Polarized Proton and Deuteron Sources

Outline

- Polarization schemata
- Optically pumped source with neutral injection (OPPIS-BNL, Anatoli Zelenski)
- Ground state atomic source with charge exchange (INR/ Juelich, Alexander Belov, Ralf Gebel)
- Polarization schemata
- The cardinal problem of high intensity sources
- Injection schemata for SIS18
- Summary, consequences and outlook

Relevant Energies for Hydrogen

- Ionization 13.6 eV
- Dissociation / Recombination: ~ 4.2 eV
- Finestructure splitting: ~ $6.0 \cdot 10^{-5}$ eV
- Hyperfinestructure splitting (p): ~ $3.0 \cdot 10^{-6}$ eV
- Hyperfinestructure splitting (d): ~ $7.0 \cdot 10^{-7}$ eV

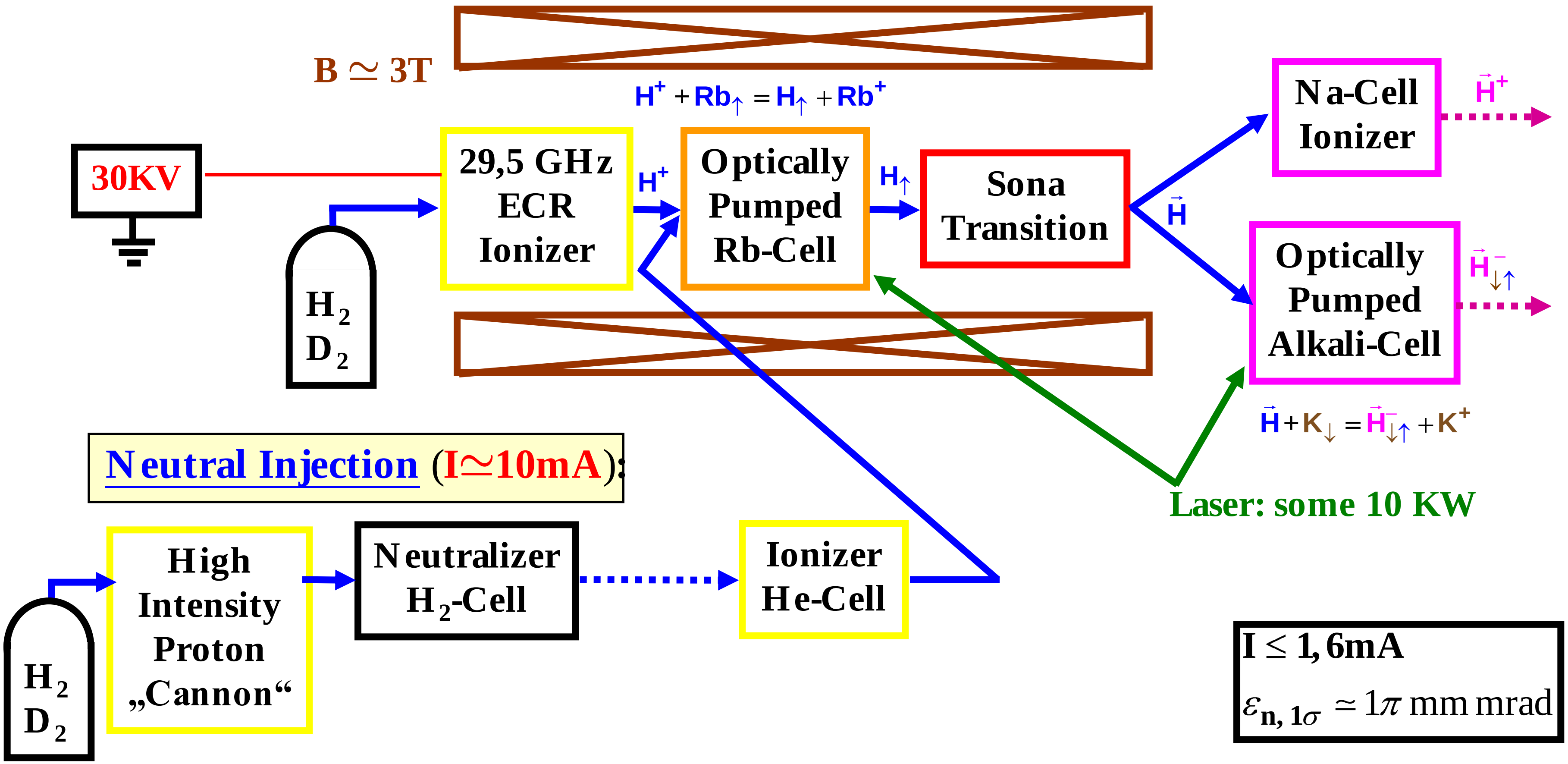
Resulting Scheme:

⇒ **Neutral Beam** ⇒ **Electron Polarization** Finestructure ⇒ **Nucleus Polarization** Hyperfinestructure ⇒ **Ionization**

