About spin dynamics in solenoidal magnetic fields at SPD

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Outlook

1. Spin Transparency (ST) mode in the NICA collider
2. Spin dynamics in the SPD solenoid
3. Luminosity reduction due to displacement of the interaction point (IP) from the SPD center
4. Summary

Spin Transparency (ST) mode in the NICA collider

Two full solenoidal snakes per ring provide ST mode.

Field integral for one snake:

BL = **(2÷51)** T·m for ***protons*** (pc= **(0.5÷13.5)** GeV) ,

BL = **(6÷165)** T·m for ***deuterons*** (pc= **(0.5÷13.5)** GeV)

Spin Navigator (SN) based on weak solenoids is used to manipulate the direction of the spins.

Maximum field integral of SN solenoids:

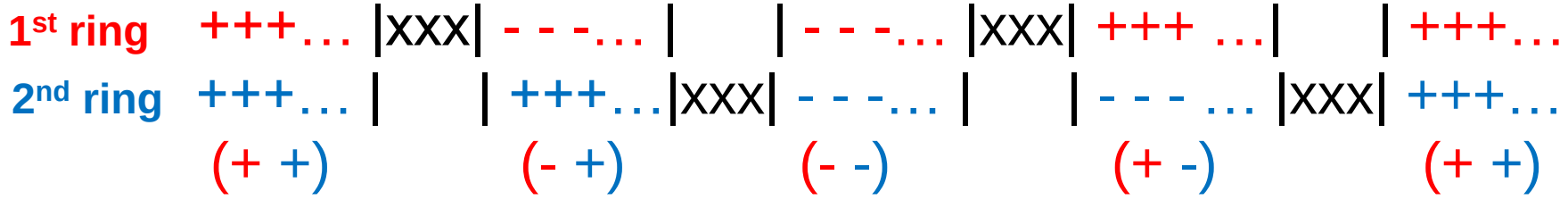
$(BL)_{SN} \leq$ **0.6** T·m for ***protons and deuterons***

The polarization control scheme allows one:

- to provide the longitudinal or the transverse polarizations at SPD/MPD (**SN**)
- to maintain polarization up to 70% during the lifetime of the beams (Snakes)
- to operate with polarized beams at any energy (maximum energy is defined by snake field integrals)
- to have the polarized beams during the asymmetric mode operation
- to have Spin-Flipper based on **SN** with reverse time less 1 sec.

Unique operation mode with spin-flippers at NICA

The new ring filling mode (all bunches with the same polarization in the both rings) and the **new operation** (sequential switching-on of the spin-flippers in the rings) [*S.S. Shimanskiy*]:



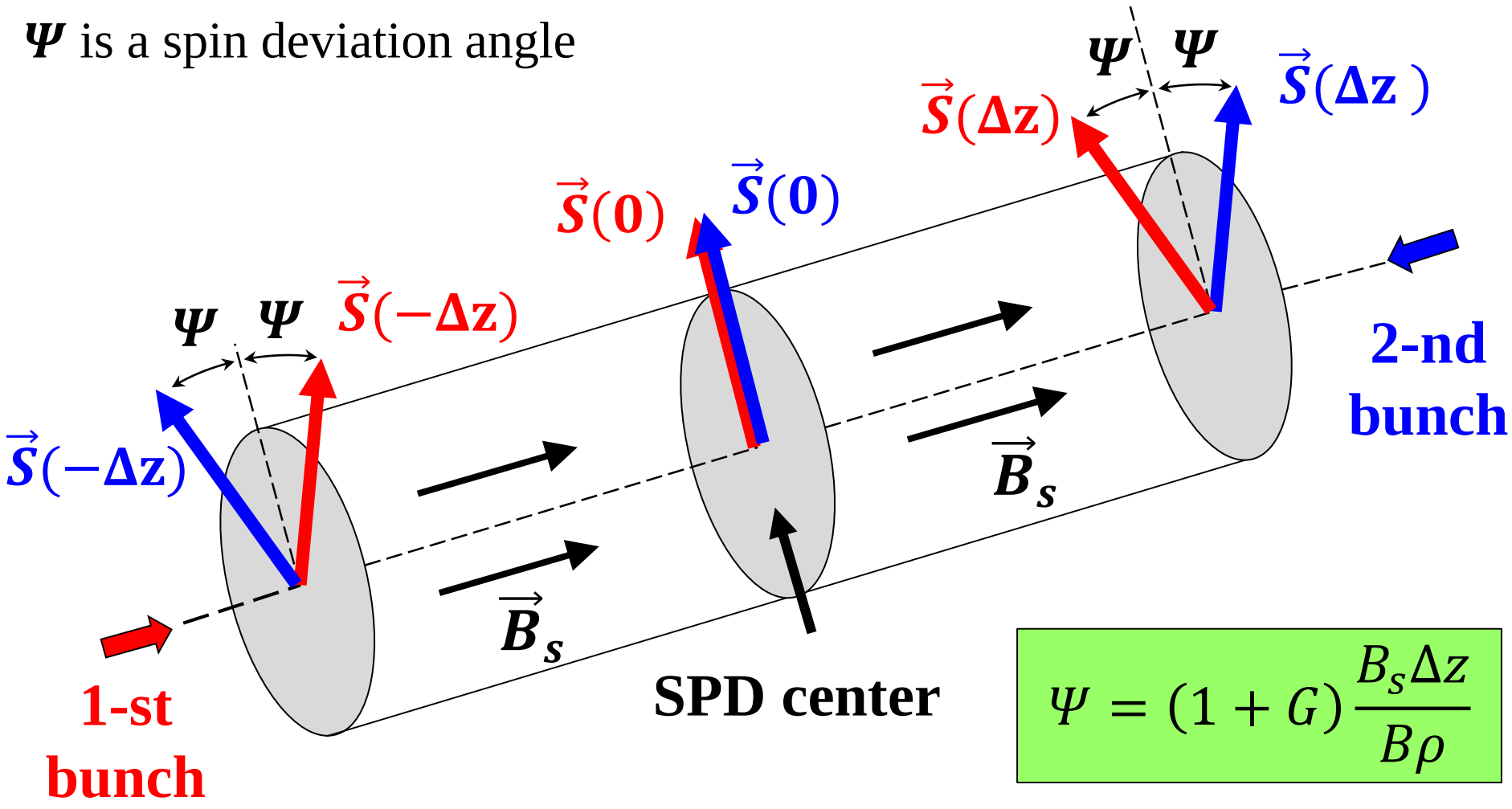
|xxx| - spin-flipper switching-on, no data taking
| | - spin-flipper switching-off, no data taking

