Project Progress Review (PPR) 2-2026

WP- 15

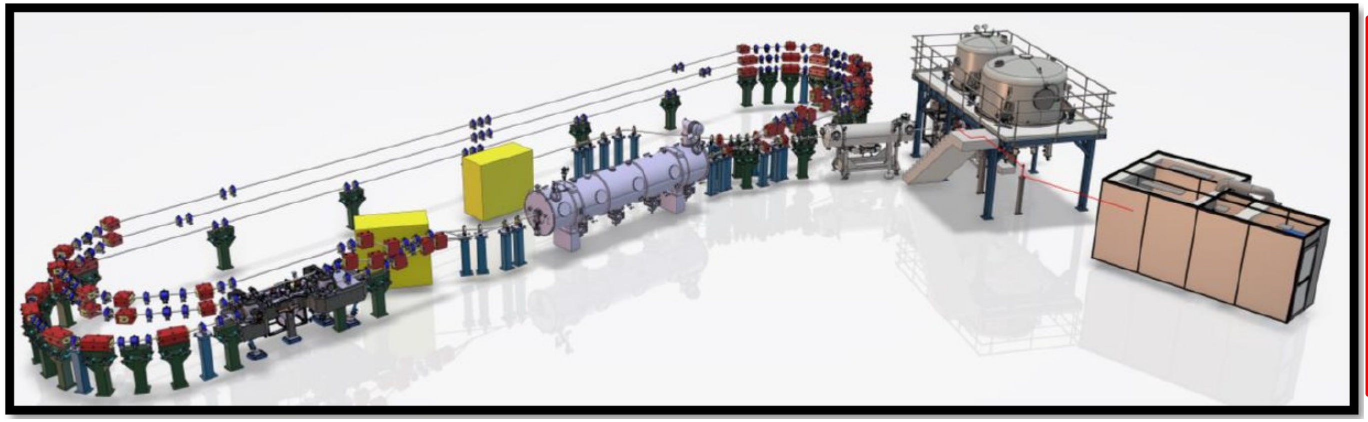
Présenté par:

Sarah Naïmi

19 mars 2026

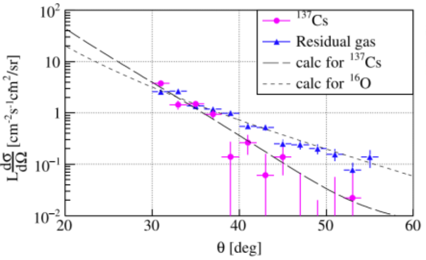
DESTIN@PERLE: electron scattering on rare isotopes

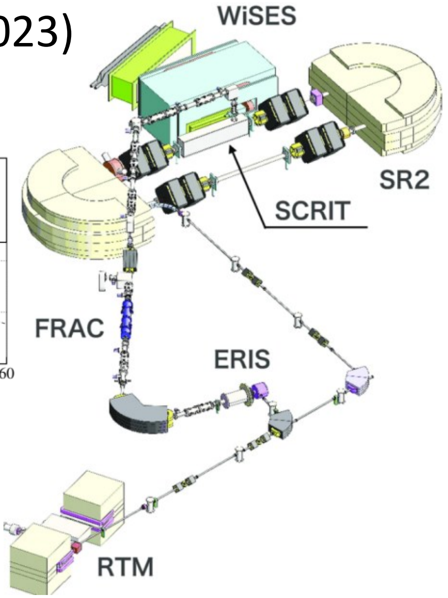
Diffusion noyaux-électrons PERLE 1/3 tours