Polarized Proton and Deuteron Sources

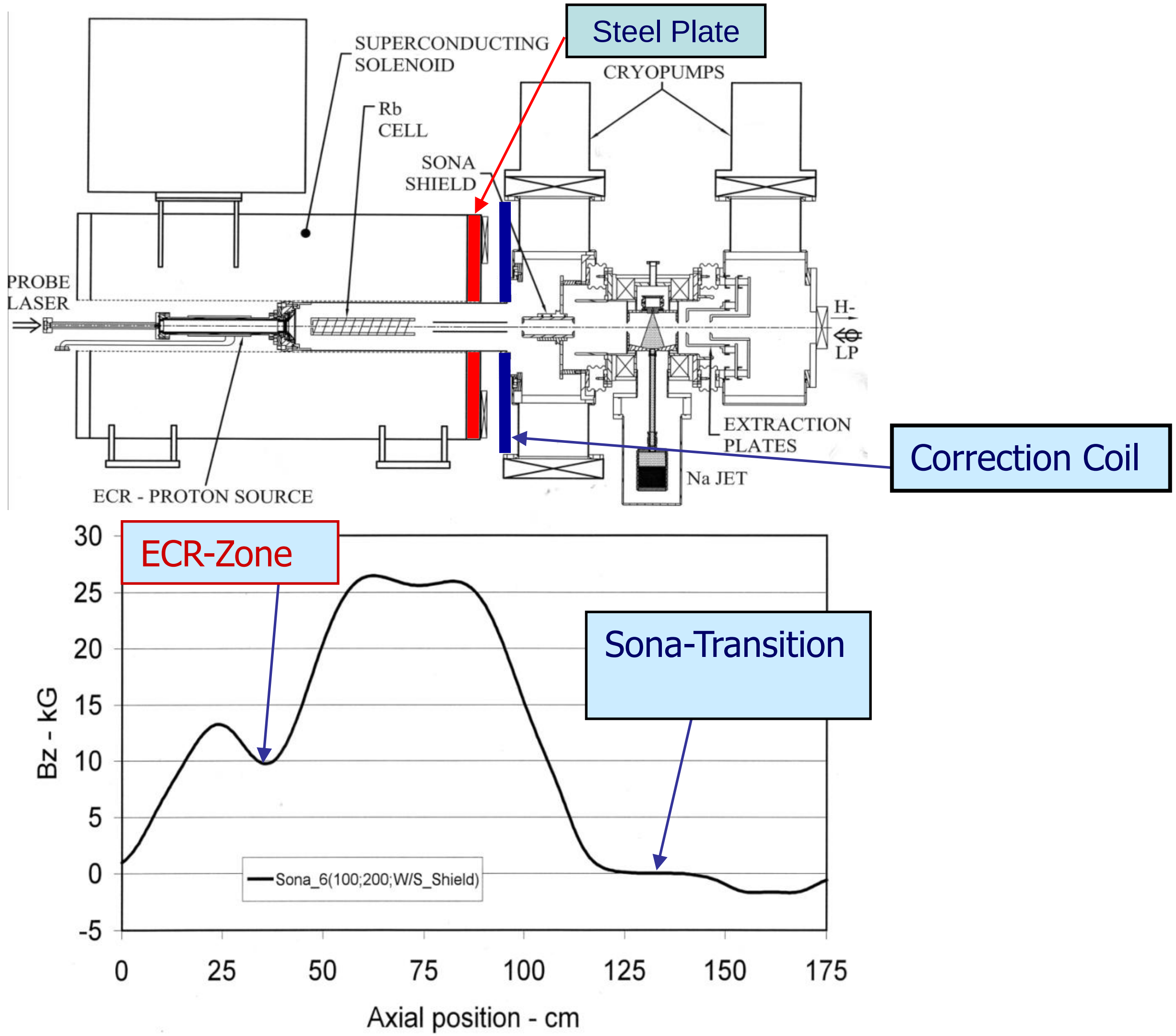
Scheme for Fast Atomic Beams

Fast Beam (**1-3 KeV**): Optically Pumped Polarized Ion Source (**OPPIS**)
BNL - Anatoli Zelenski



