Luminosity estimations for ELISE and DERICA projects

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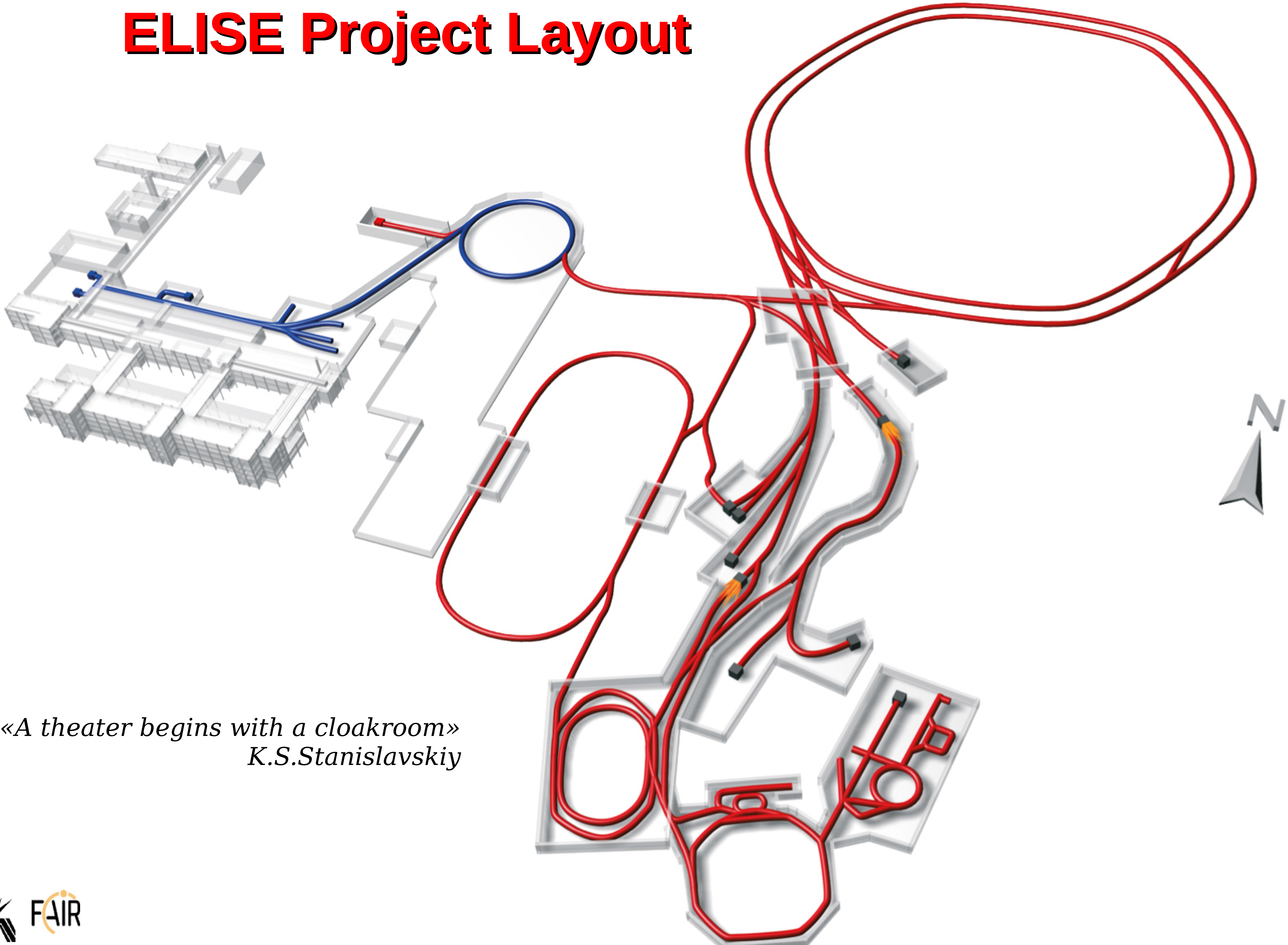
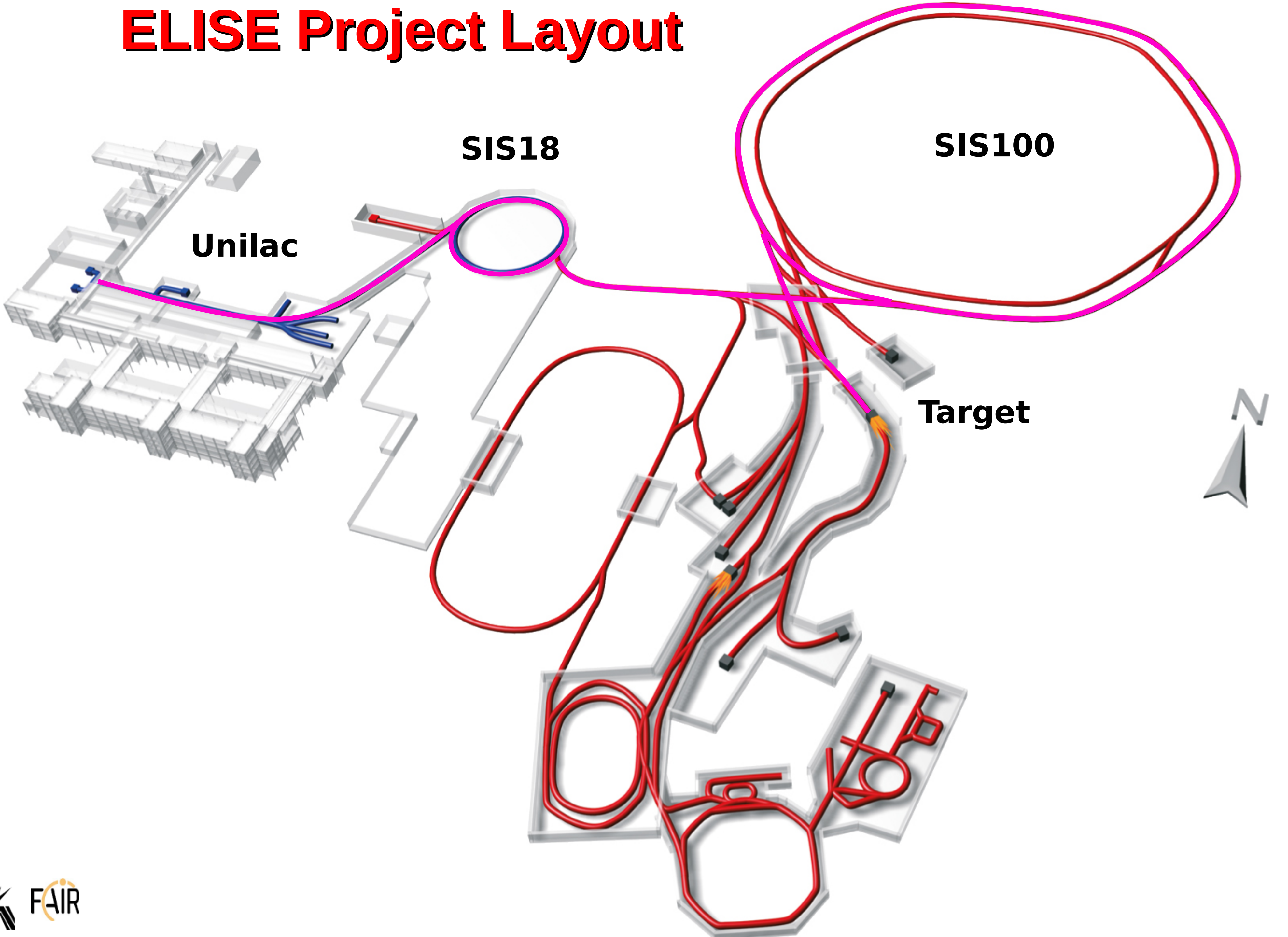
ELISE Project Layout



«A theater begins with a cloakroom»
K.S.Stanislavskiy

ELISE Project Layout



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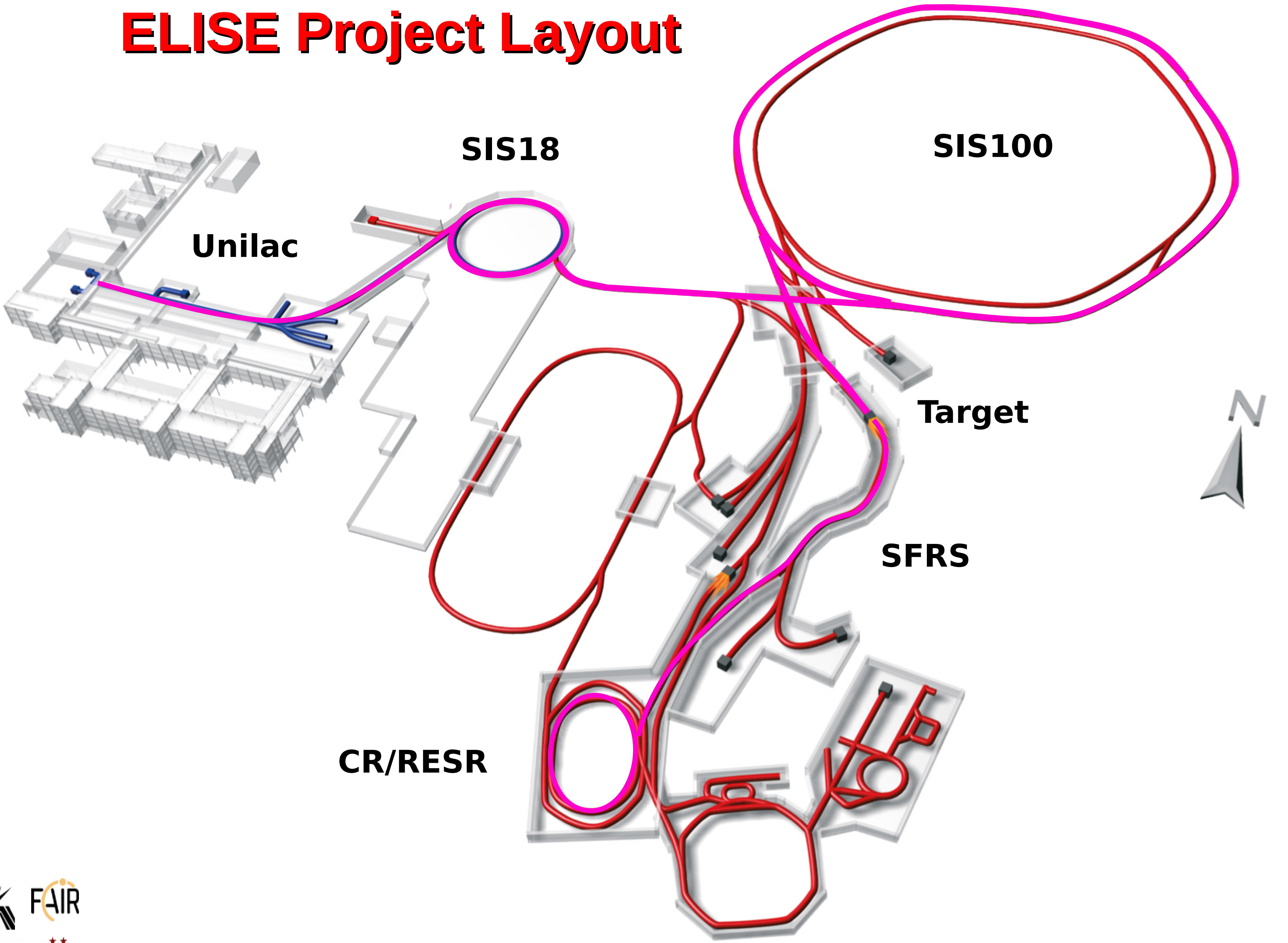

