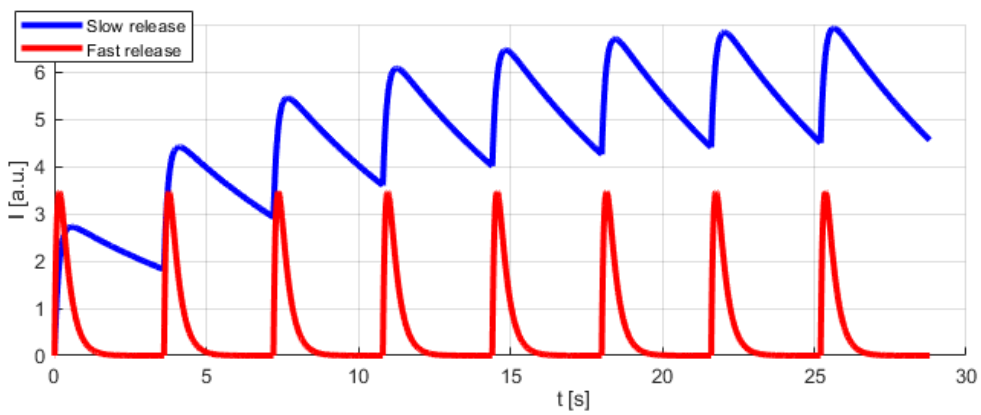


The ISOLDE Facility:

- Release times vary greatly (from tens of milliseconds to hours, days or longer)