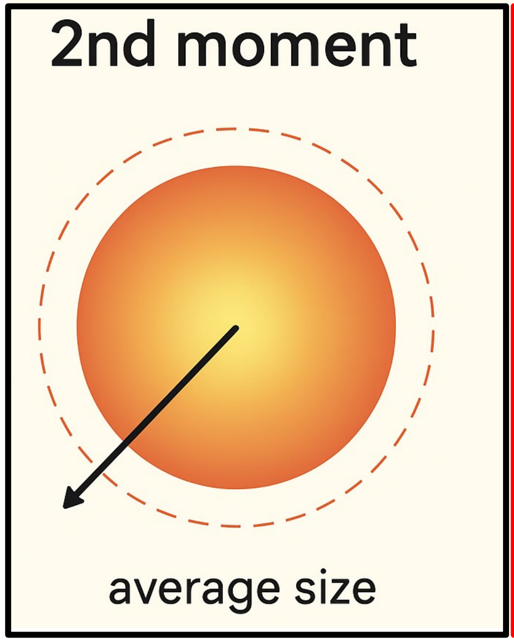


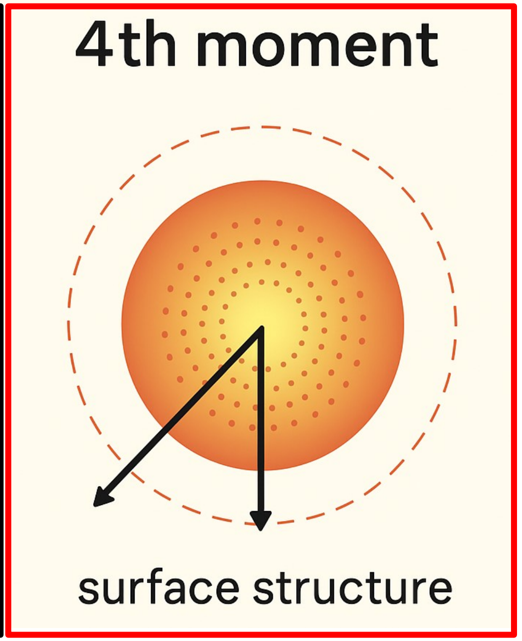
Similar to SCRIT@RIKEN (Japan):
1st electron scattering on rare isotopes
e- beam: 150-300 MeV

Tsukada+PRL,131(2023)







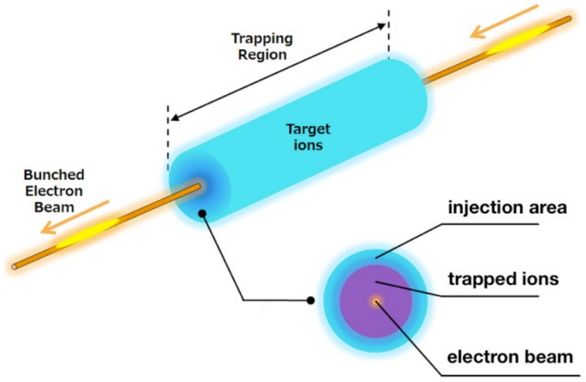


Electron scattering at low q

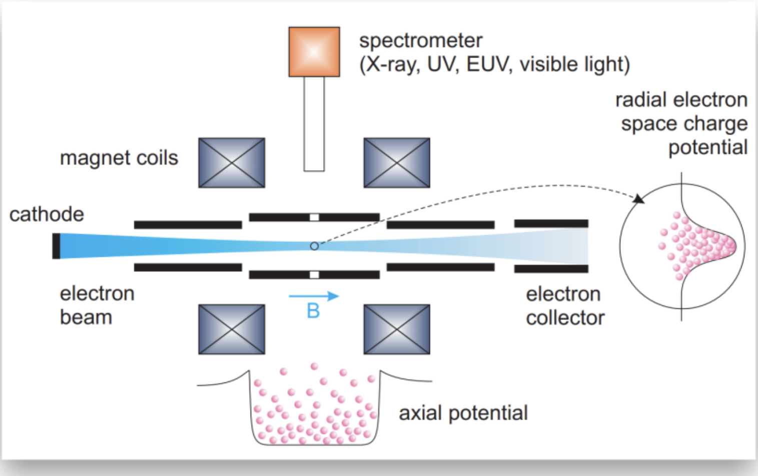
→ PERLE will be the only facility to provide electrons for low-q scattering on the rare isotopes nuclei

Choix technologique : EBIT à confirmer

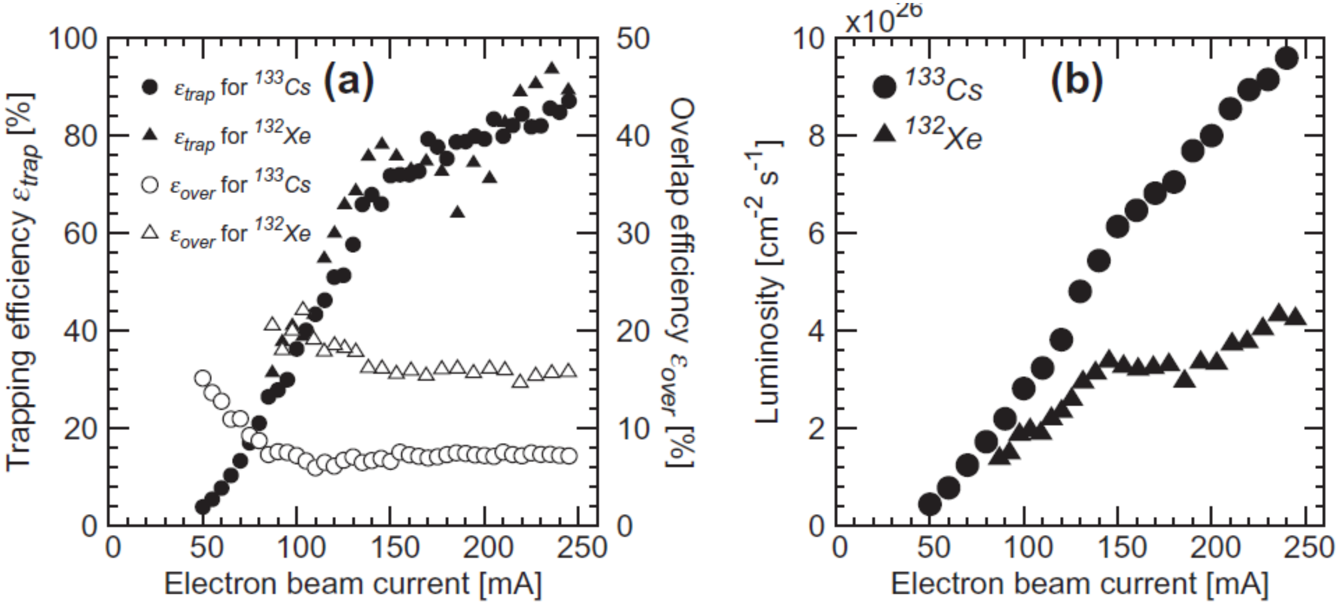
SCRIT principle: relies on intense electron beam for trapping radially **200mA**