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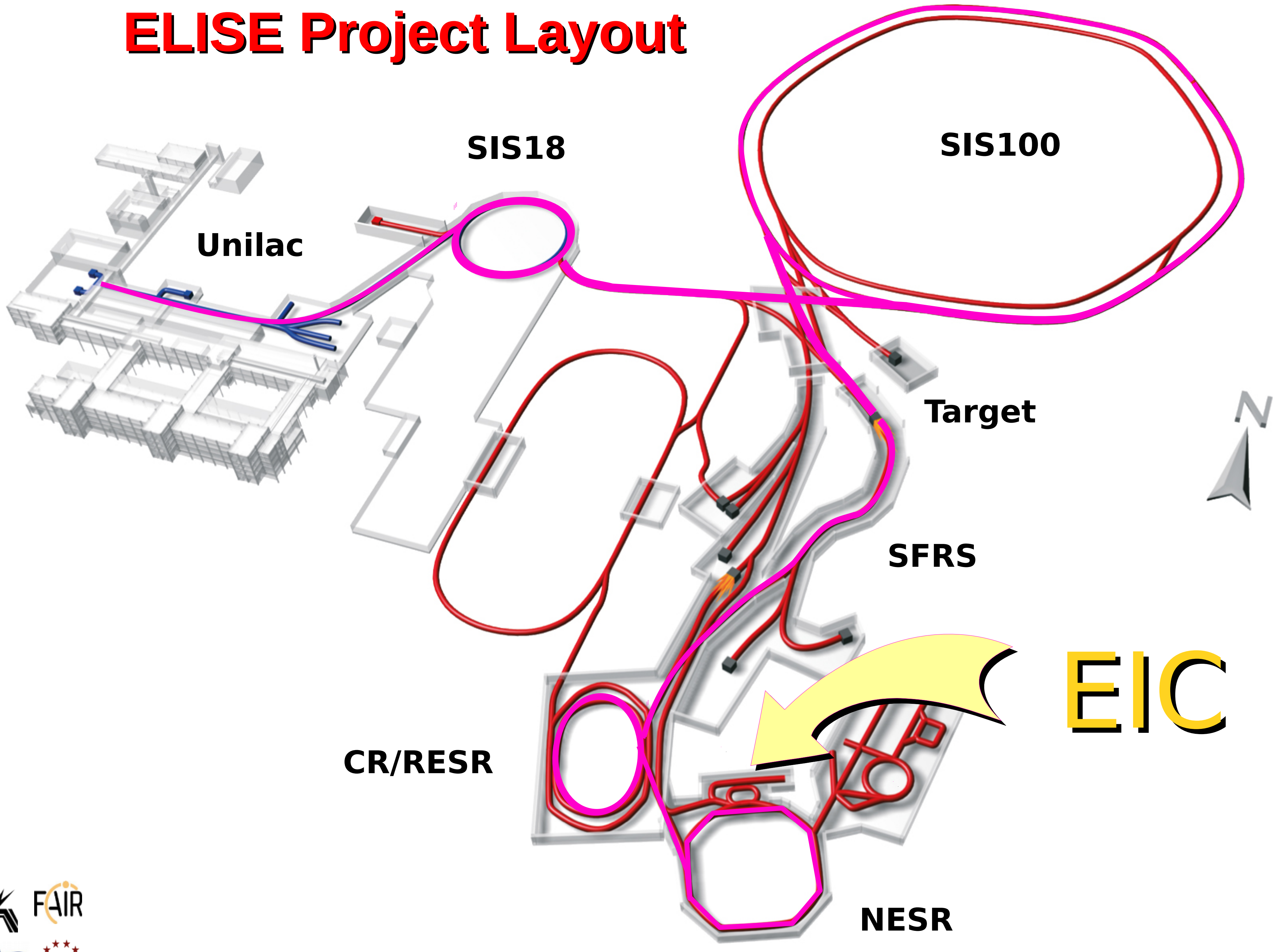


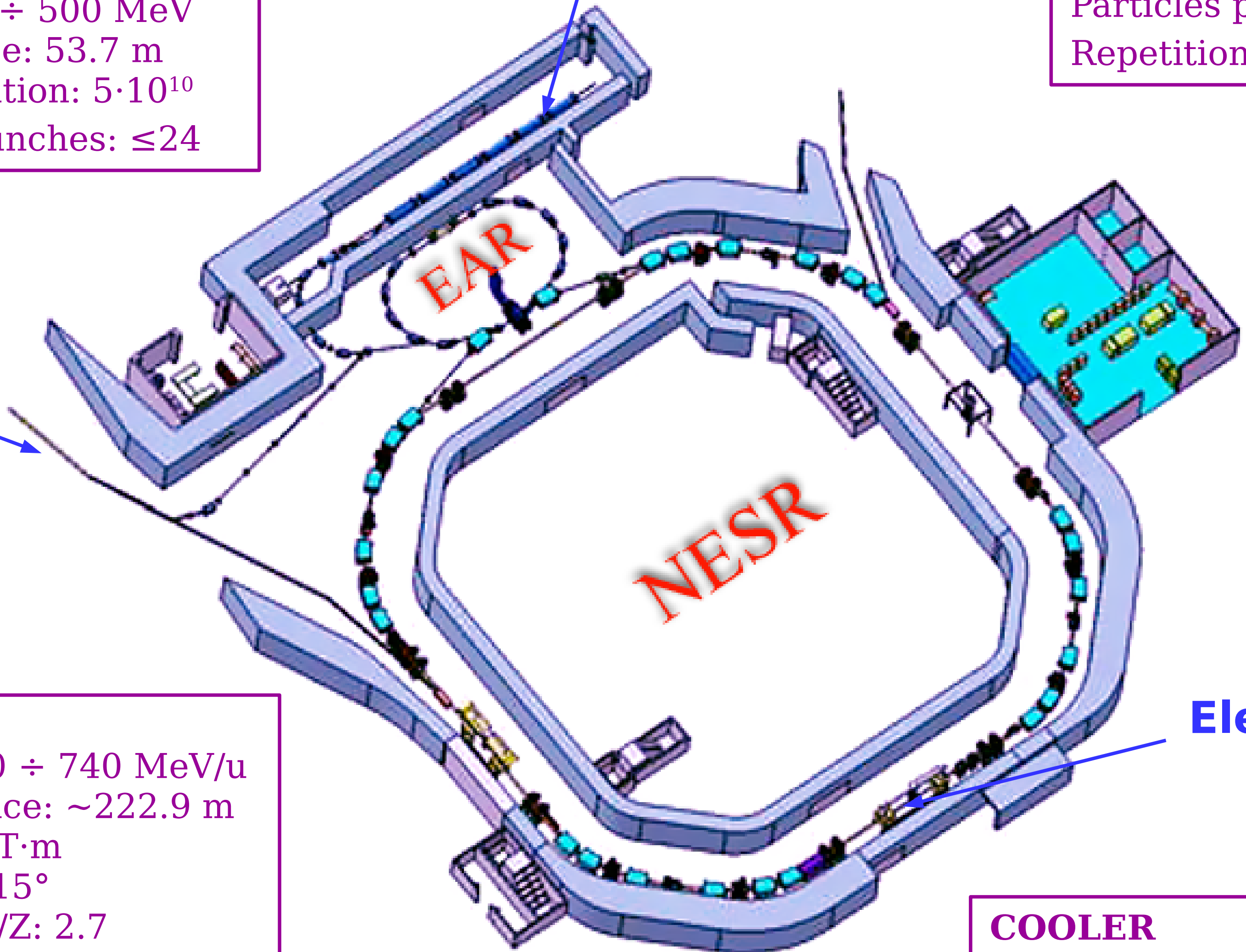
ELISE: collider layout

EAR
Energy: 125 ÷ 500 MeV
Circumference: 53.7 m
Bunch population: $5 \cdot 10^{10}$
Number of bunches: ≤24

Electron LINAC

LINAC
Energy: 125 ÷ 500 MeV
Length: ~35 m
Particles per pulse: $5 \cdot 10^{10}$
Repetition rate: 10Hz

Injection from CR/RESR



Electron Cooling

NESR
Energy: 120 ÷ 740 MeV/u
Circumference: ~222.9 m
Rigidity: 13 T·m
Bends: 24 · 15°
Reference A/Z: 2.7
Number of bunches: ≤120

COOLER
Length: 6 m
Magnetic field: 1 T
Cooling time: 20 ms

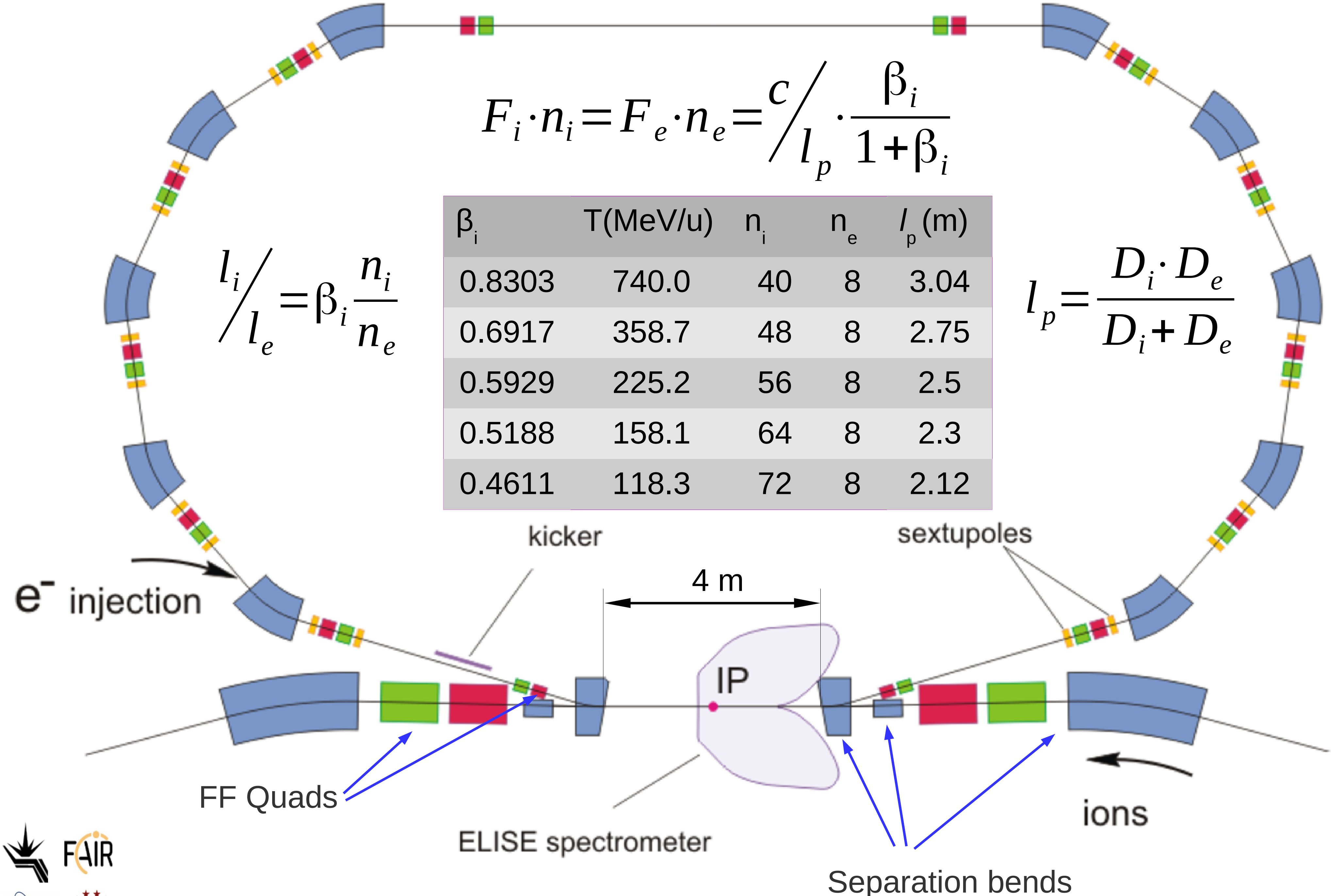
Interection Region and Electron Ring

$$F_i \cdot n_i = F_e \cdot n_e = {}^{c}\!/_{l_p} \cdot \frac{\beta_i}{1+\beta_i}$$

