# Case studies: collider design

by Dream Team

# Task statement

| Parameter | Ring 1 | Ring 2 |
|---|---|---|
| Ring circumference, m | 300 | ? |
| Ions | Protons | Deuterons |
| Energy, GeV/u | 3-10 | |
| Luminosity | 1E+30 | |
| Proton-deuteron collisions | | |

# How we were figured about

Magnetic field is 1.8 T, deuteron ring circumference is 600 m

| | p | d |
|---|---|---|
| Bending radius, $\rho$(m) | 18.53 | 37.06 |
| Magnets number | 40 | 40 |
| Dipole per~~sa~~centage | 0.3 | 0.3 |
| Angle of one magnet (degree) | 7. | 7. |
| Magnet length (m) | 2.26 | 4.52 |
| Circumference | 300 | 600 |
| $\beta$ | 1. | 1. |
| $f_0$(MHz) | 1. | 0.5 |

# Main intense beam effects

In case of space charge we observe the classical Laslett formula:

$$\Delta q = -\frac{Z^2}{A}\frac{Nr_i}{4\pi\beta^2\gamma^3\varepsilon}k_{bunch} \qquad k_{bunch} = \frac{C_{ring}}{\sqrt{2\pi}\sigma_s}$$

Beam – beam effect:

$$\boldsymbol{\xi}_{12} = -\frac{Z_1 Z_2}{A_2}\frac{N_2 r_i(1+\beta_1\beta_2)}{2\pi\beta_1^2\gamma_1\varepsilon}\Phi_{12}\lambda_0$$

when emittances, beta-functions, longitudinal lengths are equals

$$\Phi_{12} = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty}\frac{1}{\sqrt{1+(\alpha u)^2}}e^{-2u^2}du$$

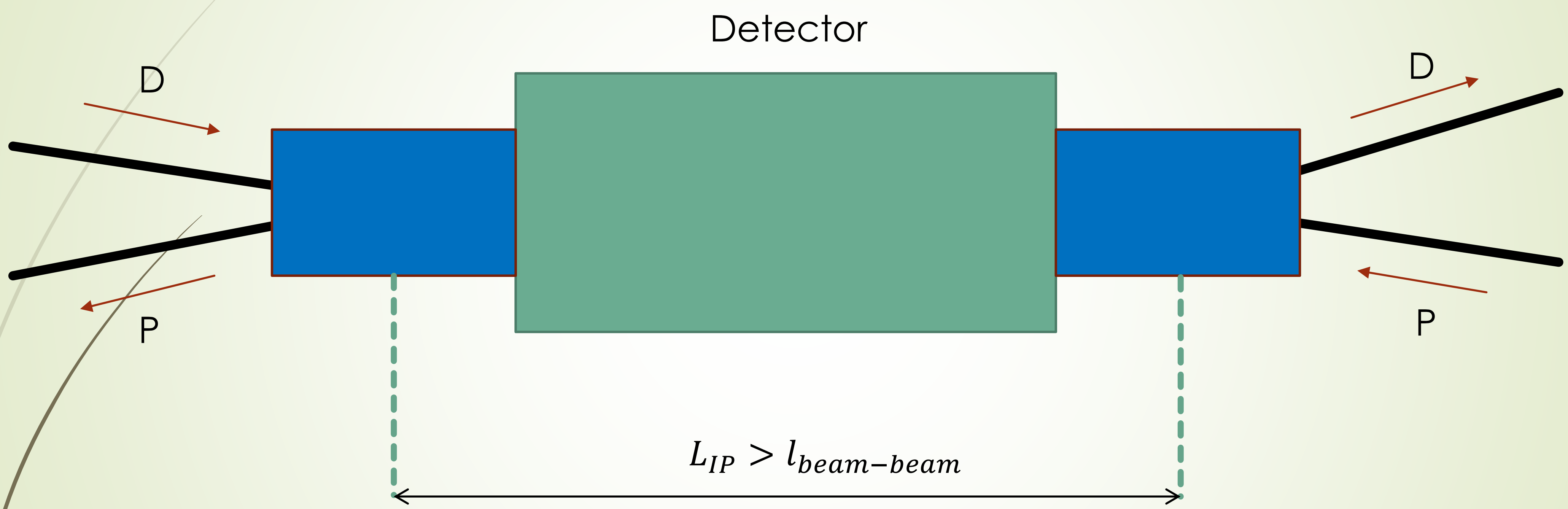
$\Phi_{12}$= 0.913, when $\sigma_s = \beta^*$