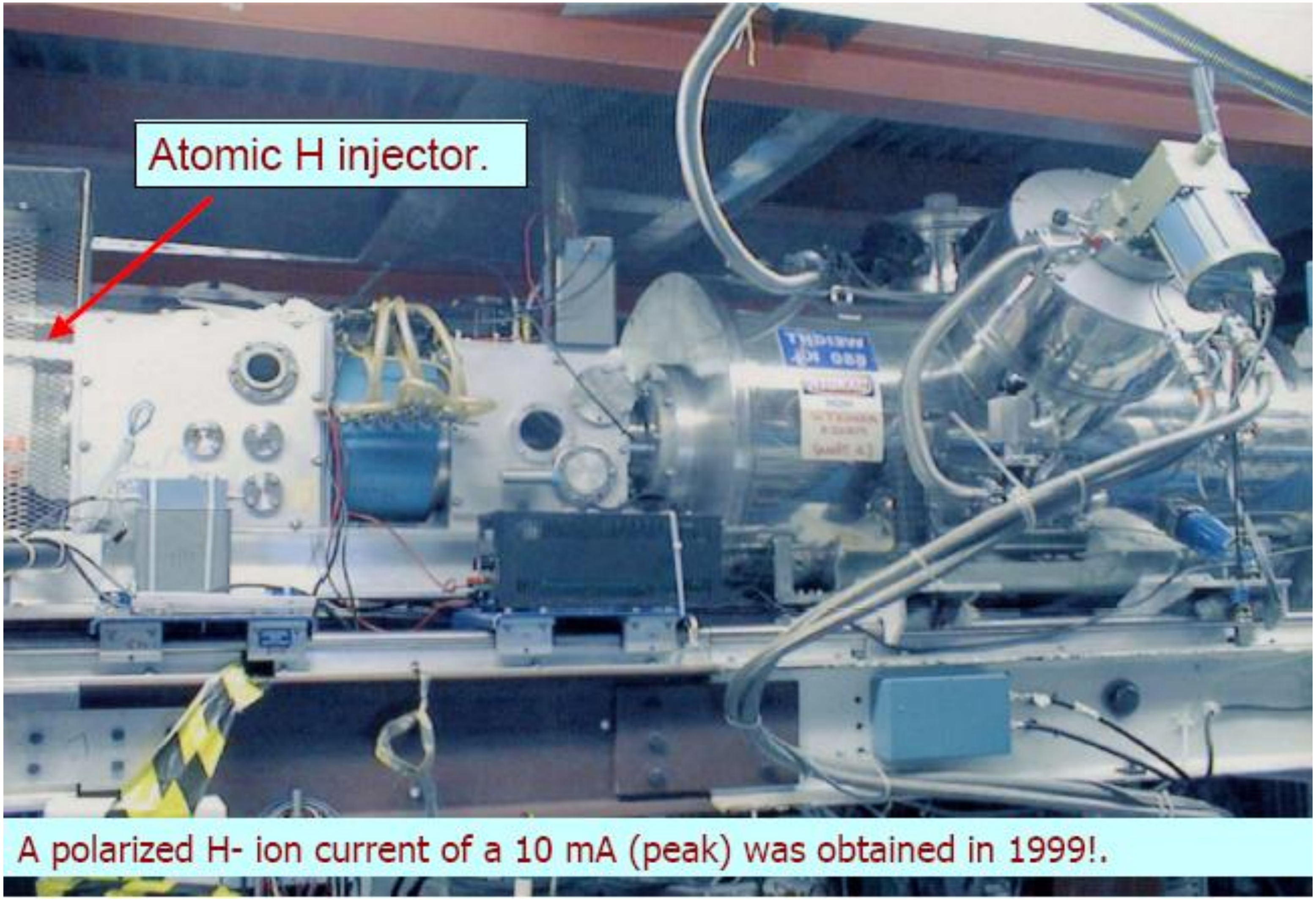
Polarized Proton and Deuteron Sources

OPPIS



Polarized Proton and Deuteron Sources

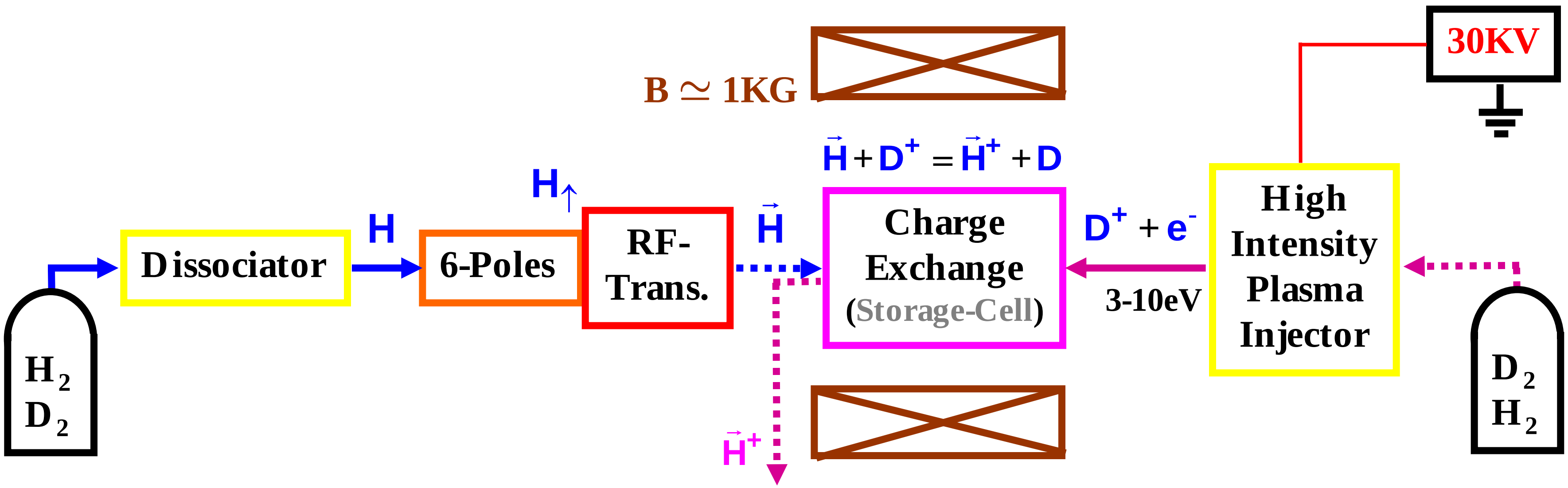
OPPIS with Neutral Injection



Polarized Proton and Deuteron Sources

Scheme for Slow Atomic Beams

Slow Beam (~ **3 meV**): Cooler Injector Polarized Ion Source (**CIPIOS**)
Moscow - Alexander Belov, Bloomington - Laddy Derenchuk, Jülich - Ralf Gebel



$I \leq 1\text{mA}$

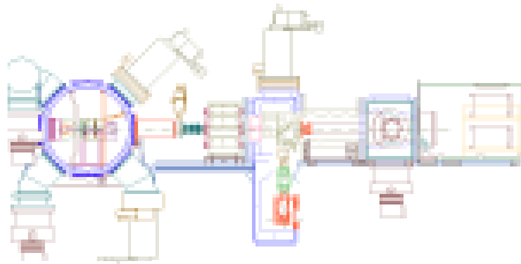
$\varepsilon_{n,\,1\sigma} \simeq 1\pi$ mm mrad