$$ {}^{l_i}\!/_{l_e} = \beta_i \frac{n_i}{n_e}$$

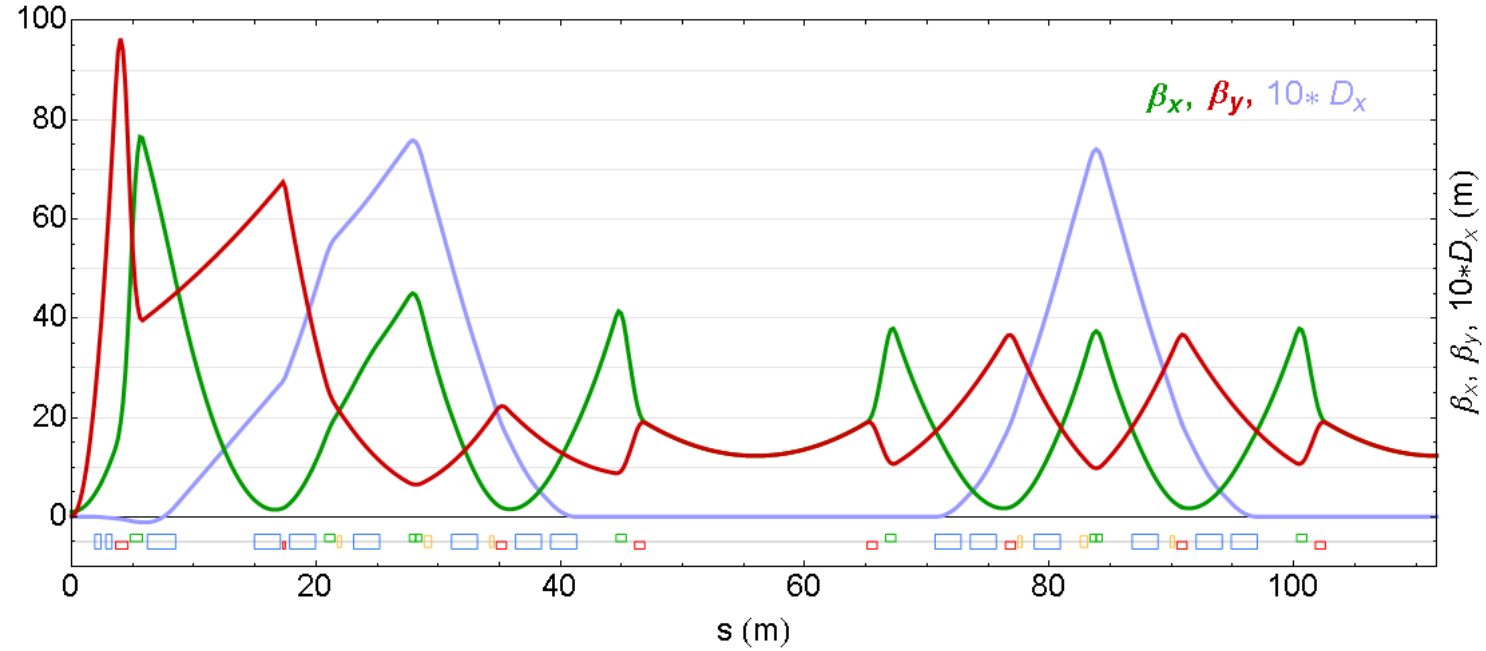
$$l_p = \frac{D_i \cdot D_e}{D_i + D_e}$$

β_i	T(MeV/u)	n_i	n_e	l_p (m)
0.8303	740.0	40	8	3.04
0.6917	358.7	48	8	2.75
0.5929	225.2	56	8	2.5
0.5188	158.1	64	8	2.3
0.4611	118.3	72	8	2.12



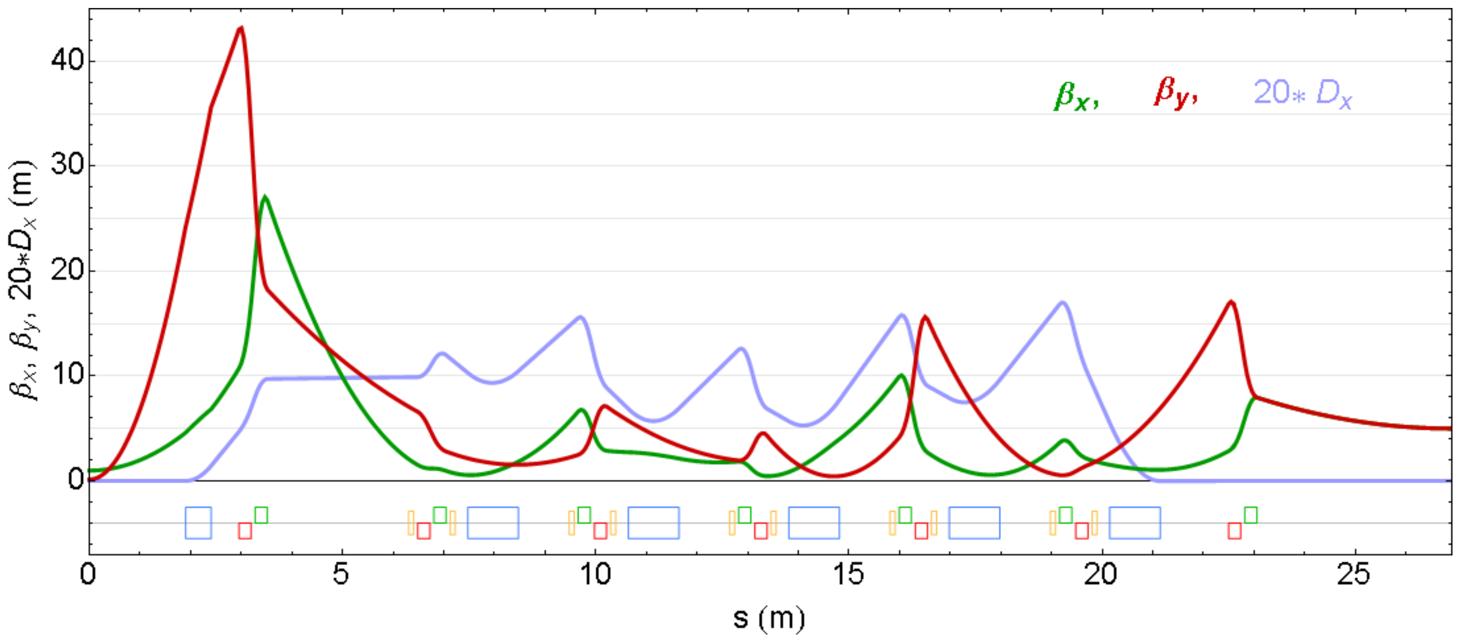
Structure Funtions

Ion ring



BetaX(IP): 15 cm
BetaZ(IP): 150 cm
BetaX(FF): 75 m
BetaZ(FF): 90 m
$\nu_x=\nu_z=0.55$
$\varepsilon_x=\varepsilon_z=$ 50 μm•mrad

Electron ring

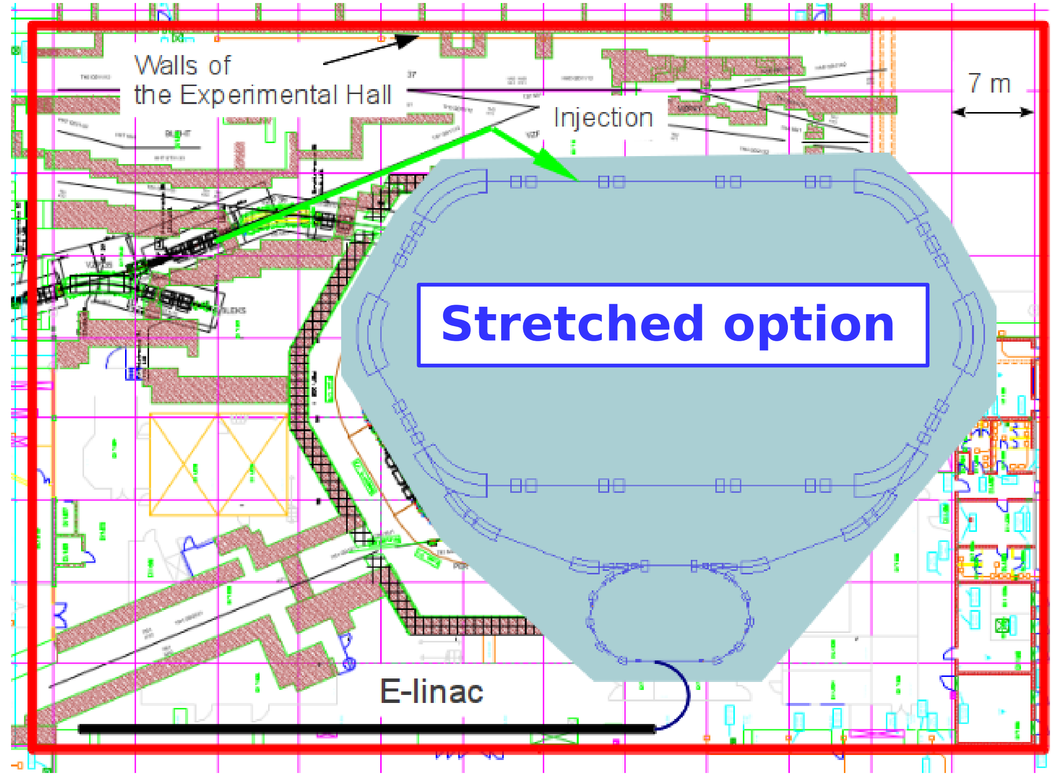


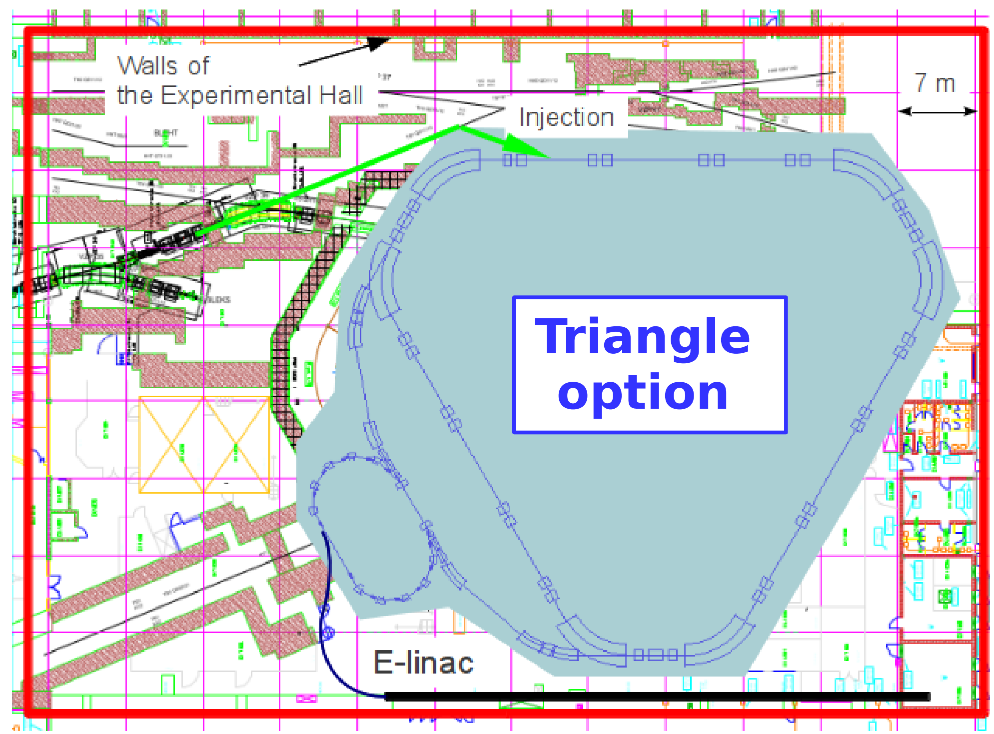
BetaX(IP): 15 cm
BetaZ(IP): 150 cm
BetaX(FF): 43 m
BetaZ(FF): 27 m
$\nu_x=\nu_z=0.2$
$\varepsilon_x=\varepsilon_z=$ 50 μm•mrad

Modified ESR

Common
Energy (max): 485.35 MeV/u
β_i (max): 0.7535
A/Z: 2.7
Rigidity: 10 T·m
Bends: 6 · 60°
Straights: 8 m
BetaX(IP): 15 cm
BetaZ(IP): 150 cm
Stretched
Circumference ion: 141.5 m
Circumference electron: 37.6 m
Additions: 8 quads
Triangular
Circumference ion: 173.56 m
Circumference electron:46.1 m
Additions: 12 quads