It is known from practice that an intense beam is stable if $|\boldsymbol{\xi}| + |\Delta q| \le 0.05$

In this case we can increase amount of the particles and emittance, we have

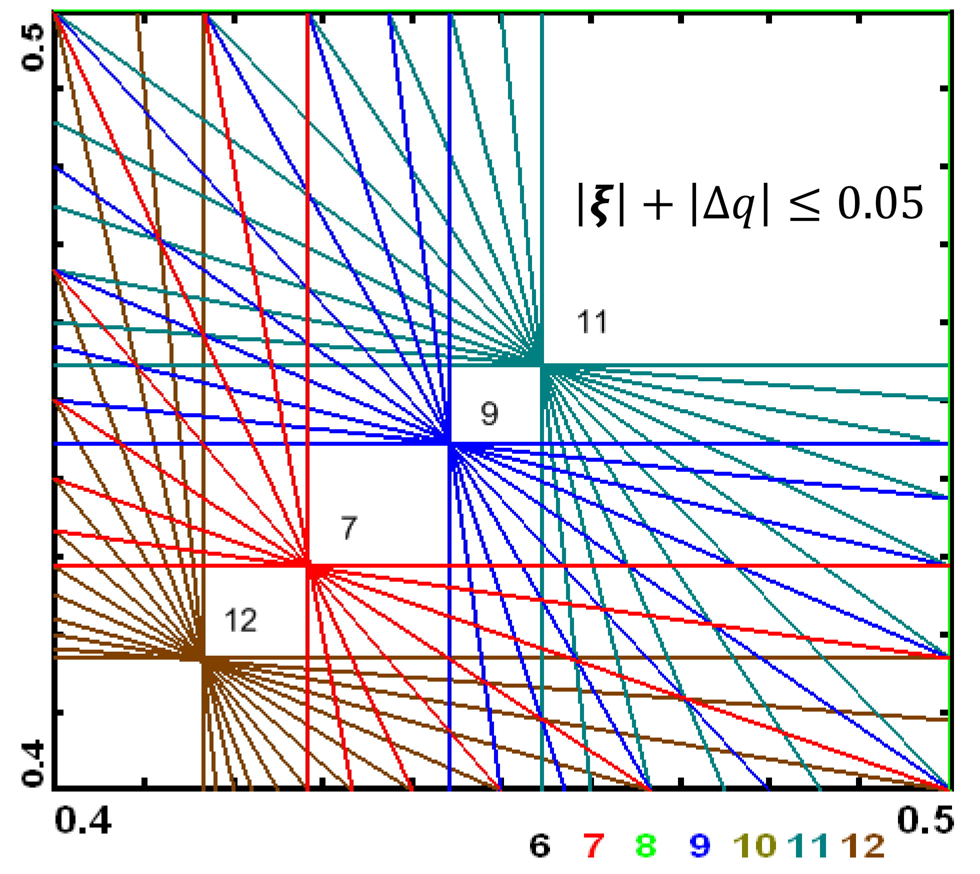
$$L \sim \frac{N_1 N_2}{\varepsilon} \sim \varepsilon$$