EBIT: Electron Beam Ions Trap

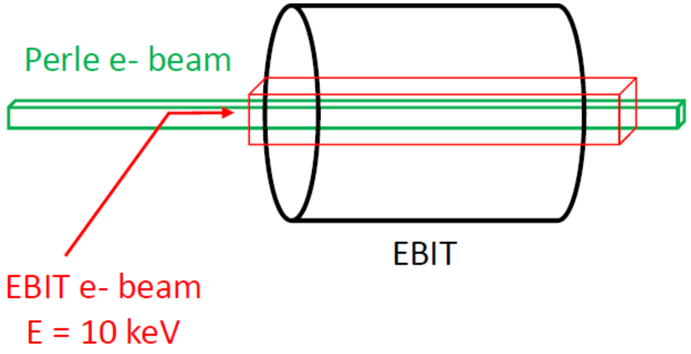


Measurement in SCRIT

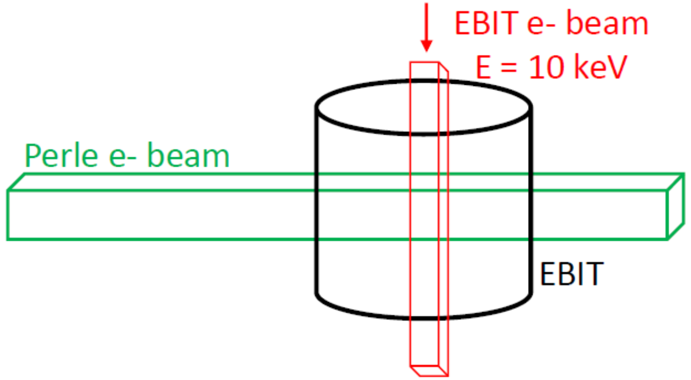


Prof. SUDA
IJCLab visit
Oct. 2025

Configuration 1: parallel EBIT beam and PERLE beam



Configuration 2: perpendicular EBIT beam and PERLE beam



Estimation détérioration du faisceau PERLE

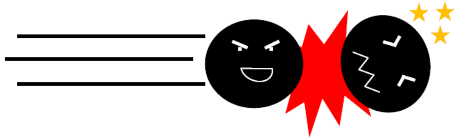
$$N_{e,lost}^{Perle} = N_e^{Perle} * \sigma_{loss} * n_e^{EBIT}$$

PhD student
Sophie Le Carlier
2025-2028

→ Get from EBIT current and, energy and spatial configuration

$n_e^{ebit} = 5.325 * 10^{10}$ e/cm^2 configuration 1 (//)
$n_e^{ebit} = 5.325 * 10^{8}$ e/cm^2 configuration 2 (90°)