$I_{StorageCell} \simeq 10\text{mA}$

Polarized Proton and Deuteron Sources

Ionization Schemata

Pulsed
Atomic Beam
Source



Pulsed
Resonant Charge
Exchange Ionizer

H_2 Feed Gas for Dissociator → ↓ ← D_2 Feed Gas for D^- Plasma

+ Sextupoles

+ 1->3 or 2->4 transitions

Polarized H^- ✓

Unpolarized D^- ✓

OR

D_2 Feed Gas for Dissociator → ↓ ← H_2 Feed Gas for H^- Plasma

+ Sextupoles

+ 1->4 and 2->6 or 3->5 transitions

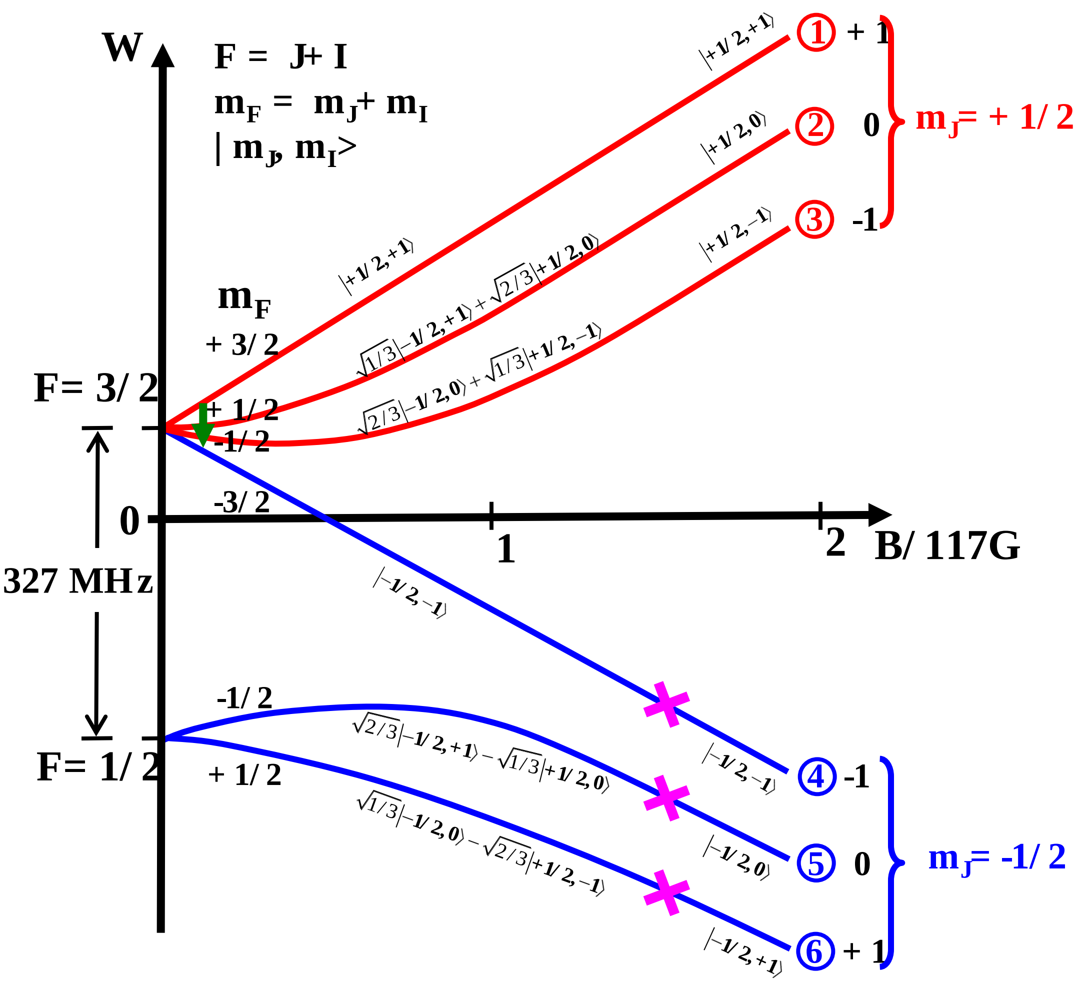
Tensor/Vector polarized D^- o

Unpolarized H^- ✓

Polarized Proton and Deuteron Sources

Polarization Scheme for Fast (1-3 keV) Atomic Beams

Deuteron



$$P_Z = \frac{N^+ - N^-}{N^+ + N^-} \qquad P_{ZZ} = \frac{N^+ - 2N^0 + N^-}{N^+ + N^0 + N^-}$$