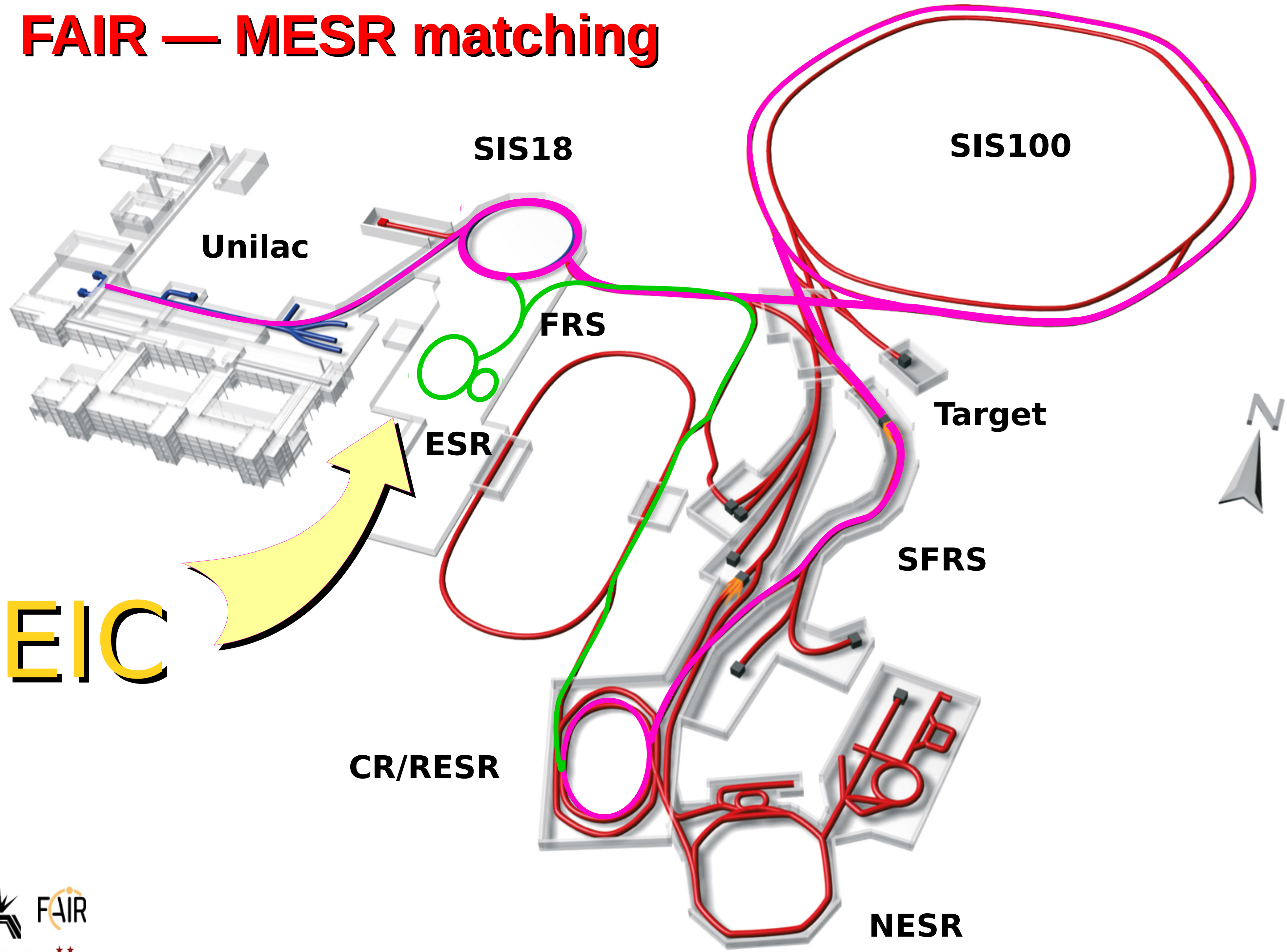
β_i	T(MeV/u)	$n_e \cdot n_i$ (Str)	$n_e \cdot n_i$ (Tri)
0.753	485.35	7×35	8×40
0.628	265.37	7×42	8×48
0.538	173.73	6×42	7×49
0.471	124.42	6×48	7×56



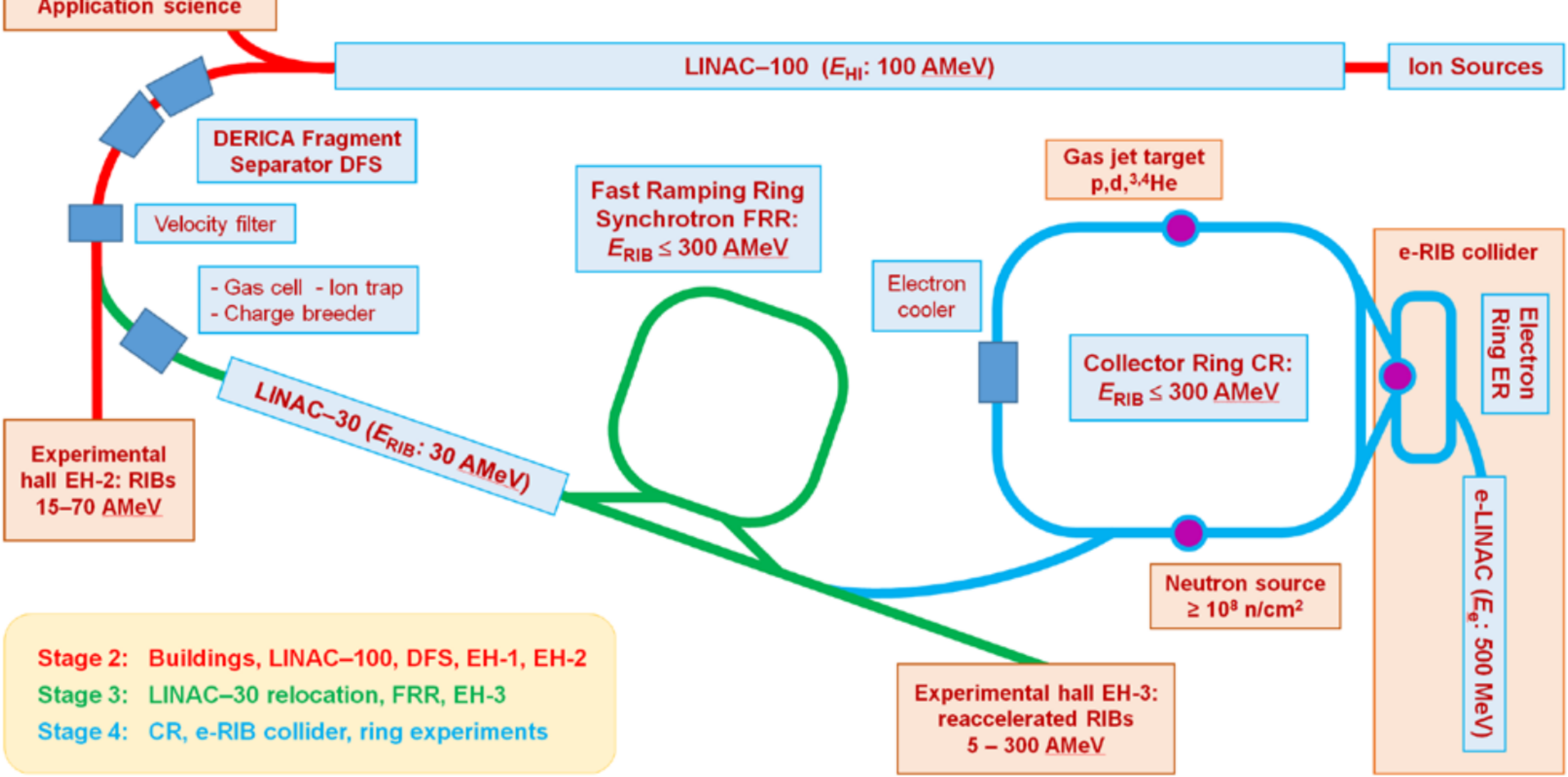


Bernhard Franzke

FAIR — MESR matching



DERICA



Energy (max): 300 MeV/u
Circumference CR: 222.9 m
β_i (max): 0.654
Circumference ER: 56.8 m (68.7)
Bunches rate: 1*6 (1*5)
A/Z: 2.7
Rigidity: 7.55 T·m

β_i	T(MeV/u)	$n_e \cdot n_i$ (Sh)	$n_e \cdot n_i$ (L)
0.654	300.0	10×60	11×55
0.561	193.45	10×70	11×66
0.491	137.48	8×64	9×63
0.436	103.6	8×72	9×72

Luminosity estimations

$$F_i \cdot n_i = F_e \cdot n_e$$
$$\sigma_{x,z} = \sqrt{\epsilon_{x,z} \cdot \beta_{x,z}}$$

$$L = F_e n_e \frac{N_{eb} N_{ib}}{4\pi \sigma_x \sigma_z}$$

$$\epsilon_x = \epsilon_z \quad \nu_x = \nu_z$$
$$\beta_x \neq \beta_z$$

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$$\beta_x \neq \beta_z$$

Beam-beam limitation

$$\xi_{ix} = \frac{Z}{A} \cdot \frac{N_{eb} r_p \beta_x}{2\pi \gamma_i \beta_i (\sigma_x + \sigma_z) \sigma_x}$$
$$\xi_{iz} = \frac{Z}{A} \cdot \frac{N_{eb} r_p \beta_z}{2\pi \gamma_i \beta_i (\sigma_x + \sigma_z) \sigma_z}$$

$$\xi_{ix} \approx 0.03 \div 0.05$$

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$$\xi_{ix} \approx 0.03 \div 0.05$$

$$L_\xi = F_i n_i \cdot \frac{A}{Z} \cdot \left(1 + \frac{\sigma_z}{\sigma_x}\right) \cdot \frac{N_{ib} \xi_{ix} \gamma_i \beta_i}{2 r_p \sqrt{\beta_x \beta_z}}$$

$$L_\xi \sim F_i N_{ib} n_i$$

Luminosity estimations

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Space charge limitation

$$\Delta\nu = \frac{Z^2}{A} \cdot \frac{N_{ib} r_p}{\gamma_i^3 \beta_i^2 \varepsilon} \cdot \frac{R}{2\sqrt{2\pi}\sigma_s}$$
$$\varepsilon = \frac{Z^2}{A} \cdot \frac{N_{ib} r_p}{\gamma_i^3 \beta_i^2 \Delta\nu} \cdot \frac{R}{2\sqrt{2\pi}\sigma_s}$$

$$\Delta\nu \approx 0.08 \div 0.1$$

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FAIR ОИЯИ ECT*

Luminosity estimations

$$F_i \cdot n_i = F_e \cdot n_e$$
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$$L = F_e n_e \frac{N_{eb} N_{ib}}{4\pi \sigma_x \sigma_z}$$

$$\epsilon_x = \epsilon_z \qquad \nu_x = \nu_z$$
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$$\xi_{ix} = \frac{Z}{A} \cdot \frac{N_{eb} r_p \beta_x}{2\pi \gamma_i \beta_i (\sigma_x + \sigma_z)\sigma_x}$$
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$$L_{Ne} = F_e n_e \frac{A}{Z^2} \cdot \frac{N_{eb} \Delta\nu \gamma_i^3 \beta_i^2}{4\pi r_p \sqrt{\beta_x \beta_z}} \cdot \frac{2\sqrt{2\pi}\sigma_s}{R}$$