→ Get from two body elastic scattering computation



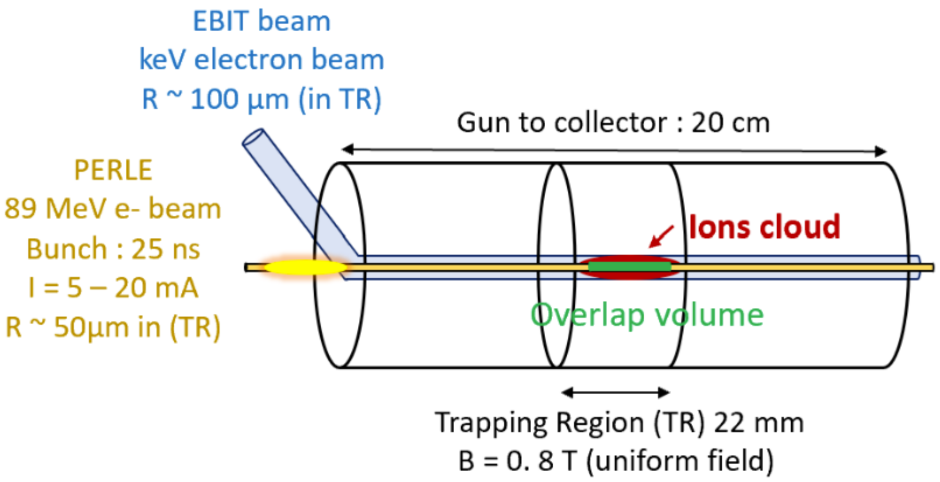
$$\sigma_{loss} = \int_{\theta_{1,L}}^{\theta_{2,L}} \frac{d\sigma_{3,L}}{d\Omega_{3,L}} d\Omega_{3,L} = \int_{\theta_{1,L}}^{\theta_{2,L}} \frac{\alpha^2}{4s} \left[\frac{3 + \cos\theta^2}{1 - \cos\theta}\right]^2 \frac{(\gamma^2(1 \pm \cos\theta)^2 + \sin^2\theta)^{\frac{3}{2}}}{\gamma(1 \pm \cos\theta)} d\Omega_{3,L}$$

Comparison work with Suda San

→ Get from PERLE current:
$I_{PERLE} = 5\ mA$

$$\rightarrow N_e^{Perle} = \frac{I_{PERLE}}{1.602*10^{-19}} = \frac{5*10^{-3}}{1.602*10^{-19}} = 3.12 * 10^{16}\ \#e/s$$

Etude avec le piège de HINA



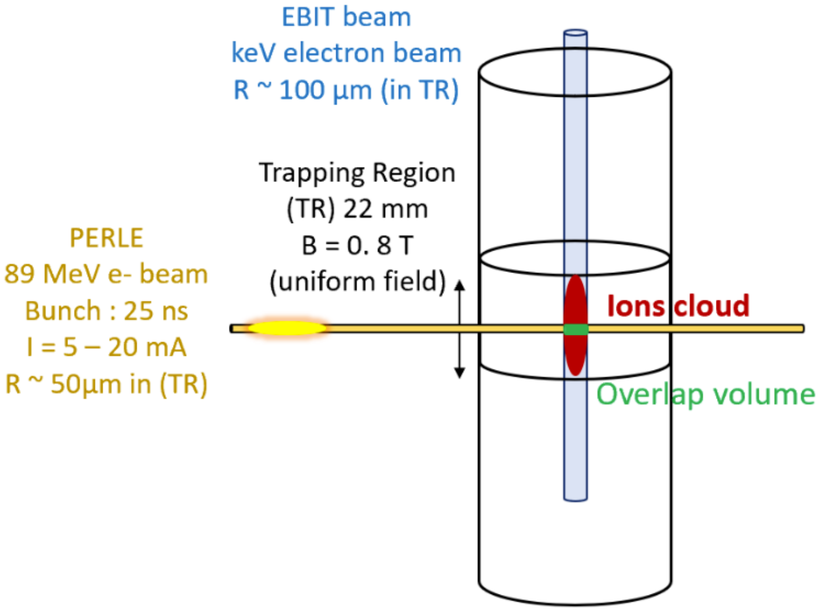


Table 1.4: Luminosity for several PERLE beam current

Configuration	5 mA	10 mA	20 mA
Parallel	1.44×10^{25}	2.87×10^{26}	5.74×10^{26}
Vertical	1.3×10^{23}	2.6×10^{24}	5.2×10^{24}

$$L = \frac{I_e}{e} * \frac{N_t}{\sigma_{beam}}$$

$$C_{\text{trap}} = \frac{L_{\text{trap}} I_{\text{EBIT}}}{e\sqrt{2U_{\text{EBIT}}c^2/m_e}} \cdot \frac{1}{Z} \cdot f_c$$

$I_{\text{EBIT}} = 0.08$ A

$U_{\text{EBIT}} = 5$ keV

$L_{\text{trap}} = 2.2$ cm

$f_c = 0.3$

$1/Z = 1/54 = 0.0185$

Table 1.3: Overlap and ion parameters for the two EBIT configurations

Quantity	Parallel	Vertical
Overlap volume V_{overlap} (cm^3)	1.73×10^{-4}	1.57×10^{-6}
Ion cloud volume V_{ions} (cm^3)	6.91×10^{-4}	6.91×10^{-4}
Overlap efficiency $\epsilon_{\text{overlap}}$	2.50×10^{-1}	3.27×10^{-3}
Effective number of trapped ions N_t	3.61×10^{5}	2.27×10^{3}
Areal ion density on beam surface (ions/cm^2)	4.59×10^{9}	4.16×10^{7}