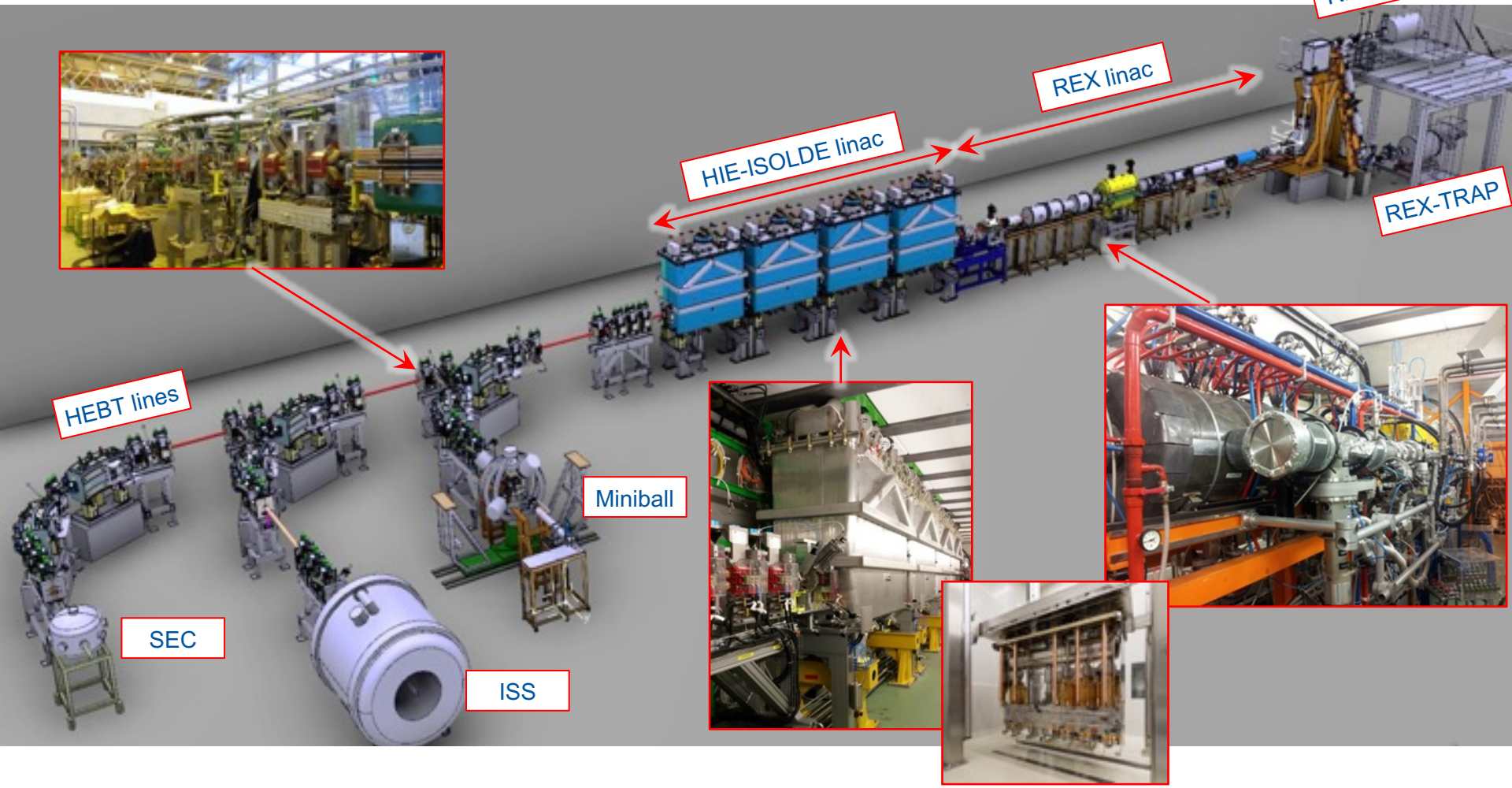


Examples of the time structure of the RIB as it is released from one of the ISOLDE targets



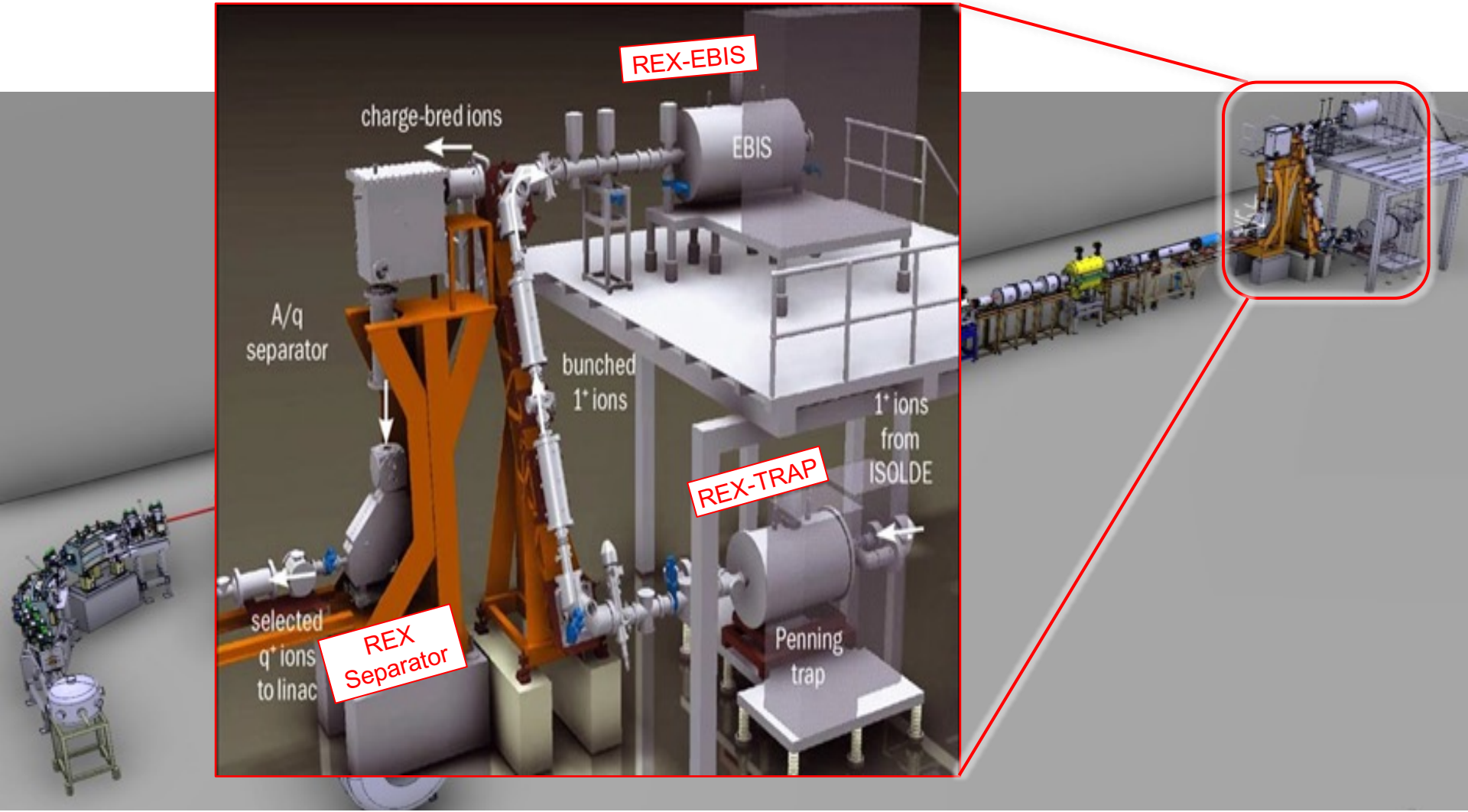
The REX/HIE-ISOLDE Post-Accelerator:

- Ions are accumulated and transversely cooled in the REX-TRAP and charge bred in the REX-EBIS
- Initial beam acceleration in the REX room temperature linac (7 RF structures, 101 MHz, 2.8 MeV/u final energy)
- Beam further accelerated in the HIE-ISOLDE superconducting linac (20 QWRs, 6 MV/m, 9.2-14.2 MeV/u)
- Beam delivered to one of the three experimental stations (ISS, SEC and Miniball)



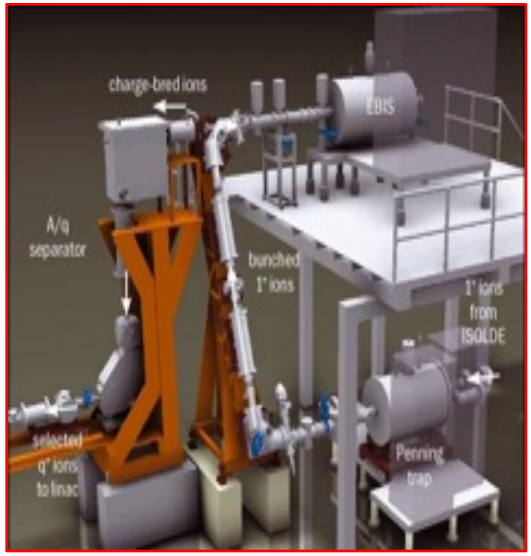
The REX-EBIS charge breeder:

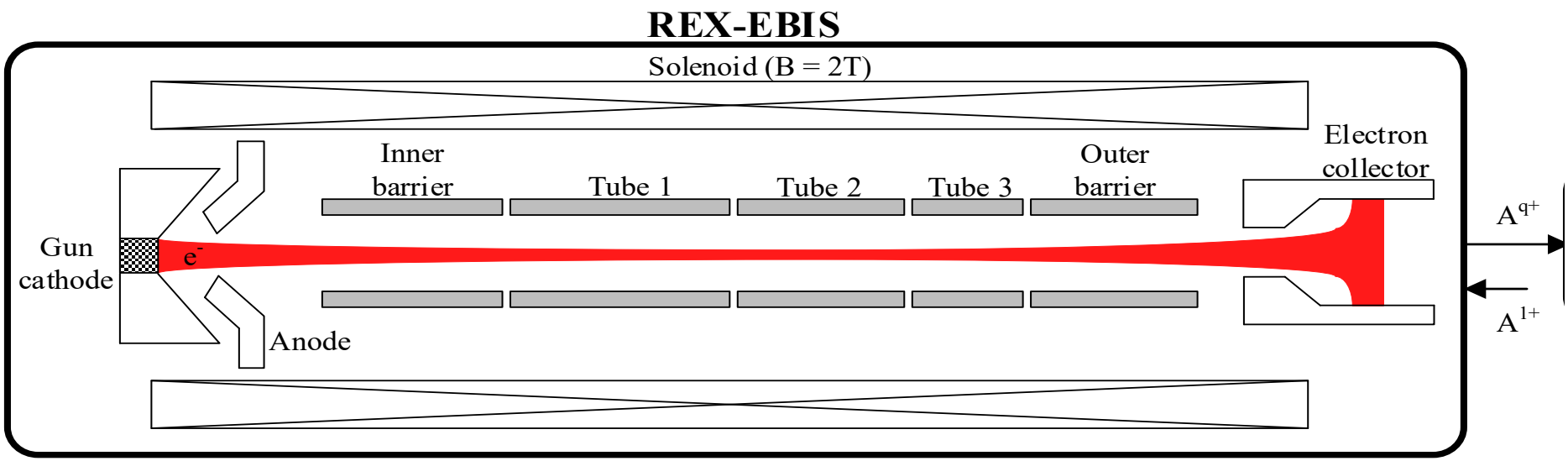
- Ions are accumulated and transversely cooled in the REX-TRAP and charge bred in the REX-EBIS
- The charge state of interest is selected in the REX separator before injection into the REX/HIE-ISOLDE linac for acceleration and delivery to one of the experimental stations



The REX-EBIS charge breeder:

- Ions injected into the REX-EBIS are singly charge
- Their charge state needs to be boosted for a more efficient acceleration
- Charge breeding by interaction with the REX EBIS electron beam during the breeding time
- Optimum breeding times depend on multiple factors:
  - Electron beam current and energy, current density…
  - Final charge state, atomic number of the RIB…
  - Alignment of the injected RIB and the electron beam…
- Typical optimum breeding times: (10^{-2} – 1) s





Schematic of the REX-EBIS charge breeder

The REX-EBIS charge breeder:

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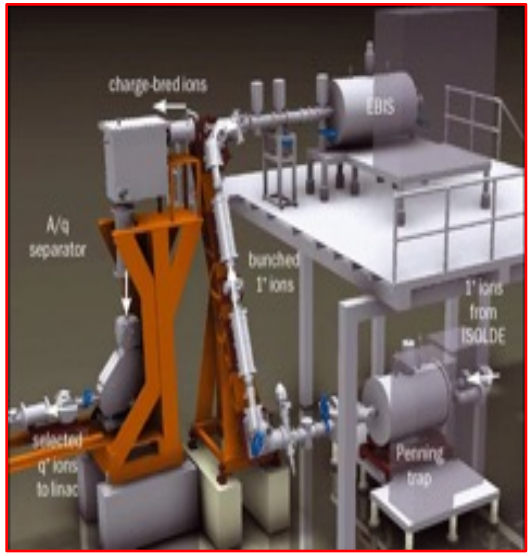
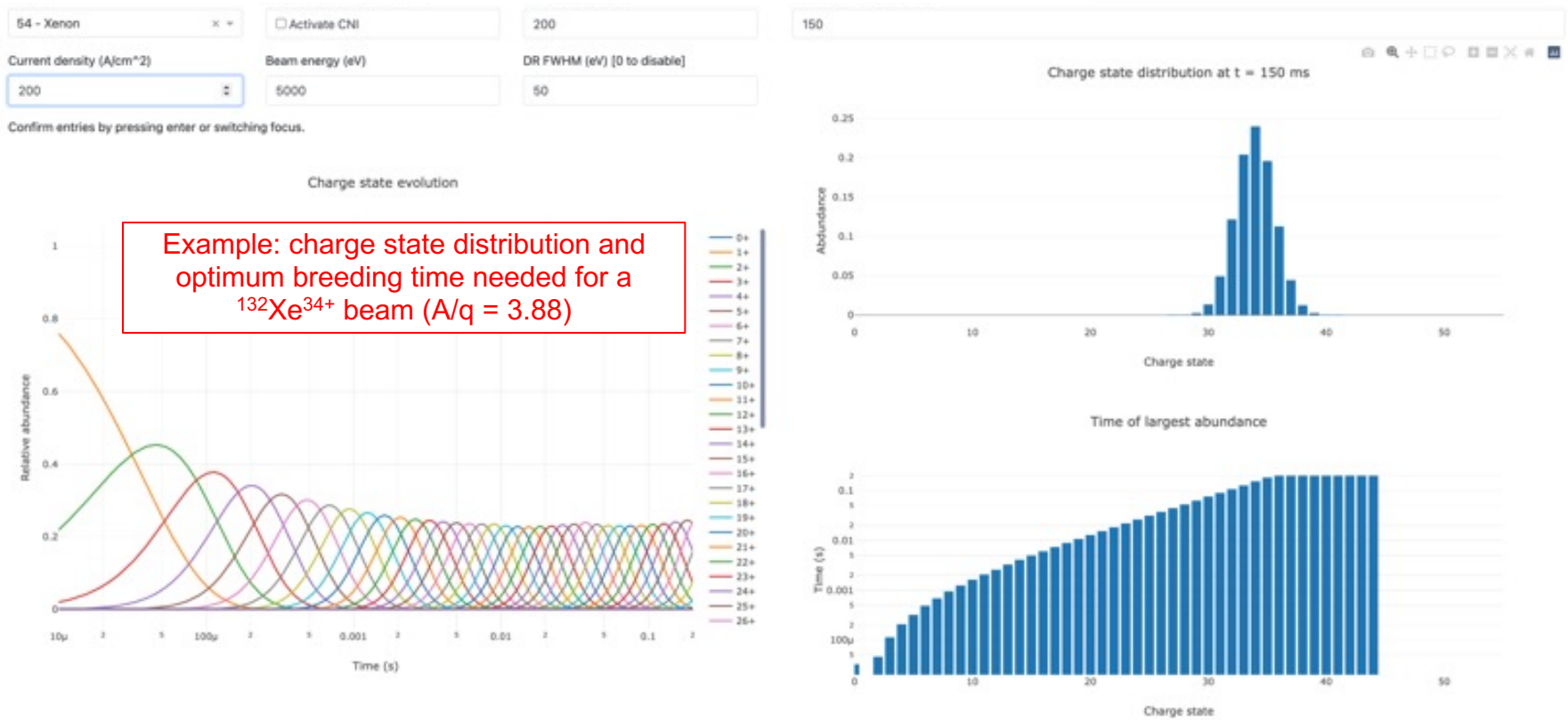