# Intersection point

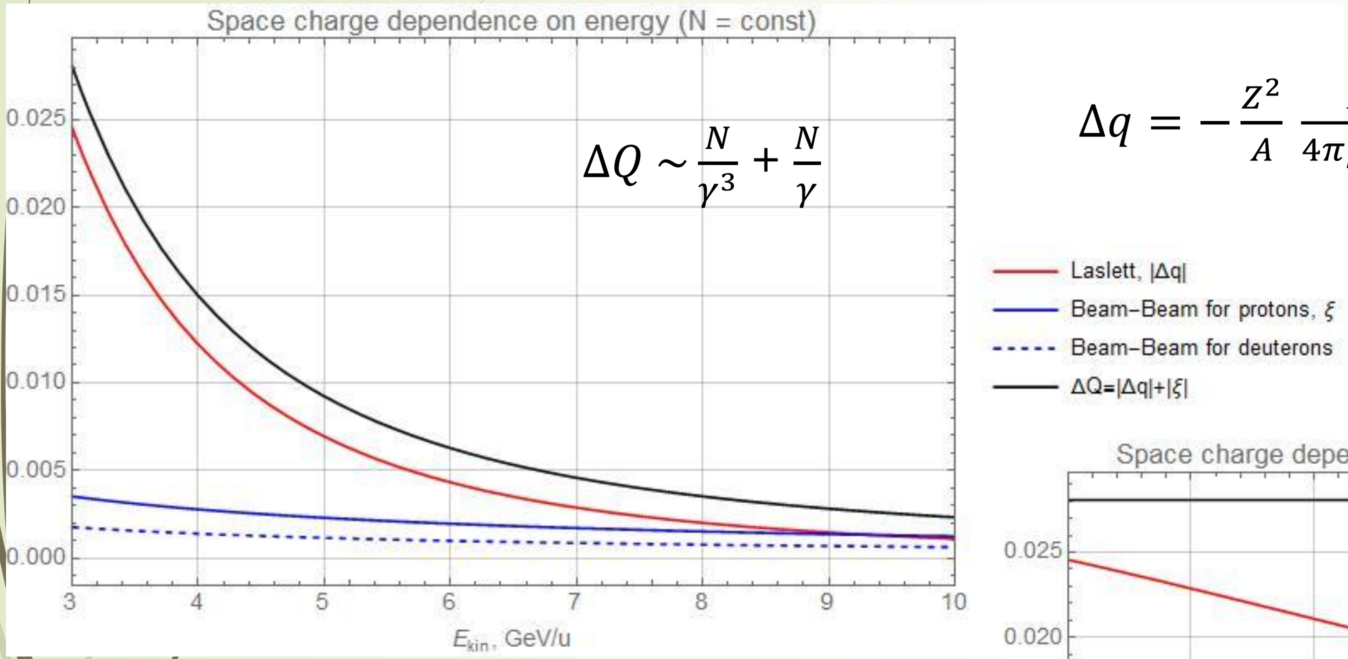


# Table of parameters

| Parameter | Value |
|---|---|
| Kinetic energy, GeV/u | 3 |
| $\sigma_s = \beta^*$, m | 0.5 |
| H, harmonic number | 100 (p), 200 (d) |
| N beam | 25 (p), 50 (d) |
| Emittance, mm*mrad | 1 |
| Particles per bunch | 6E+10 |
| $\xi_{12}$ | 0.0033 |
| $\Delta q$ (Laslett) | 0.0245 |
| $\lvert\xi\rvert + \lvert\Delta q\rvert$ | 0.0278 |
| Luminosity | 1.09E+30 |