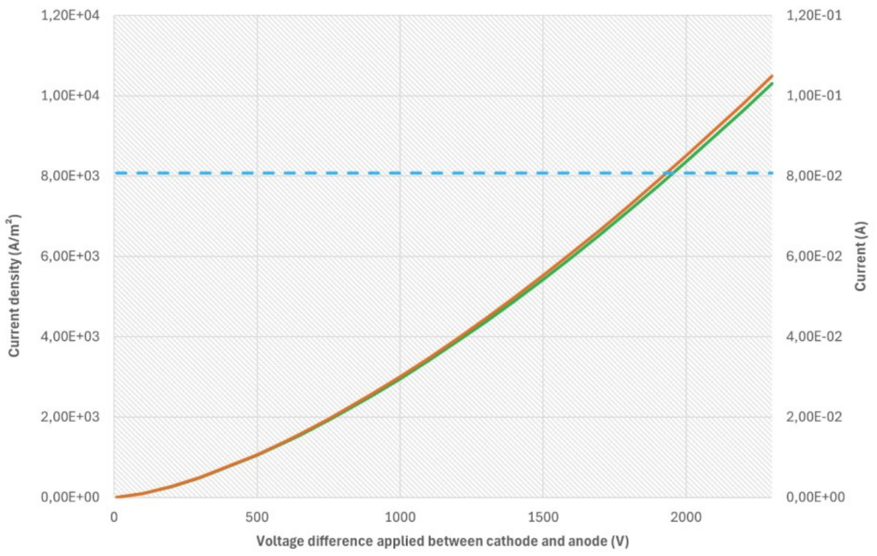
Modification piège pour augmenter la luminosité

Table 1.5: Number of trapped ions

U_{EBIT} (eV)	5000	2000	1000	500
Number of ions trapped	1.45×10^6	3.1×10^6	6.27×10^6	1.38×10^7

$$J = \frac{4}{9}\varepsilon_0 \left(\frac{2q}{m}\right)^{1/2} \frac{V_d^{3/2}}{d^2}$$

U_{EBIT} (eV)	PERLE Current (A)	Configuration Parallel	Configuration Vertical
5000	0.005	9.93×10^{25}	9.03×10^{23}
	0.01	1.99×10^{26}	1.81×10^{24}
	0.02	3.97×10^{26}	3.61×10^{24}
2000	0.005	3.08×10^{26}	2.80×10^{24}
	0.01	6.17×10^{26}	5.61×10^{24}
	0.02	**1.23×10^{27}**	1.12×10^{25}
1000	0.005	6.23×10^{26}	5.66×10^{24}
	0.01	**1.25×10^{27}**	1.13×10^{25}
	0.02	**2.49×10^{27}**	2.27×10^{25}
500	0.005	**1.37×10^{27}**	1.25×10^{25}
	0.01	**2.74×10^{27}**	2.49×10^{25}
	0.02	**5.48×10^{27}**	4.98×10^{25}



$$r_H = r_B \sqrt{0.5 + \sqrt{0.25 + \frac{8 m_e k_B T r_c^2}{q^2 B^2 r_B^4} + \frac{B_c^2 r_c^4}{B^2 r_B^4}}}.$$

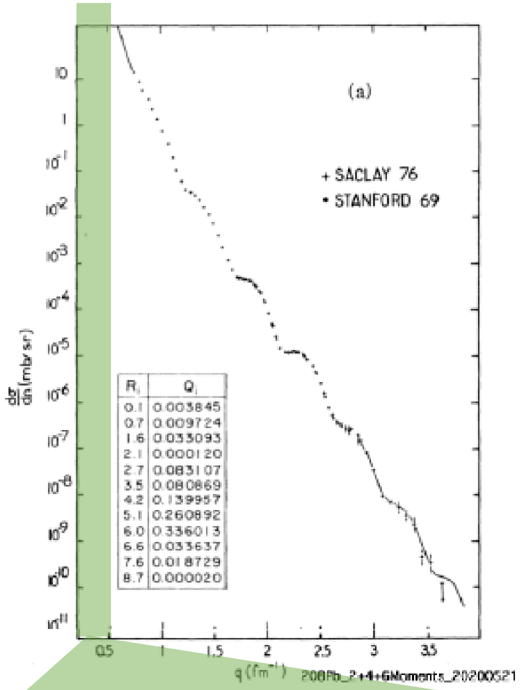
2000 eV		5000 eV	
r_B	r_H	r_B	r_H
41.4	74.5	32.9	72.1