$$I_r = \frac{N^+ + N^0 + N^-}{3}$$

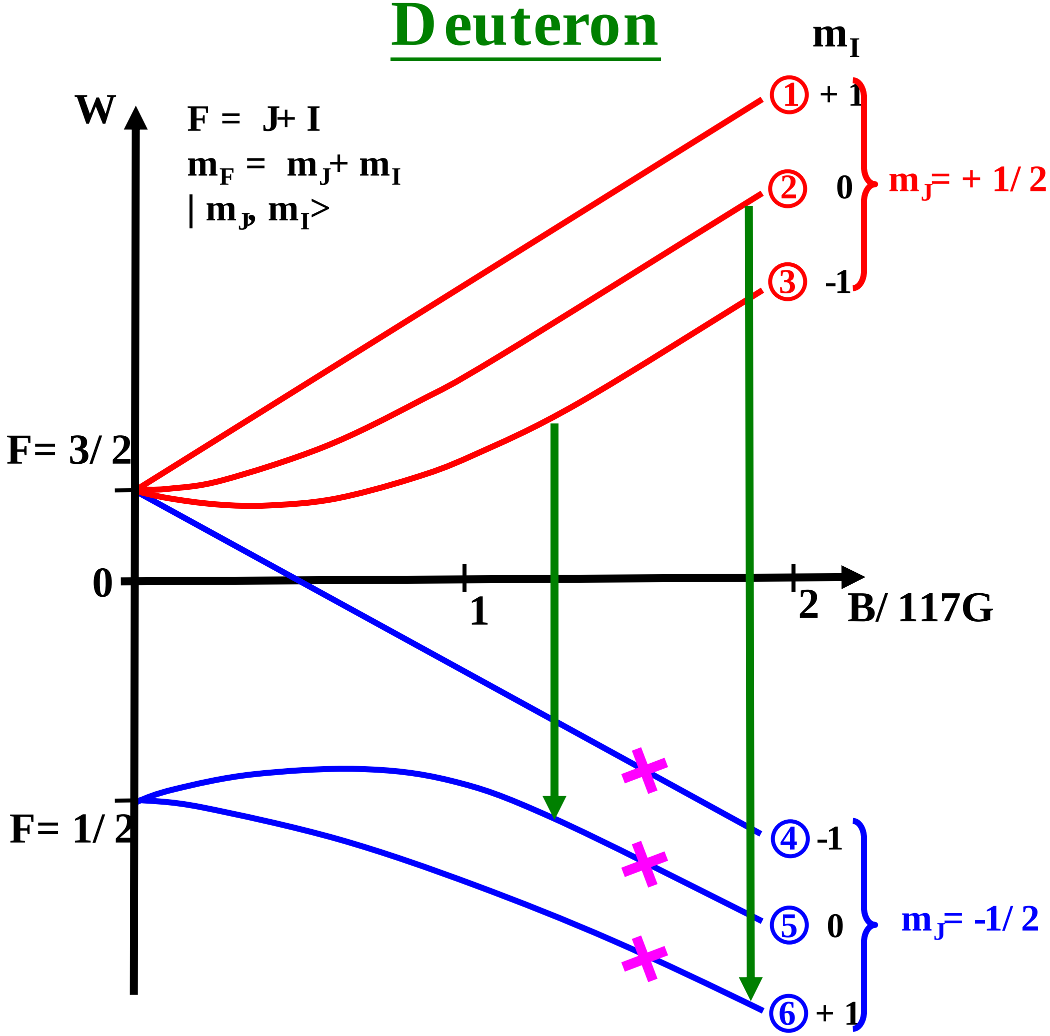
N - Number of occupied states

State No.	Unpolar.	Electron Polar.	Sona Trans.	H^- & Pauli
①				
②				
③				
④				
⑤				
⑥				
P_Z			-2/3	-1
$P_Z^2 \cdot I_r$			4/9	1/3 = 3/9
P_{ZZ}			0	-1
$P_{ZZ}^2 \cdot I_r$			0	1/3

Polarized Proton and Deuteron Sources

Polarization Scheme for Slow (~ 3 meV) Atomic Beams

Deuteron



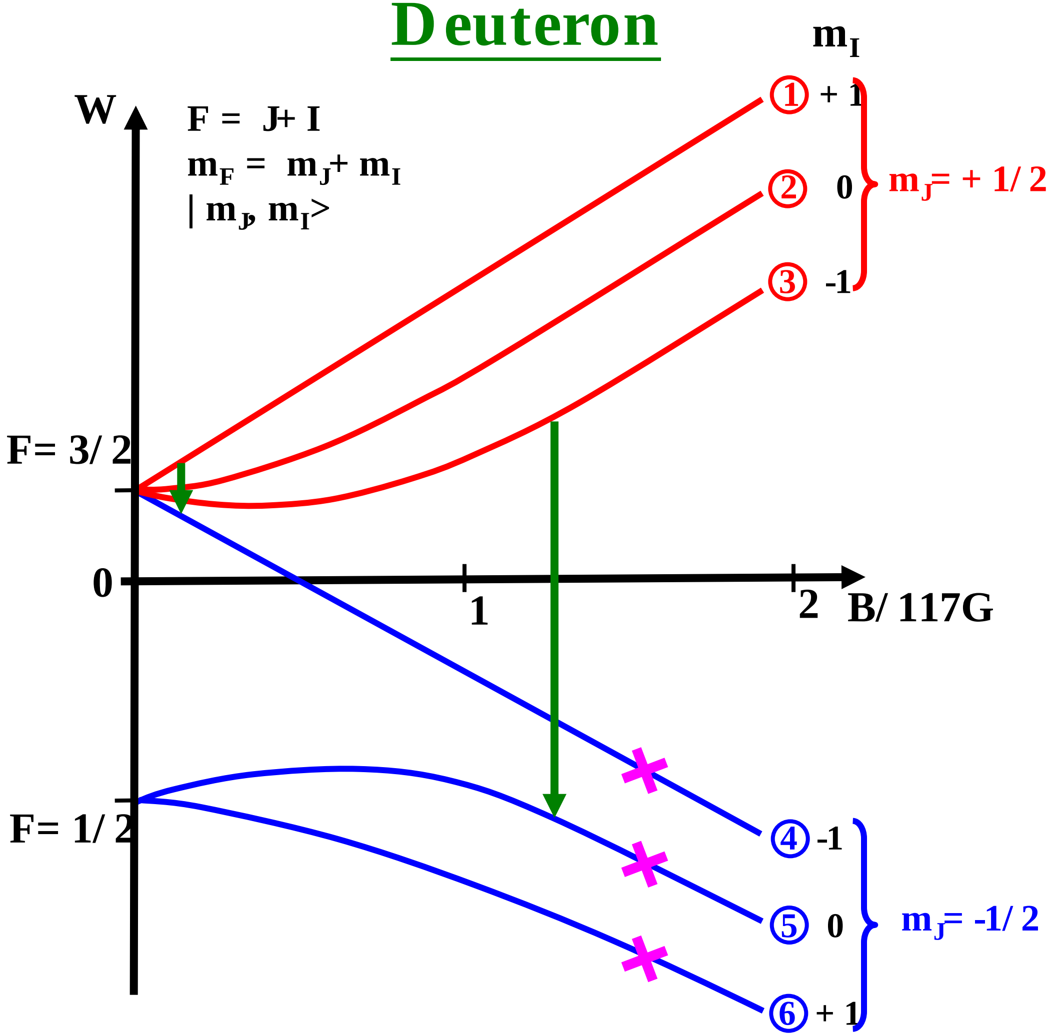
6-Pole → RF-Trans. (3→5) → 6-Pole → RF-Trans. (2→6)

State No.	Unpolar.	Electron Polar. (1st 6-Pole)	RF-Trans. (3→5)	2nd 6-Pole	RF-Trans. (2→6)
①					
②					
③					
④					
⑤					
⑥					
P_Z			1/ 3	1/ 2	1
$P_Z^2 \cdot I_r$			1/ 9	1/ 6	2/ 3
P_{ZZ}			-1	-1/ 2	1
$P_{ZZ}^2 \cdot I_r$			1	1/ 6	2/ 3