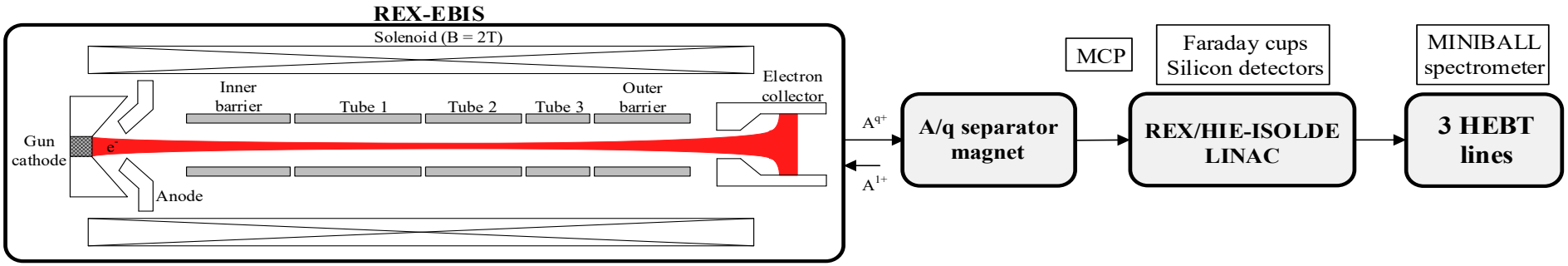


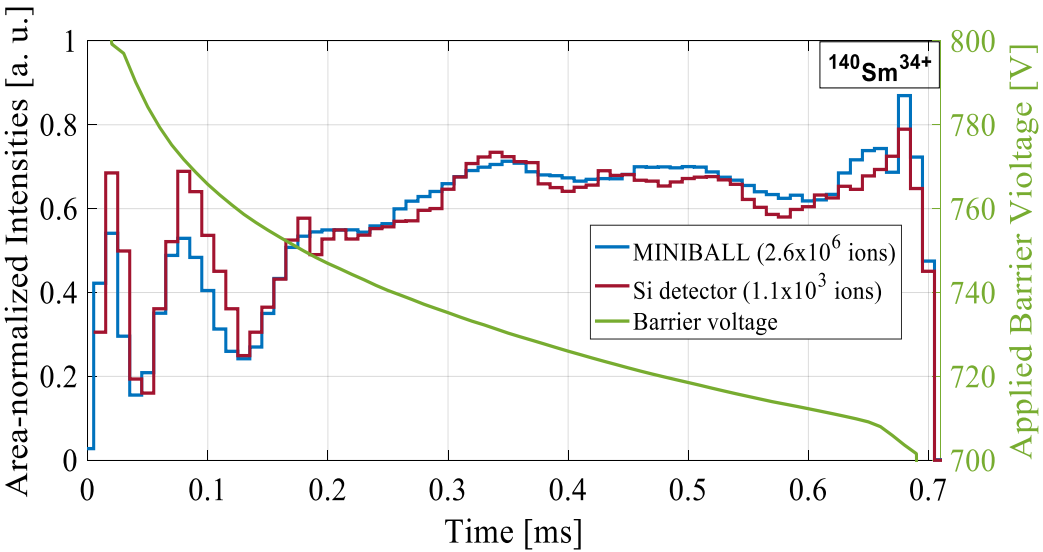
Example: charge state distribution and optimum breeding time needed for a $^{132}Xe^{34+}$ beam (A/q = 3.88)

The REX-EBIS charge breeder:

- After charge breeding, the RIB pulses are extracted from the REX-EBIS
- Pulse lengths are typically ~ (60 – 100) us long when the potential outer barrier is opened “instantaneously”
- Pulse lengths can be modified by opening the the outer barrier slowly (i.e. slow extraction):

1. Measurement of the axial energy distribution of the ions of interest after extraction from the REX-EBIS
2. Calculation of the inverse function and application to the trap barrier
3. Measurement of the resulting time structure
4. Adjustments of the ion pulse shape





Summary:

Beam time structure in the REX/HIE-ISOLDE post-accelerator:

- Proton pulses from the PSB (i.e. CERN supercycle structure): every 1.2 seconds or a multiple
- RIB release time: typically (10^{-2} – 1) s
- Optimum breeding time of the REX-EBIS charge breeder: typically (10^{-2} – 1) s
- Extraction from the REX-EBIS charge breeder:
  - Natural: ~ (60 – 100) us
  - Slow extraction: ~ (0.25 – 1.5) ms
- REX/HIE-ISOLDE RF frequency: 101.28 MHz (T = 9.87 ns)
- Limitations of the REX RF systems:
  - Maximum repetition rate: 50 Hz
  - Maximum pulse length: 2 ms

Possible injection scheme into the ISRS:

- A multi-harmonic buncher could be used to increase the separation between bunches
- Train extraction from the REX-EBIS could increase the separation further
  - Outer electrode needs to be pulsed between closed and partially opened
  - Pulsing needs to be very fast (raise time ~ 10 ns)
- The resulting combined separation between bunches could be potentially extended to ~ 10 us (maybe longer if the other electrodes are also modulated in time and the ions are trapped close to the outer electrode)