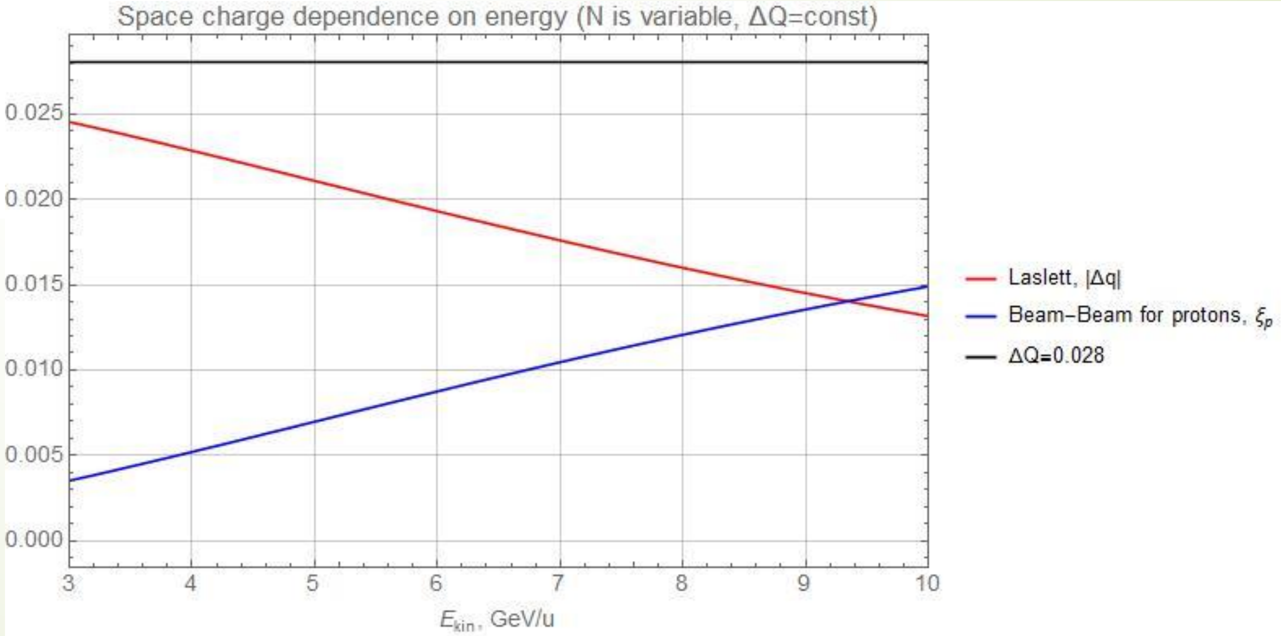


# Space charge and beam-beam



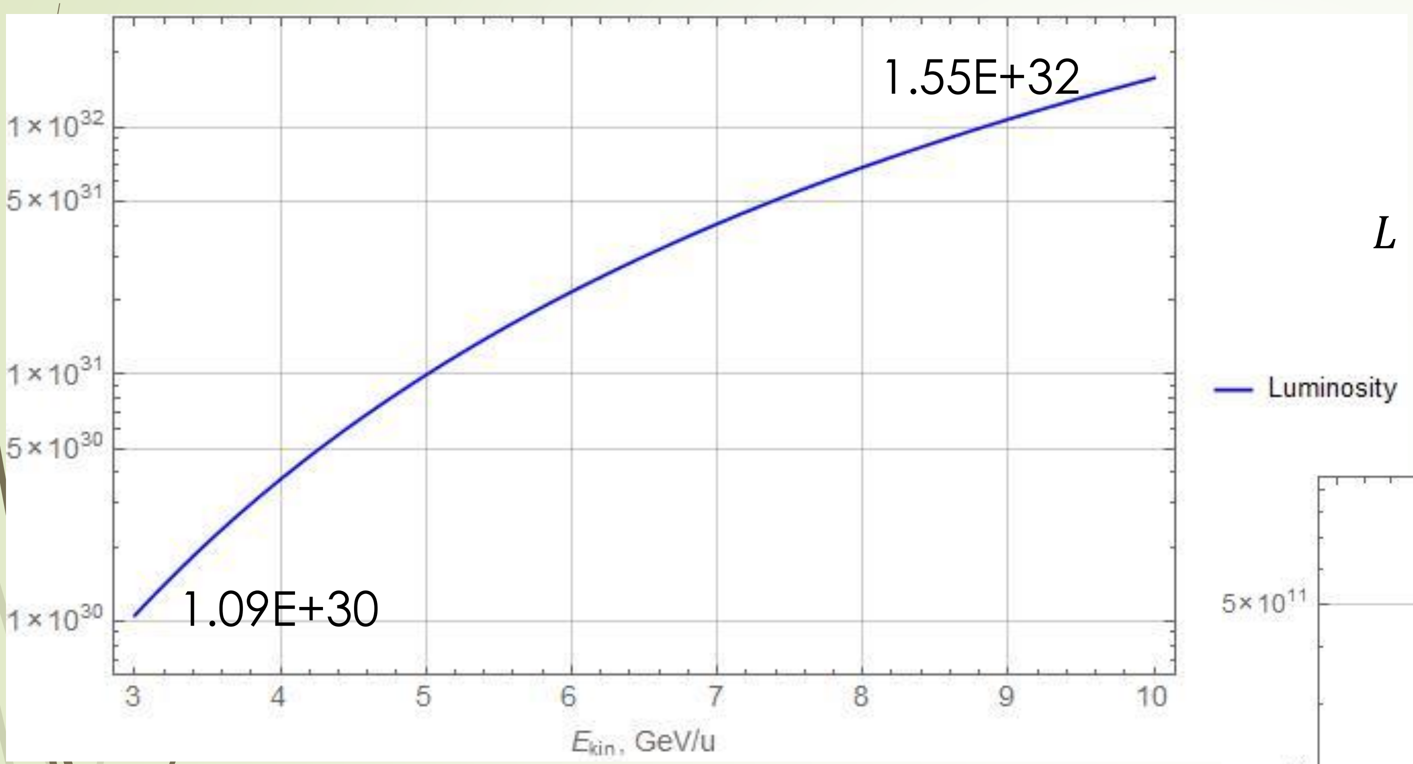

$$\Delta Q \sim \frac{N}{\gamma^3} + \frac{N}{\gamma}$$

$$\Delta q = -\frac{Z^2}{A}\,\frac{N r_i}{4\pi\beta^2\gamma^3\varepsilon}\,k_{bunch}$$