Polarized Proton and Deuteron Sources

Polarization Scheme for Slow (~ 3 meV) Atomic Beams

Deuteron



6-Pole → RF-Trans. (2→6) → 6-Pole → RF-Trans. (1→4)

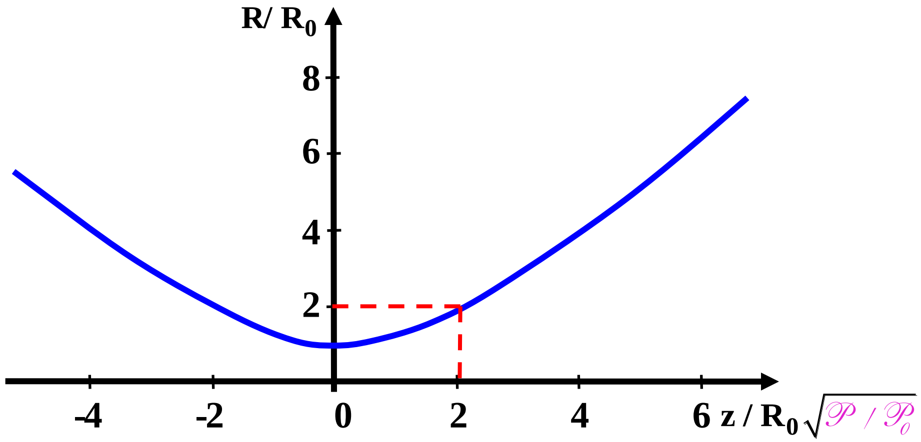
State No.	Unpolar.	Electron Polar. (1st 6-Pole)	RF-Trans. (2→6)	2nd 6-Pole	RF-Trans. (1→4)
①					
②					
③					
④					
⑤					
⑥					
P_Z			1/ 3	0	-1
$P_Z^2 \cdot I_r$			1/ 9	0	2/ 3
P_{ZZ}			1	1	1
$P_{ZZ}^2 \cdot I_r$			1	2/ 3	2/ 3

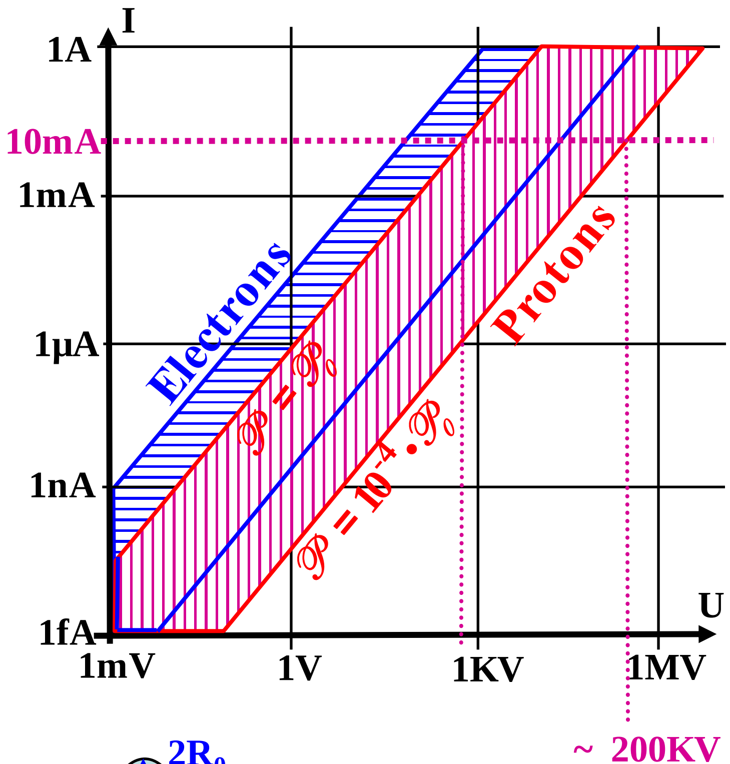
Polarized Proton and Deuteron Sources

The Cardinal Problem of High Intensity Sources - Perveanz

Perveanz: $\mathscr{P} = \frac{I}{U^{3/2}}$; $\mathscr{P}_0 = 2\pi\varepsilon_0 \cdot \sqrt{\frac{2q}{m}}$

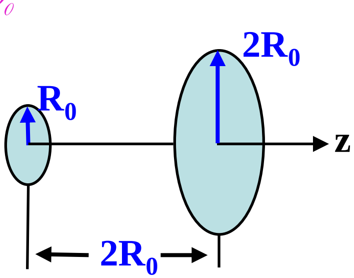
$$\frac{d^2R}{dz^2} = \frac{\mathscr{P}}{\mathscr{P}_0} \cdot \frac{1}{R}$$