$$< r_c^4 > = \int r^4 \rho_c(r)\, d^3 r$$

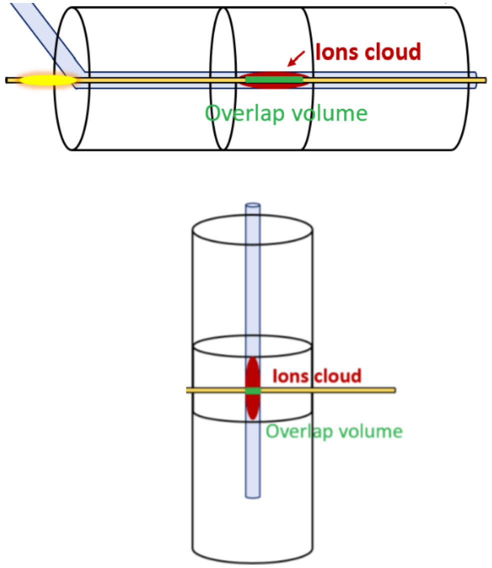
1) elastic scattering at very high *q* (0^+ nuclei)

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma_{\mathrm{Mott}}}{d\Omega} |F_c(q)|^2$$

$$F_c(q) = \int \rho_c(\vec{r}) e^{i\vec{q}\vec{r}} d\vec{r}$$



R_i	Q_i
0.1	0.003845
0.7	0.009724
1.6	0.033093
2.1	0.000120
2.7	0.083107
3.5	0.080869
4.2	0.139957
5.1	0.260892
6.0	0.336013
6.6	0.033637
7.6	0.018729
8.7	0.000020



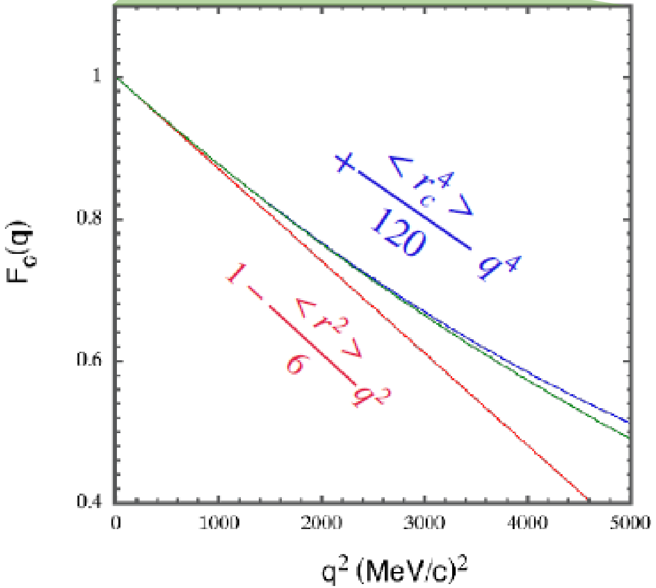
2) elastic scattering at very low *q*

NEW!

$$F_c(q) \sim 1 - \frac{< r_c^2 >}{6} q^2 + \frac{< r_c^4 >}{120} q^4 + \ldots$$

$$\frac{d\sigma_{\mathrm{Mott}}}{d\Omega} \propto 1/q^4$$

=> low-L SCRIT exp. ??



Advantages:

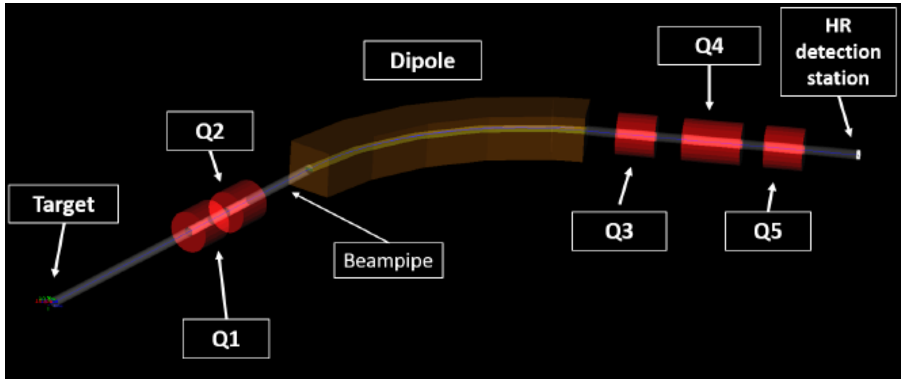
Large cross section!