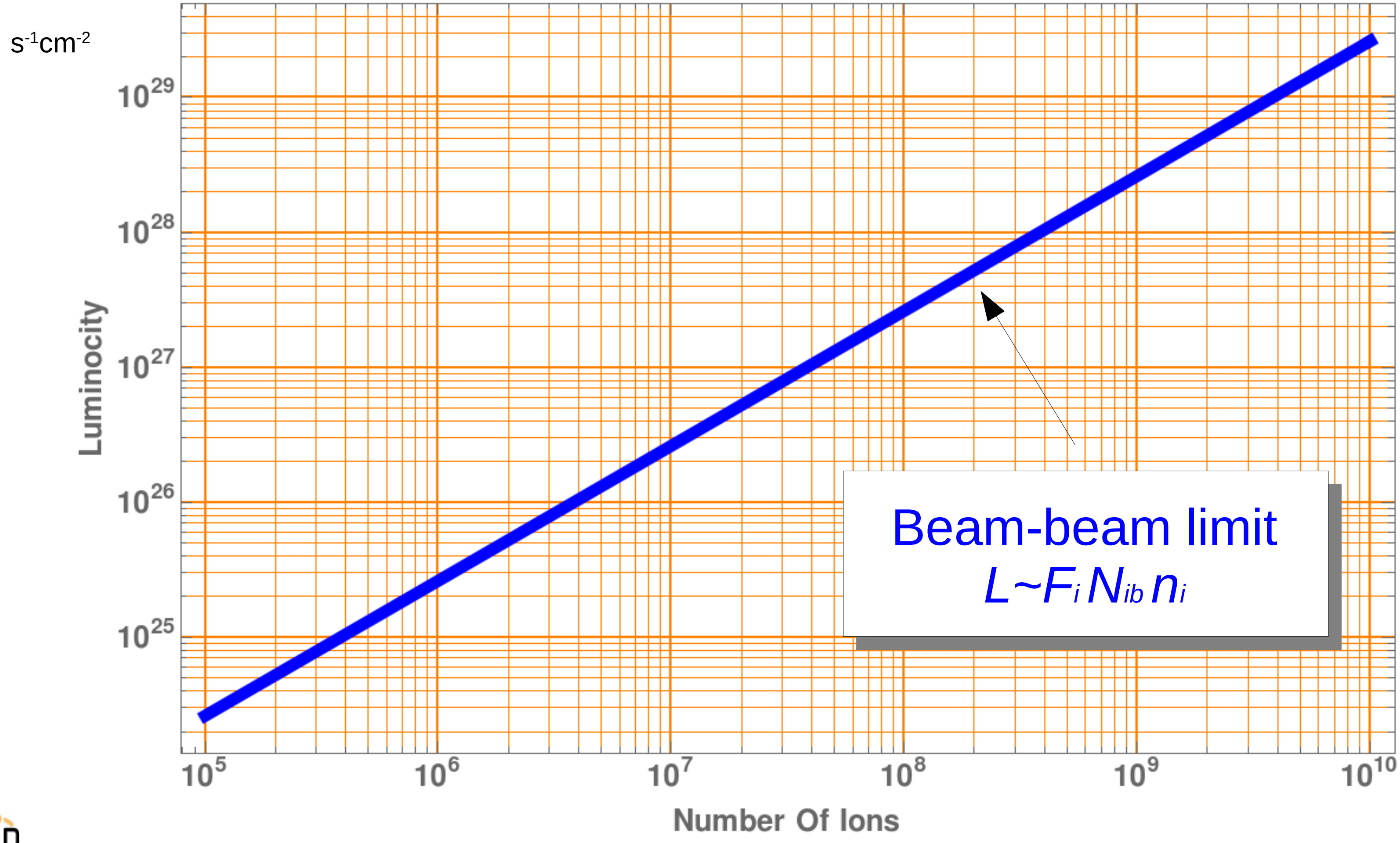
$$L_{Ne} \sim const$$

Luminosity: ELISE

$N_e \approx 5 \cdot 10^{10}$

Element	A	Z	Ni_{stored}
Be	11	4	$2.1 \cdot 10^{10}$
U	248.4	92	$4 \cdot 10^{8}$

40×8



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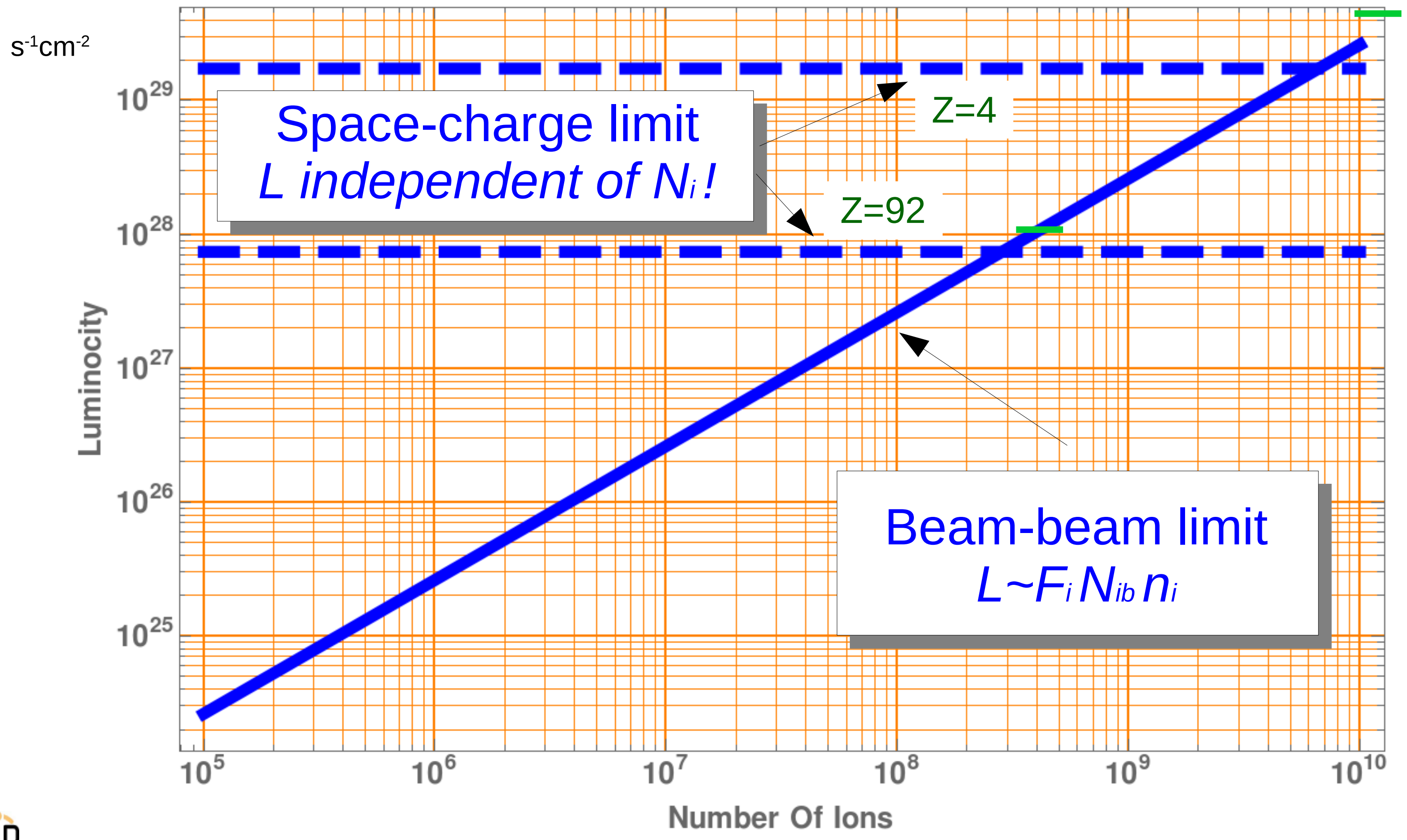

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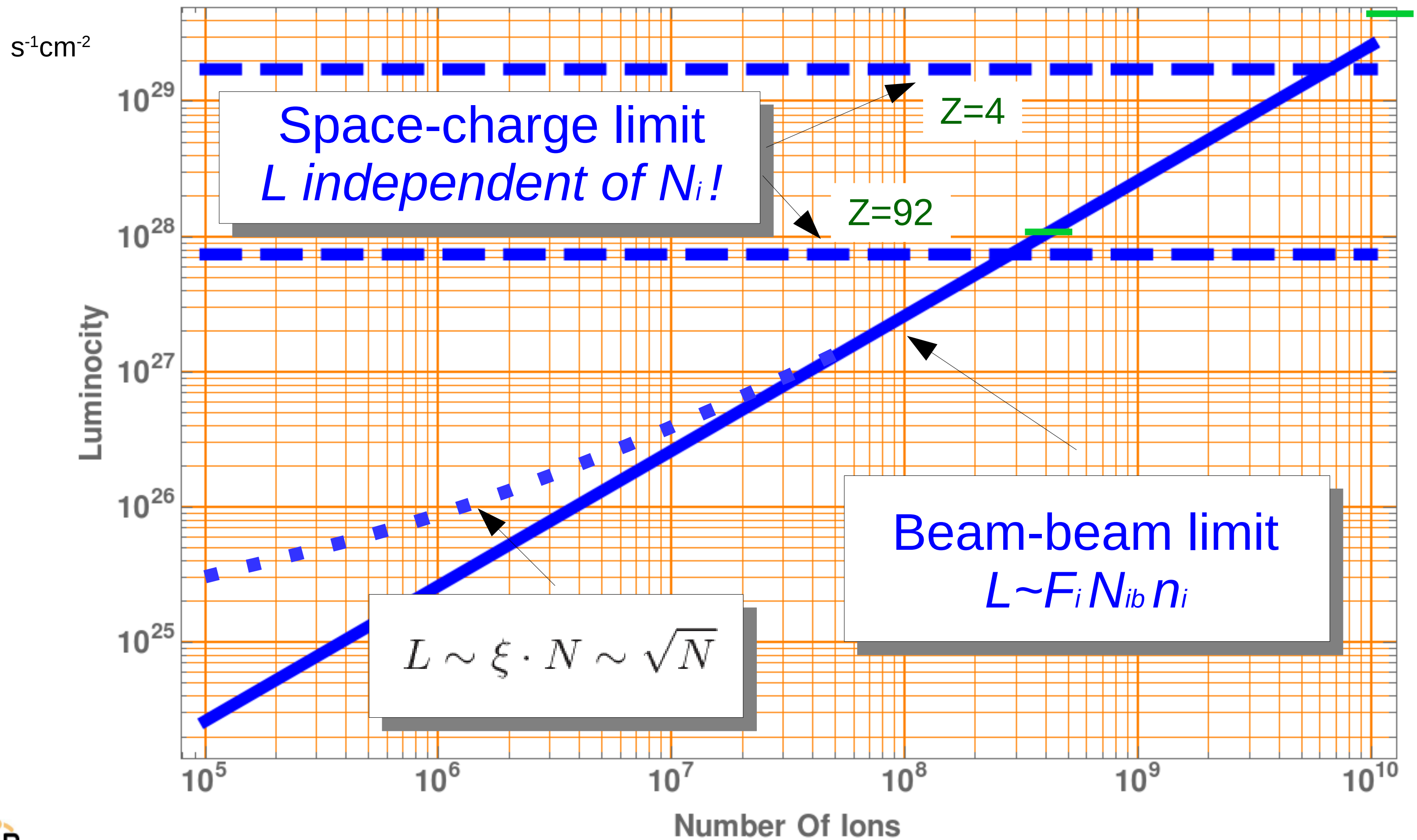


Luminosity: Energy scaling

Beam-beam limitation

$$L_\xi = F_i n_i \cdot \frac{A}{Z} \cdot \left(1 + \frac{\sigma_z}{\sigma_x}\right) \cdot \frac{N_{ib}\xi_{ix}\gamma_i\beta_i}{2r_p\sqrt{\beta_x\beta_z}}$$

Space charge limitation

$$L_{Ne} = F_e n_e \frac{A}{Z^2} \cdot \frac{N_{eb}\Delta\nu\gamma_i^3\beta_i^2}{4\pi r_p\sqrt{\beta_x\beta_z}} \cdot \frac{2\sqrt{2\pi}\sigma_s}{R}$$