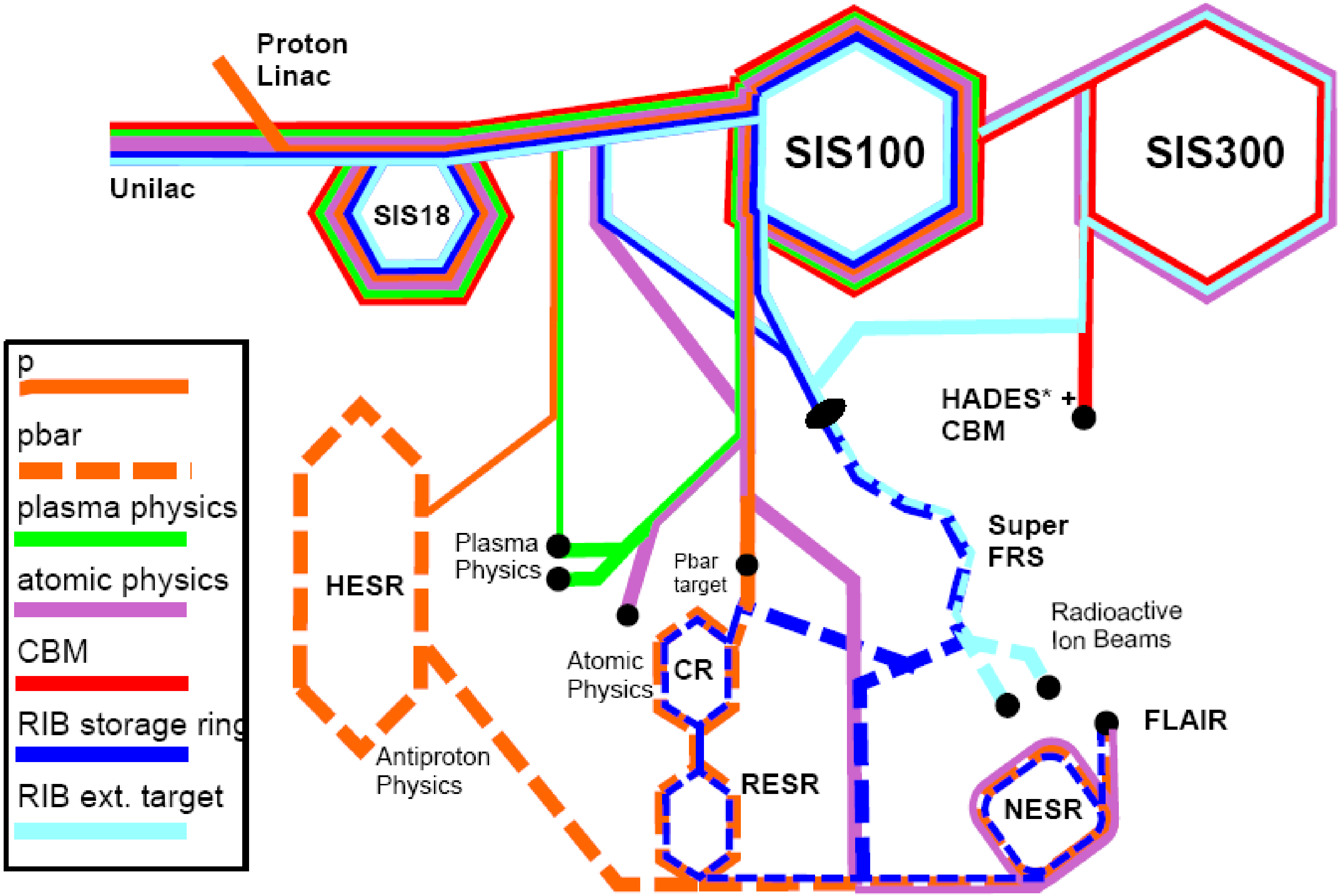
Space charge limit: $\mathscr{P} = \mathscr{P}_0$