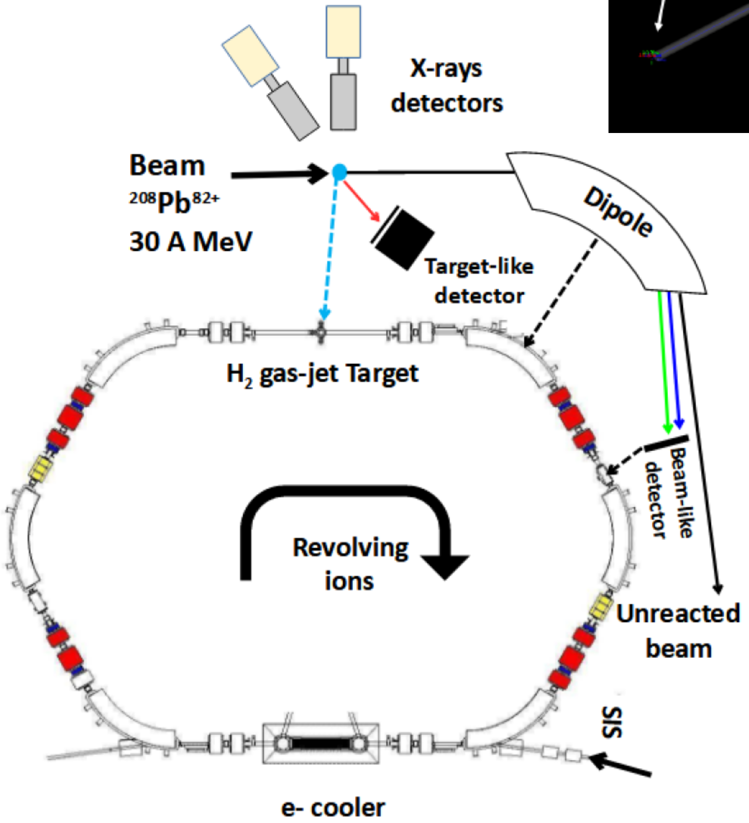
Not limited to 0+ nuclei

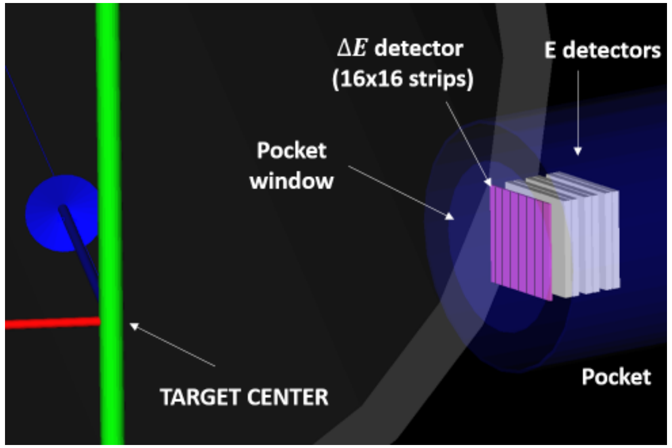
Can be done with low luminosity (low e- current & RI beam)

La suite : le spectromètre avec G4Beamline

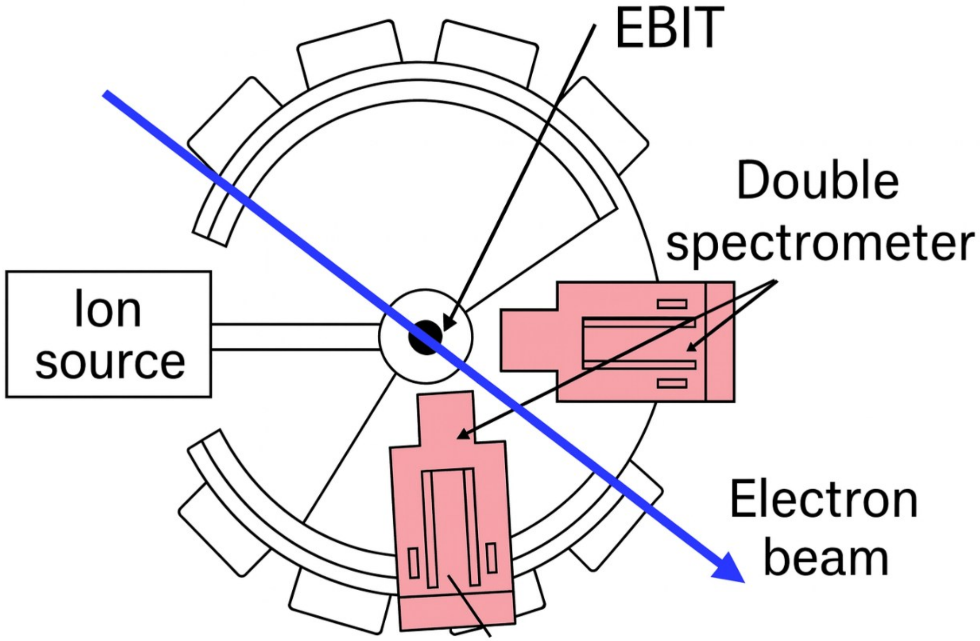
Michele Sguazzin PhD
In-ring reaction @GSI