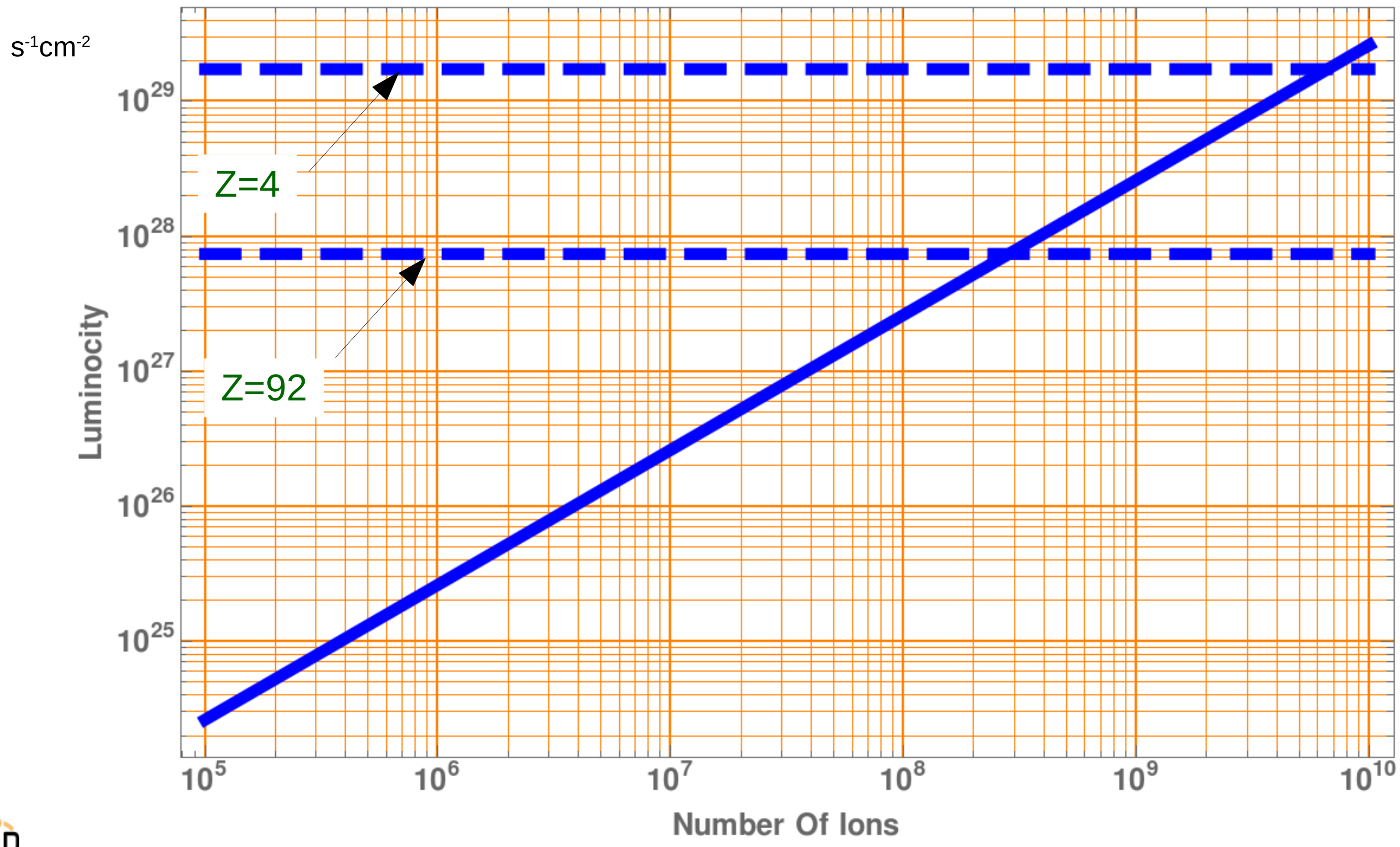
$$F_{i,e} \cdot n_{i,e} = c/l_p \cdot \frac{\beta_i}{1+\beta_i}$$

$$L_\xi \sim \frac{\gamma_i\beta_i^2}{1+\beta_i}$$

$$L_{Ne} \sim \frac{\gamma_i^3\beta_i^3}{1+\beta_i}$$

Luminosity comparison

	$^{11}Be^{4+}$	$^{248.4}U^{92+}$	Circumference	Energy MeV/u	Bunches
ELISE	$2.1\cdot10^{10}$	$4\cdot10^{8}$	222.9 m	740.0	8×40
MESR	$2.1\cdot10^{10}$	$4\cdot10^{8}$	173.56 m	485.35	8×40
DERICA	$1.5\cdot10^{10}$	-	222.9 m	300.0	11×55



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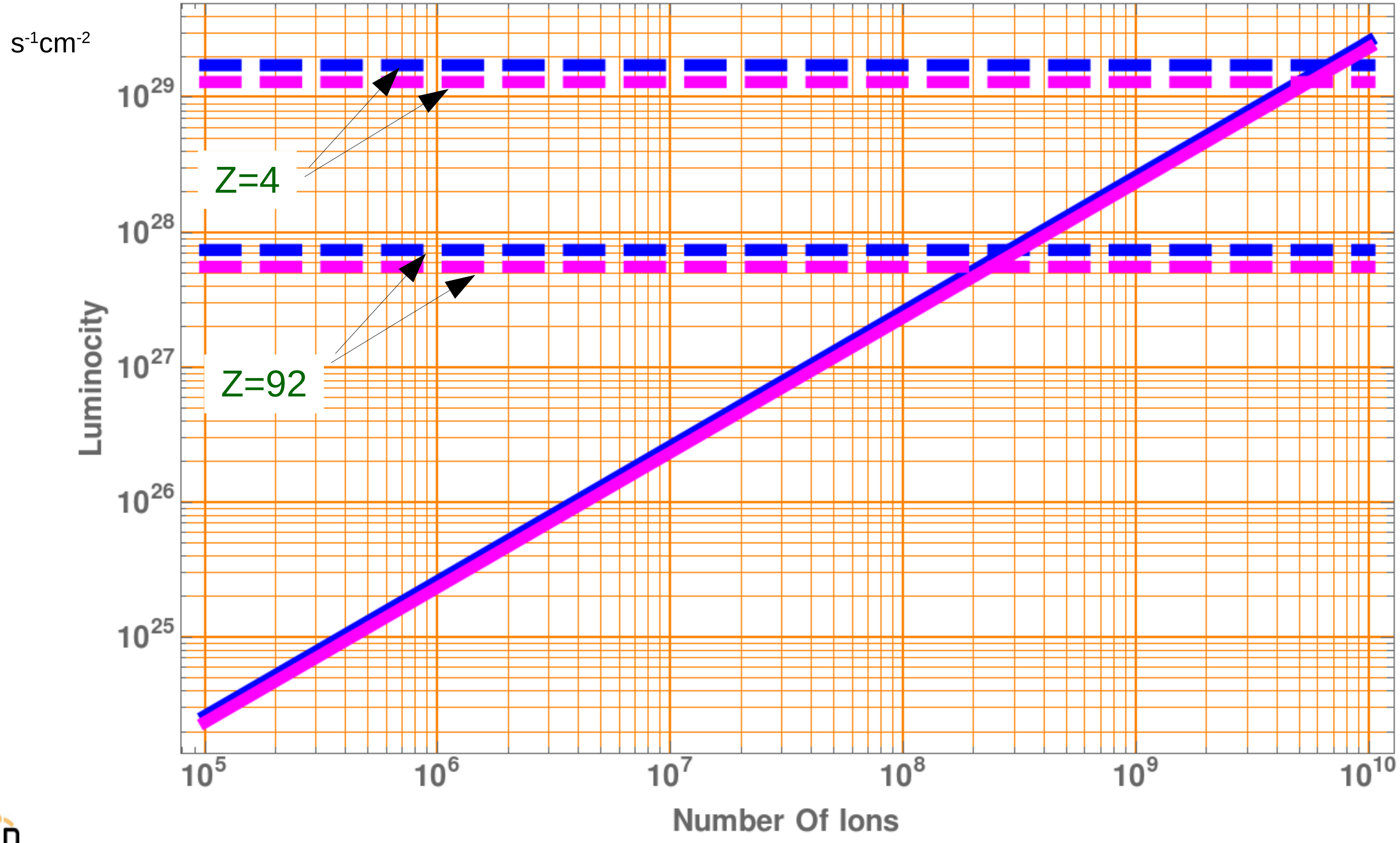

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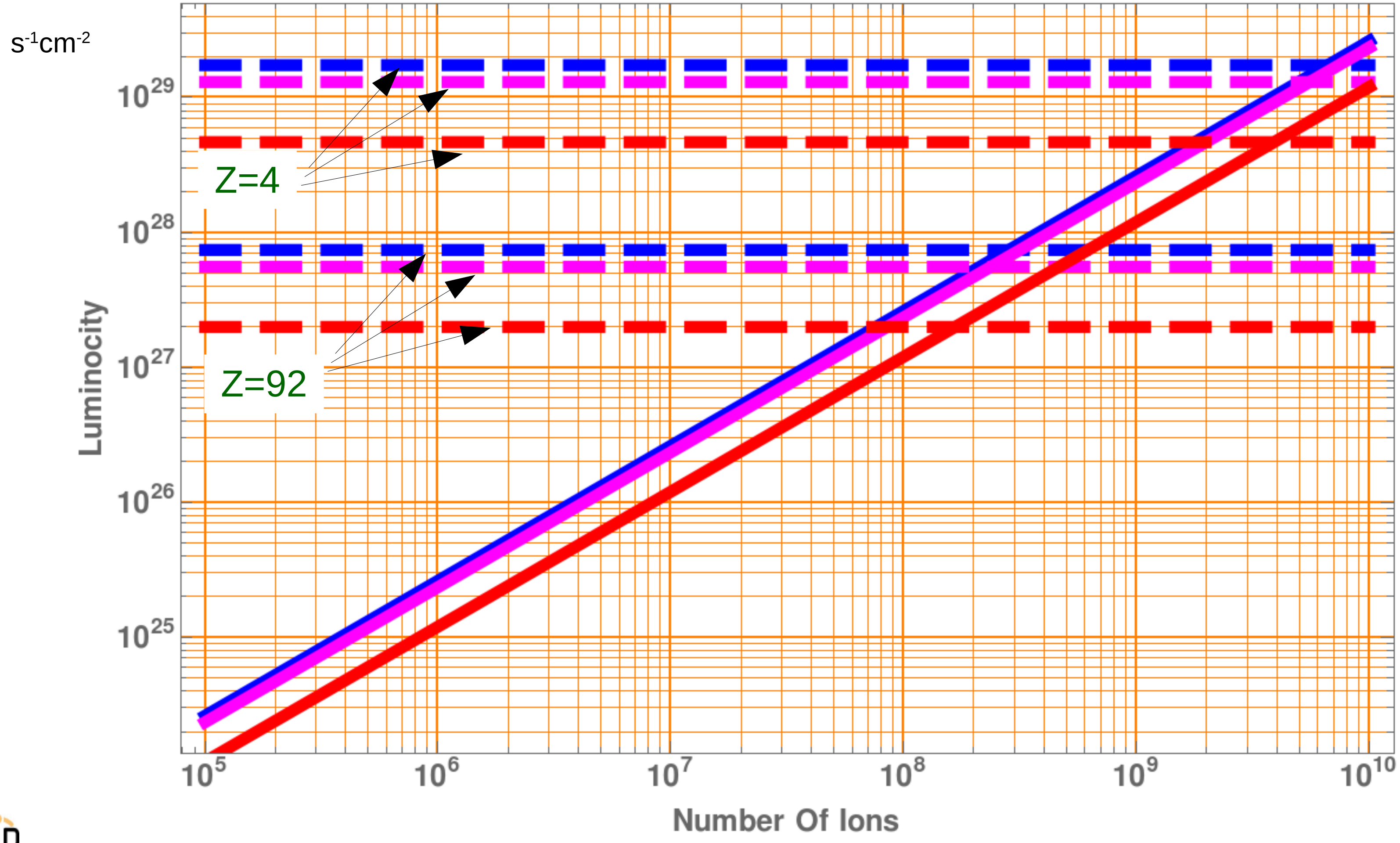

Possible improvements: Circumference

$$L_{Ne} = F_e n_e \frac{A}{Z^2} \cdot \frac{N_{eb} \Delta\nu \gamma_i^3 \beta_i^2}{4\pi r_p \sqrt{\beta_x \beta_z}} \cdot \frac{2\sqrt{2\pi}\sigma_s}{R}$$

Possible improvements: Circumference

Factor 2x

$$L_{Ne} = F_e n_e \frac{A}{Z^2} \cdot \frac{N_{eb} \Delta\nu \gamma_i^3 \beta_i^2}{4\pi r_p \sqrt{\beta_x \beta_z}} \cdot \frac{2\sqrt{2\pi}\sigma_s}{R}$$