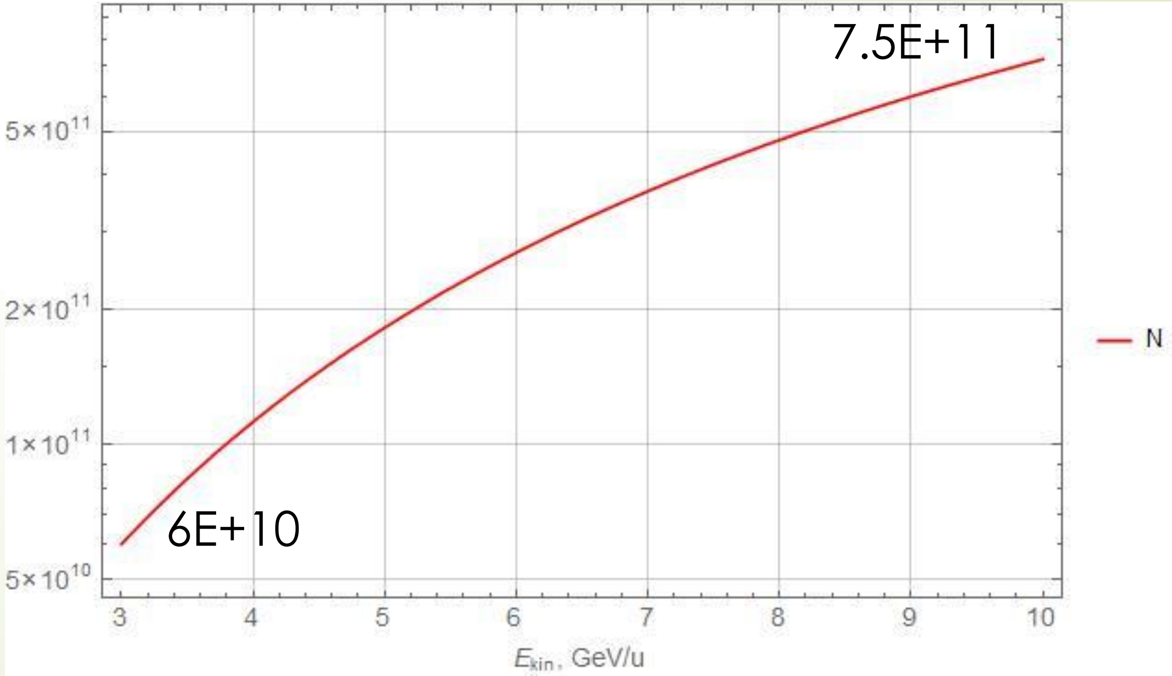

$$\boldsymbol{\xi}_{12} = -\frac{Z_1 Z_2}{A_2}\,\frac{N_2 r_i (1+\beta_1\beta_2)}{2\pi\beta_1^2\gamma_1\varepsilon}\,\Phi_{12}\lambda_0$$

# Luminosity and particles number

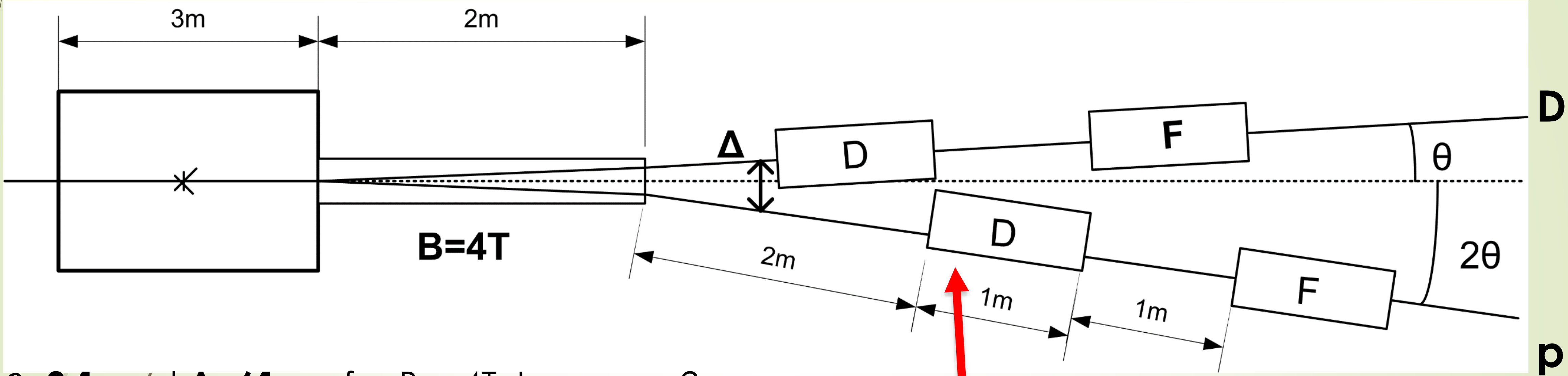



$$L = \frac{N_{bunches} N_p N_d f_0}{4\pi\varepsilon\beta^*}\Phi_{hg}$$

$\Phi_{hg} = 0.7578$
If $\sigma_s = \beta^*$



# Final Focusing Estimation ($E_{kin}$ = 10 GeV/u)




***θ*=0.1** and **Δ=61cm** for B = 4T, Lmagn = 2m

$$F_{dublet} = \frac{L_{full}}{2}$$ (where L=550 cm)

$$\beta^* = 0.5m \rightarrow \beta_{max} = 61m \rightarrow \sigma_{max} \approx 0.8cm$$

$$f \approx \sqrt{F_{dublet} * L_{dublet}}$$

$$a = \frac{6\sigma_{max}}{2} = 2.3cm \ - aperture\ radius$$

$$G = \frac{1}{300}\frac{pc}{e}\frac{1}{fl}$$

**G ≈ 4.6 kG/cm**

$$J = \frac{ca^2}{8\pi}G$$

**J ≈ 9 kA**

# Dreams about lattice (for $E_{kin}$=3 GeV)

| | k, $m^{-2}$ | G, kG |
|---|---|---|
| Final Focusing: dublet | | |
| F | 0,6 | 0,82 |
| D | -0,6 | -0,82 |
| FODO | | |
| F | 0,825 | 1,1 |
| D | -0,745 | -1,0 |