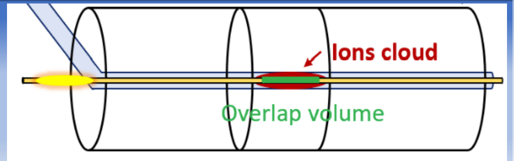


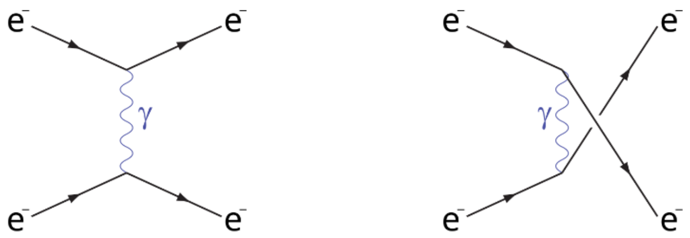


SELENE@PERLE



Estimation détérioration du faisceau PERLE





(a) t-channel (b) u-channel

Figure 2.5: Møller scattering Feynman diagrams t and u channel

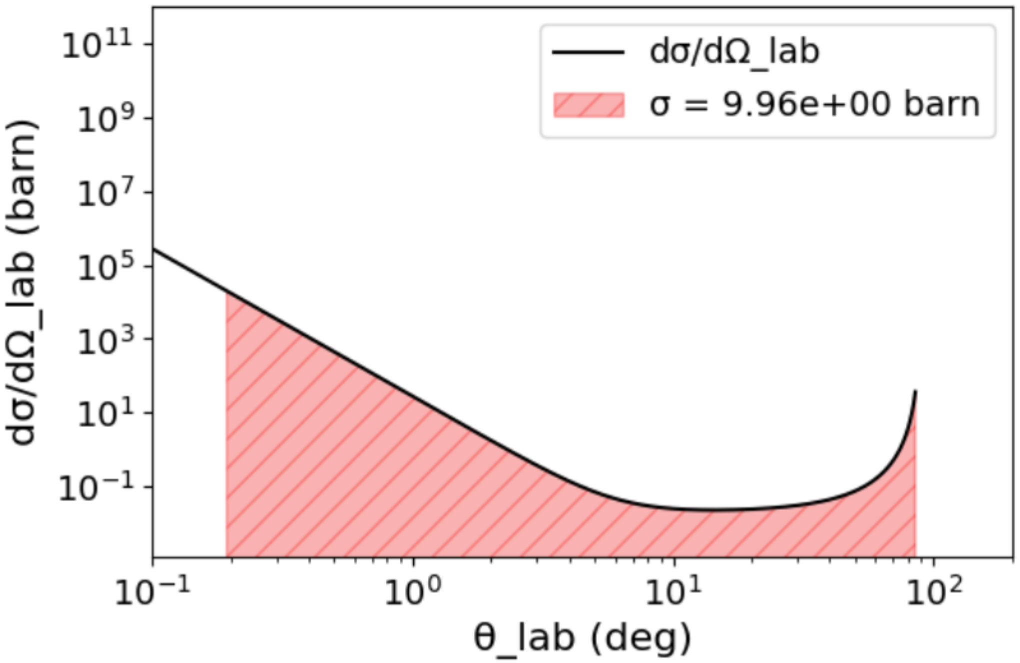


Table 2.3: Final calculation of N_{lost} in Møller scattering process ($r_{\text{PERLE}} = 250\,\mu$m, $I_{\text{PERLE}} = 20$ mA, $\sigma_{\text{loss}} = 9.96$ barn).

Configuration	Energy (eV)	n_e (cm^{-2})	N_{lost} (s^{-1})	f_{loss} (%)
Parallel	500	6.1×10^{12}	7.58×10^{6}	6.11×10^{-9}
	1000	4.3×10^{12}	5.35×10^{6}	4.31×10^{-9}
	2000	3.1×10^{12}	3.85×10^{6}	3.10×10^{-9}
	5000	1.9×10^{12}	2.36×10^{6}	1.90×10^{-9}
Perpendicular	500	9.6×10^{9}	1.19×10^{4}	9.60×10^{-12}
	1000	6.8×10^{9}	8.46×10^{3}	6.82×10^{-12}
	2000	4.8×10^{9}	5.96×10^{3}	4.81×10^{-12}
	5000	3.0×10^{9}	3.73×10^{3}	3.01×10^{-12}

$$P_{\text{tot,wall}} = 2\pi\,\Phi\,n\,L \int_0^{\pi} \frac{d\sigma}{d\Omega}(\theta_{\text{LAB}})\,E_{\text{kin}}(\theta_{\text{LAB}})\,\sin\theta_{\text{LAB}}\,d\theta_{\text{LAB}}.$$

$P_{\text{tot,wall}} \simeq 0.574$ W

2.61 W/m

TDR – WP15 avancement rédaction

TDR WP15 ~60%