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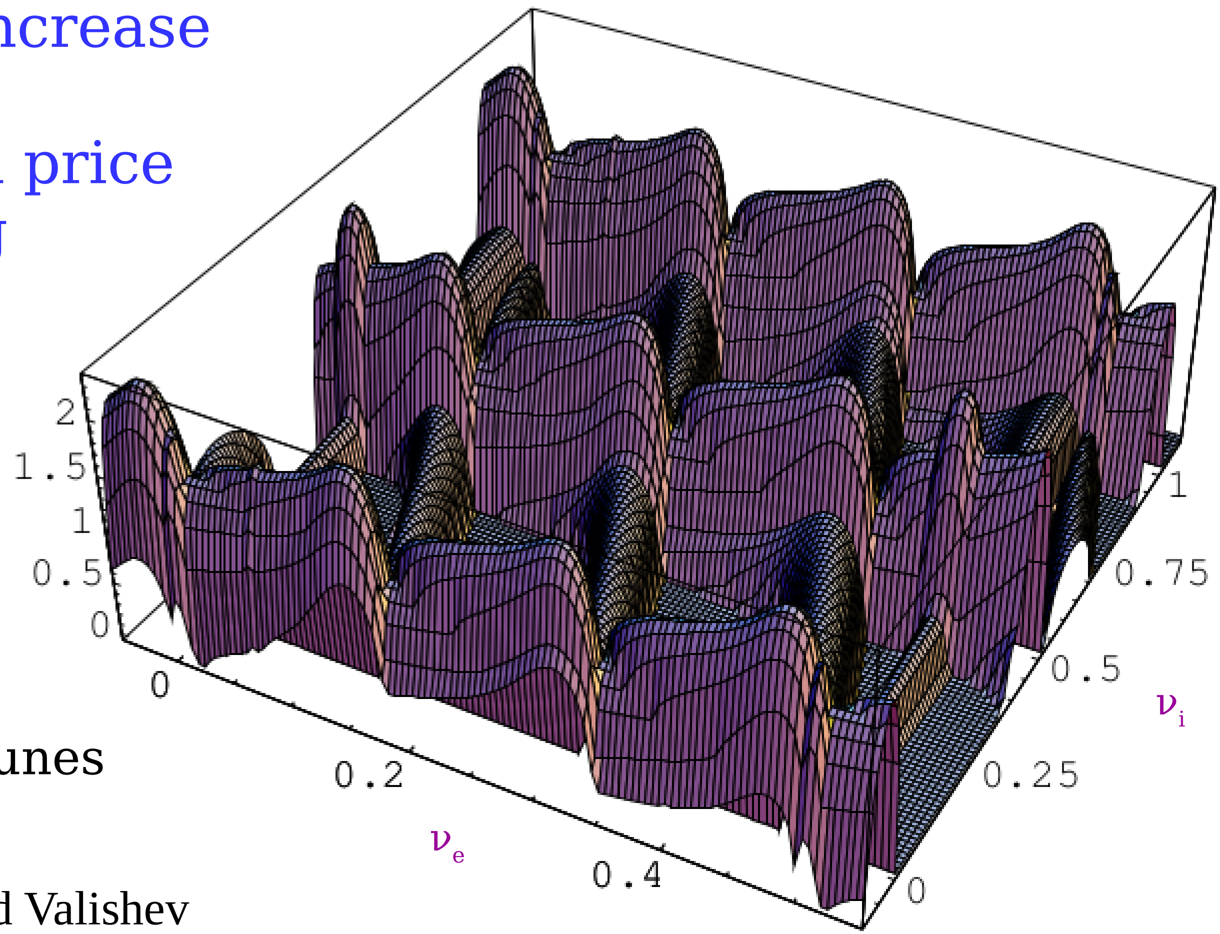
Factor 2x

Disadvantages

- Less room for all needed experiments
- Maintenance prices increase

Advantages

- Reduced construction price
- Full size electron ring



Coherent betatron tunes simulation for 1×6 bunches

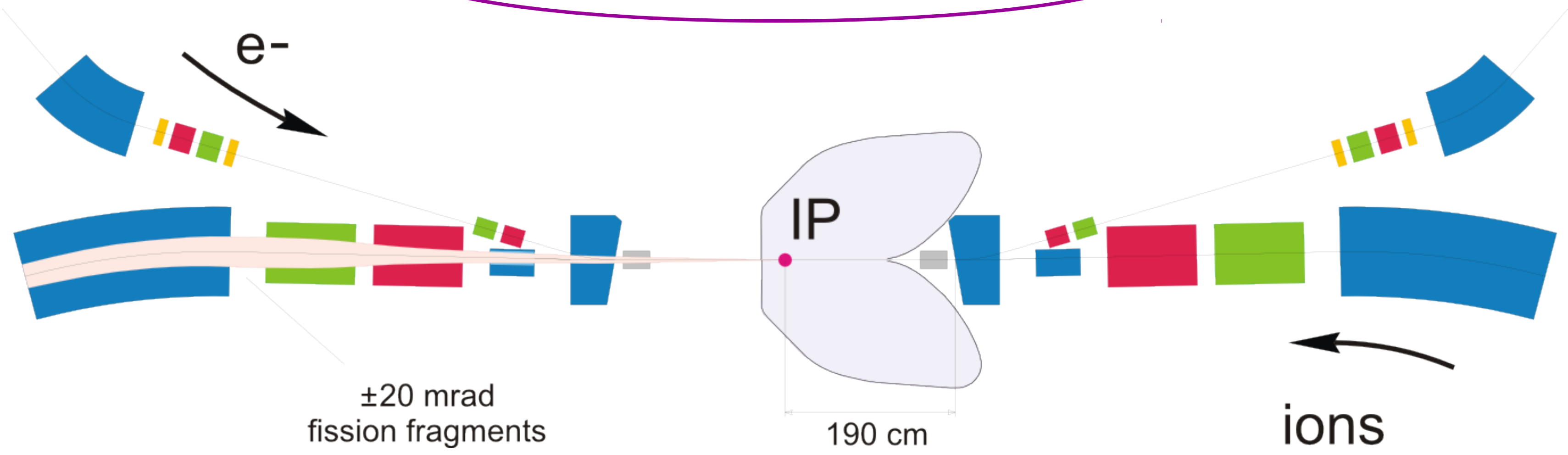
Alexand Valishev

Possible improvements:
Interaction region

$$L_{Ne} = F_e n_e \frac{A}{Z^2} \cdot \frac{N_{eb} \Delta\nu \gamma_i^3 \beta_i^2}{4\pi r_p \sqrt{\beta_x \beta_z}} \cdot \frac{2\sqrt{2\pi}\sigma_s}{R}$$

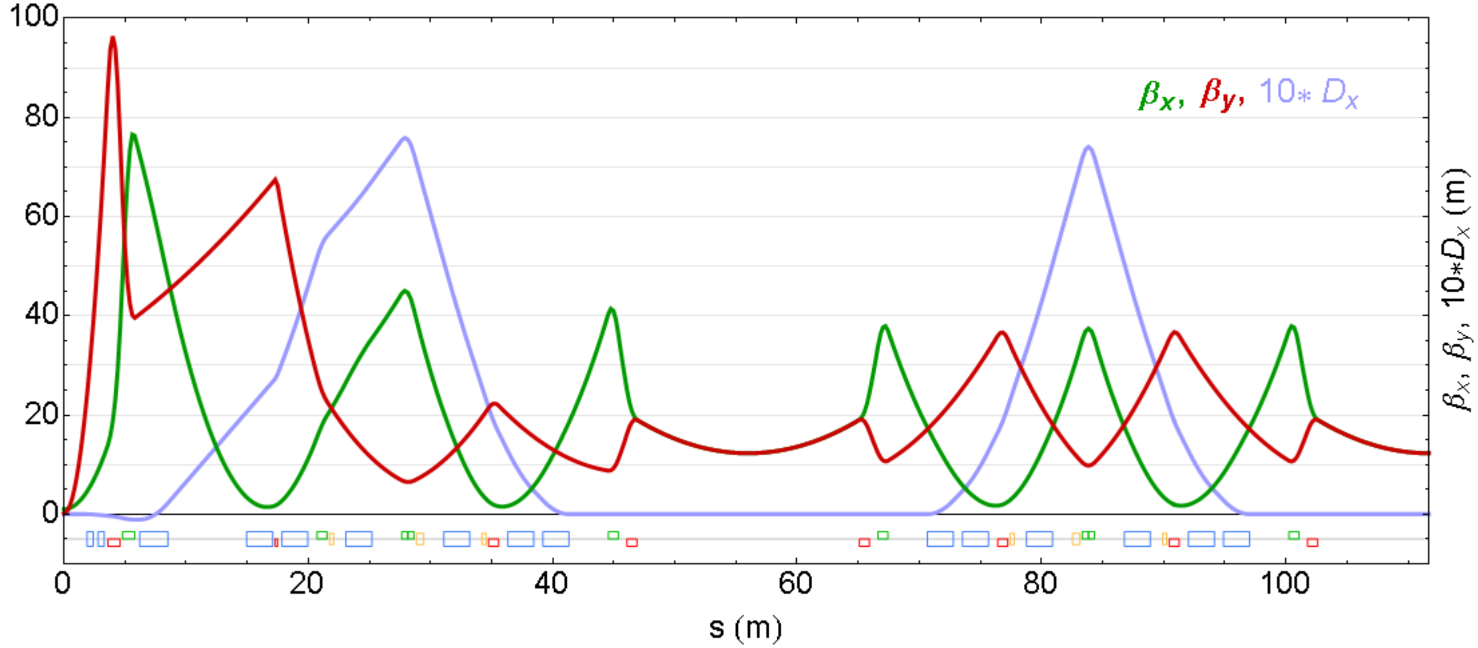
$$\beta = \beta_0 + \frac{s^2}{\beta_0}$$

BetaZ (IP): 15 cm → 1cm ?