Emittance dominated : $\mathscr{P} = 10^{-4} \cdot \mathscr{P}_0$



Polarized Proton and Deuteron Sources

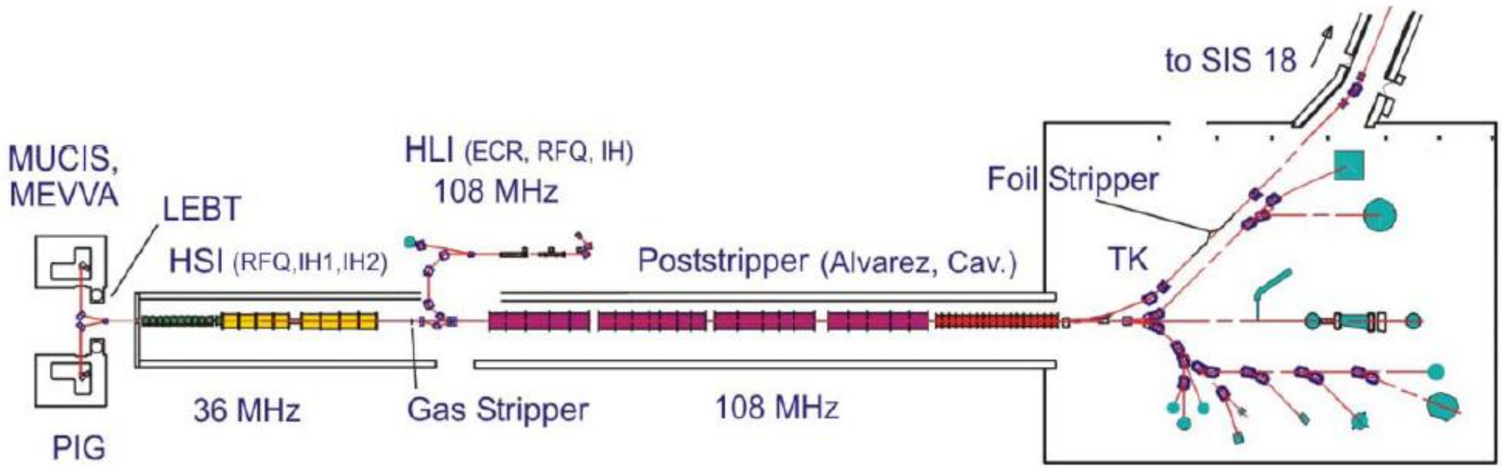
Injection Schemes for SIS18

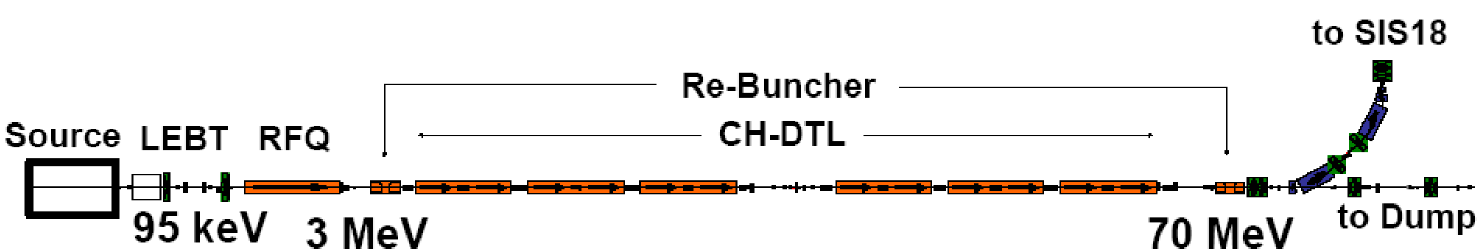


Polarized Proton and Deuteron Sources

Injection Schemes for SIS18

The Universal Linear Accelerator UNILAC-upgrade

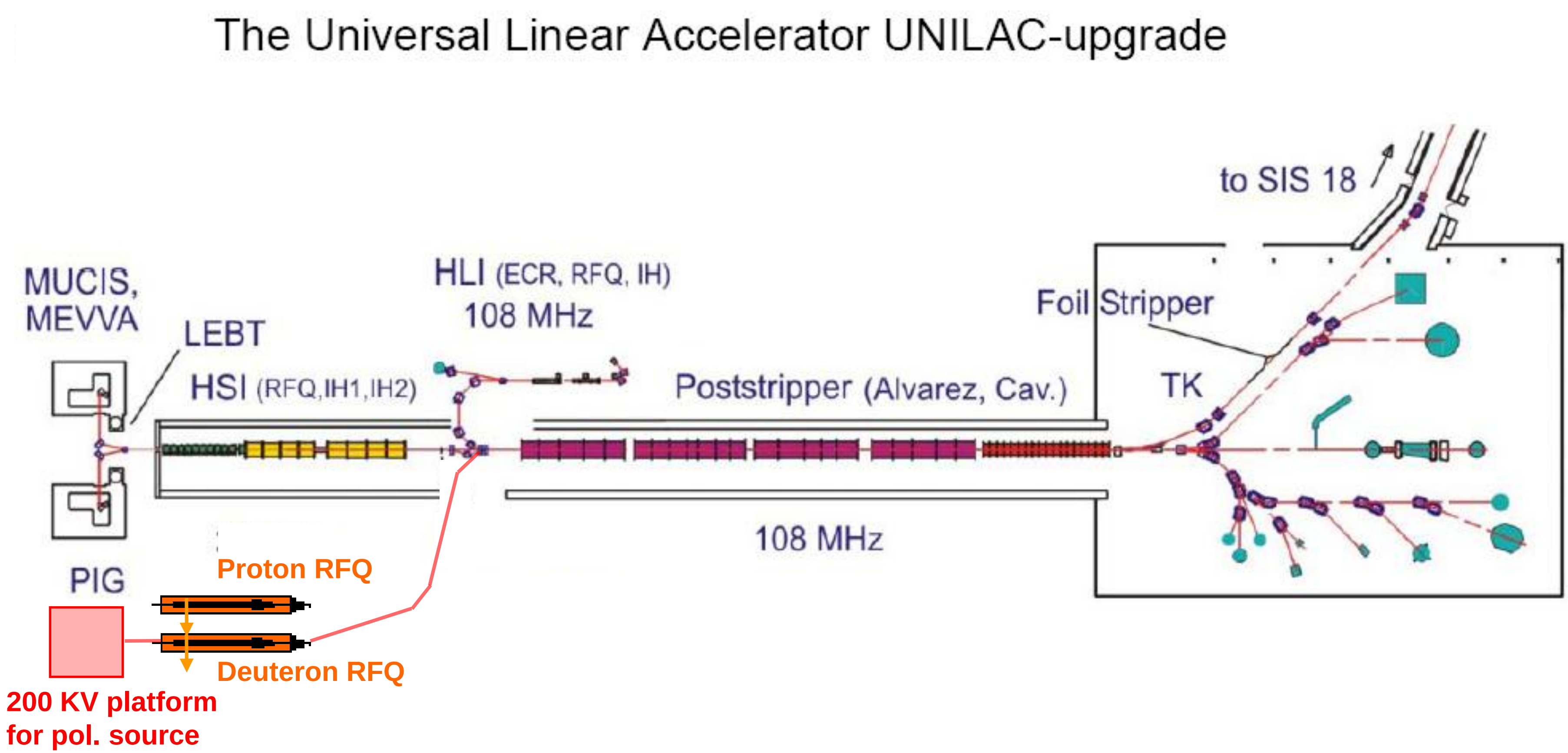




Conceptual layout of the proton linac of FAIR comprising a proton source, a RFQ, and a Drift Tube Linac (DTL) based on 12 CH-cavities.

Polarized Proton and Deuteron Sources

Injection Schemes for SIS18



Polarized Proton and Deuteron Sources

Summary, Consequences and Outlook

- The Slow Atomic Beam „CIPIOS“ type of source gives more polarization and is more flexible than an „ OPPIS“ type of source with respect to polarization schemata.
- For a 10mA polarized beam „CIPIOS“ contains less charge exchange cells than a Fast Atomic Beam „ OPPIS“ type of source.
- „CIPIOS“ is shorter.

But:

- For the Slow Atomic Beam type of source the atomic beam intensity should be increased by a factor 2-3 to become > $3 \cdot 10^{17}$ atoms per second.
- It has to be shown, whether the target-cell can stand this intense current.
- An extraction scheme at about 200KV has to be developed (extraction from a magnetic field at 200 KV).

Thank You