IP Region optimization

Structure functions of NESR

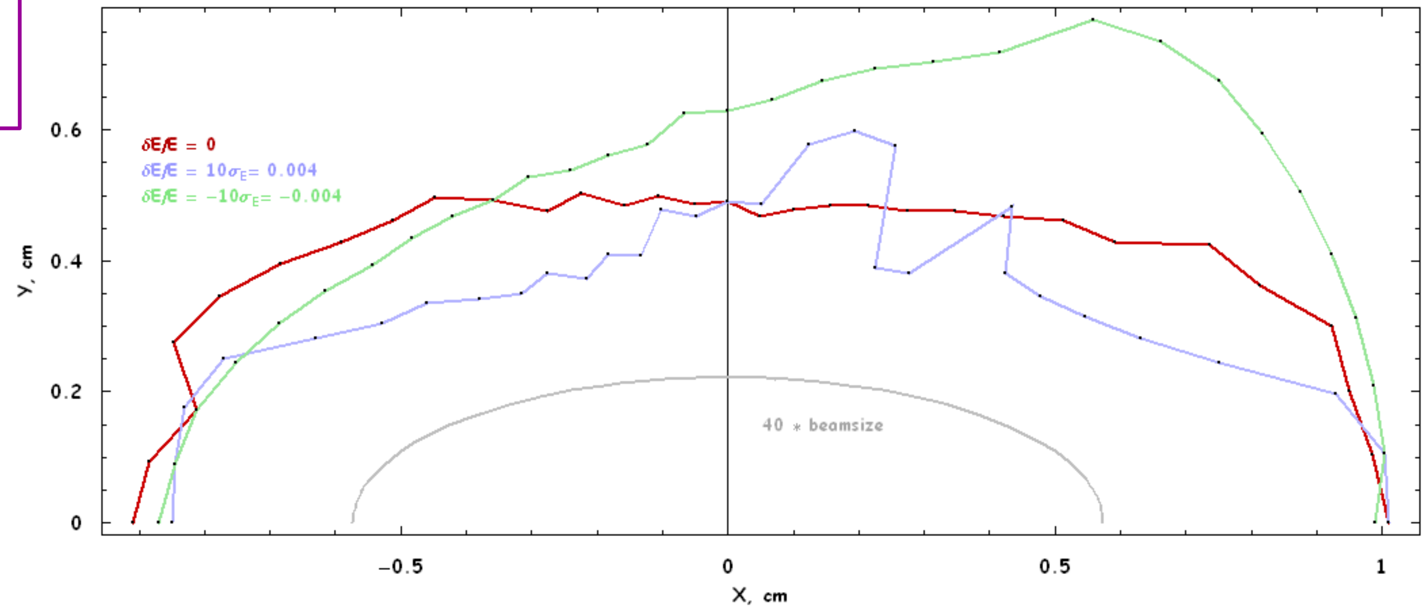


BetaZ (maximum): ≈90 m
BetaZ (IP): 15 cm

IP region length → 1/2
$Beta_0$ → ≈0.25

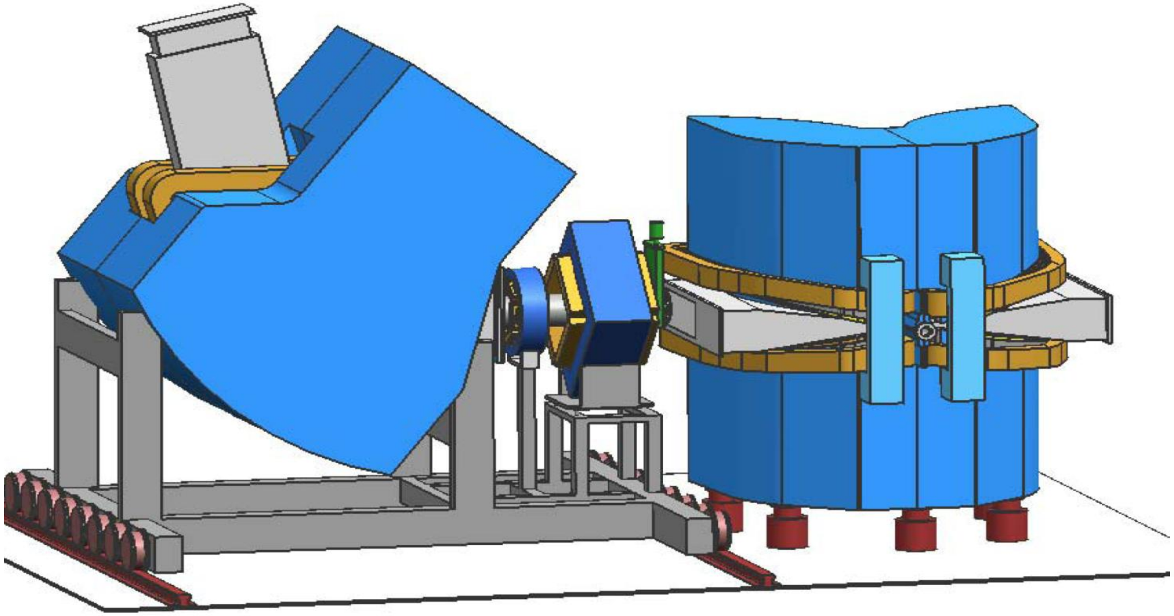
IP region length → 1/3
$Beta_0$ → ≈0.1

Dynamic aperture of NESR



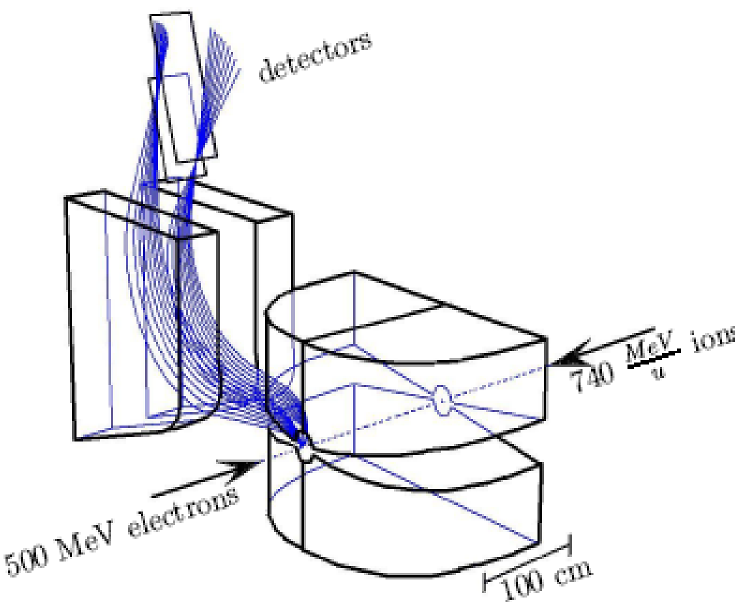
D.Shwartz

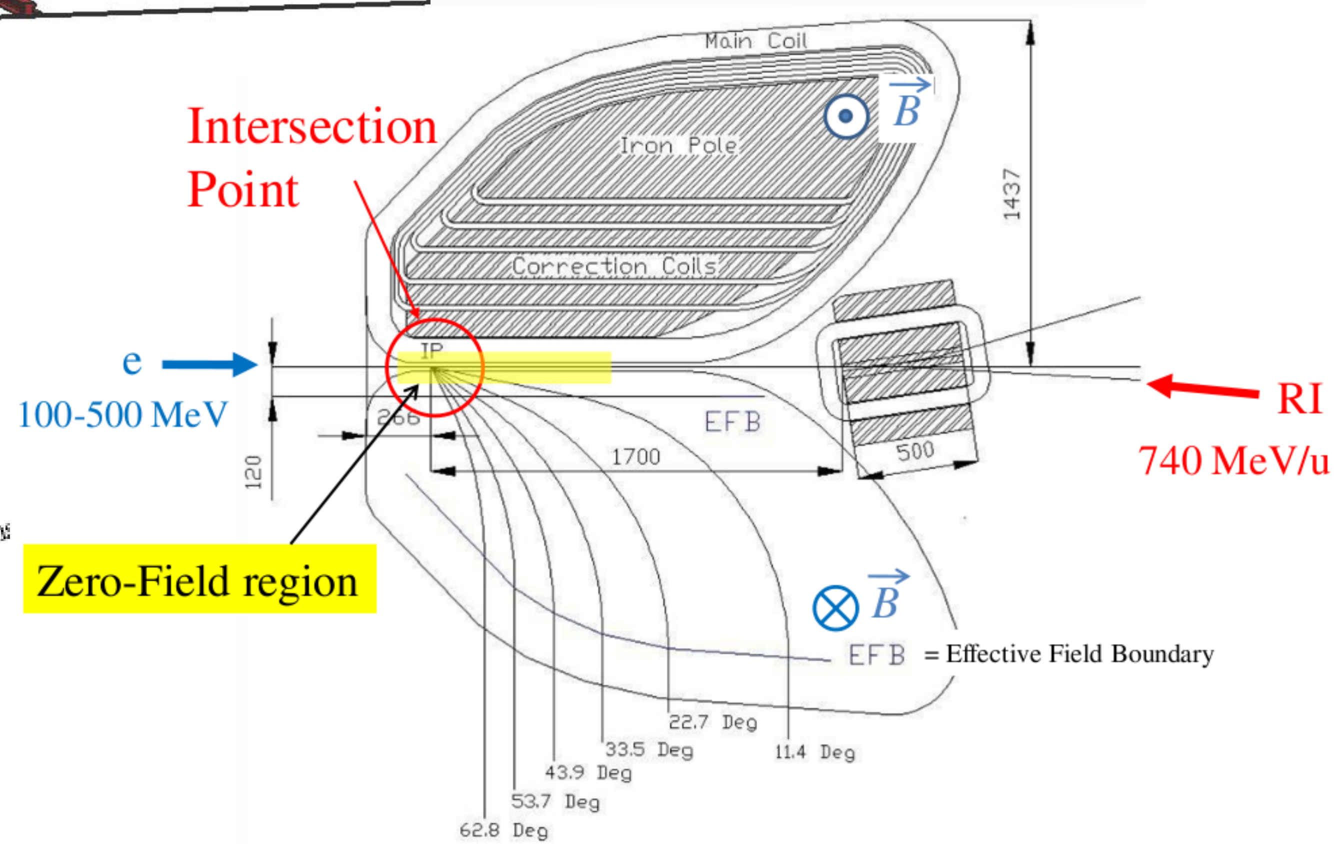
ELISE Electron Spectrometer



Angle 10° ÷ 45°

Midplane



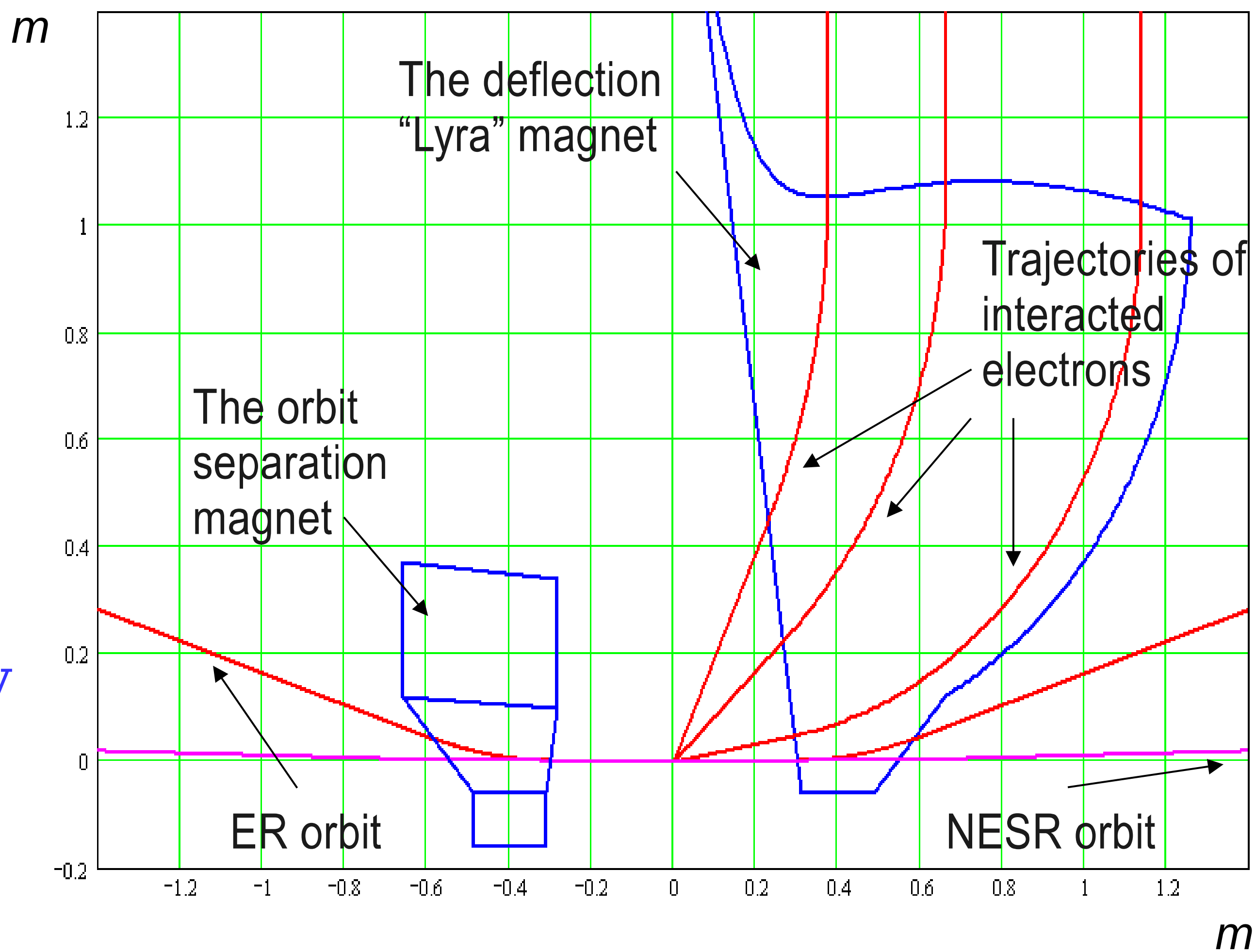


Georg Berg

Electron Spectrometer Alternative

Disadvantages
- Complicated design
- Increased cost
- Supercoductivity

Advantages
- Angle 10° ¸ 75°
- Tight integration with Final Focusing
- Increased luminocity by factor of $3 \div 5$
- Increased $F_i n_i$
- Supercoductivity



Thank You!