There are no problem with measurement of the bunch 2 bunch luminosity and ***no problem to reverse the polarization at the ion source during ring fillings***!

Spin dynamics in the SPD solenoid field

Δz is a displacement of IP from the SPD center

Ψ is a spin deviation angle



$$\Psi = (1 + G)\frac{B_s \Delta z}{B\rho}$$

$B\rho$ is a magnetic rigidity

Spin deviation angle (Ψ) due to the displacement (Δz) of IP from the SPD center. Deuterons

E, GeV/u	pc, GeV	$(BL)_{sol}$, T · m	Δz, cm	Ψ, grad
1.5	2.34	30	50	3.1
			100	6.3
			30 (half bunch)	1.9
3.0	5.70	70	50	1.3
			100	2.6
			30	0.8
6.8	13.5	165	50	0.6
			100	1.2
			30	0.4

The SPD solenoid field is of **1 T for all energies**

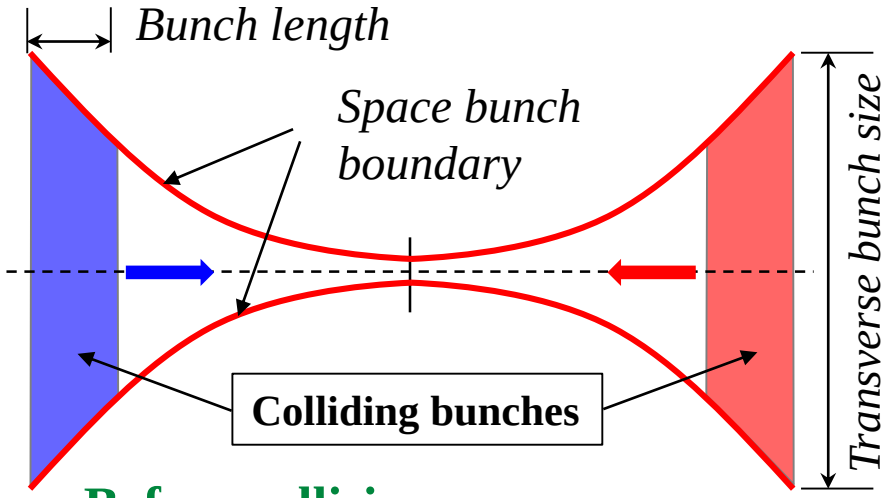
$(BL)_{sol}$ is longitudinal field integral per one snake

Spin deviation angle (Ψ) due to the displacement (Δz) of IP from the SPD center. Protons

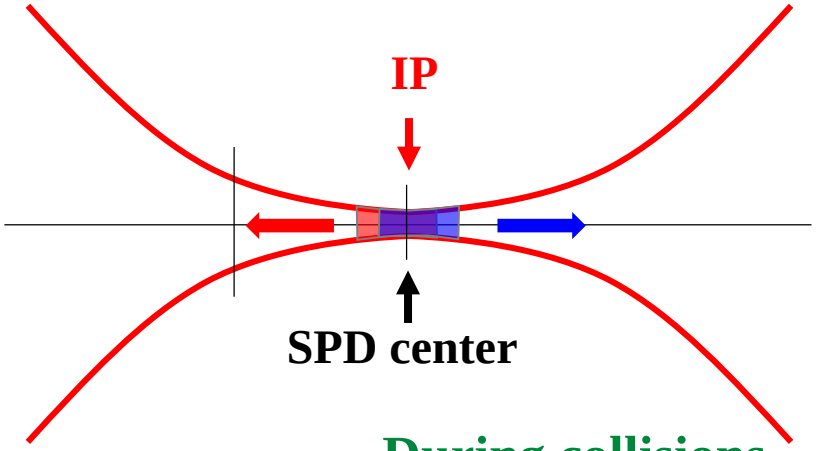
E, GeV	pc, GeV	$(BL)_{sol}$, T · m	Δz, cm	Ψ, grad
1.5	1.2	4.4	50	20.5
			100	41
			30 (half bunch)	12.3
3.0	2.9	11	50	8.4
			100	16.8
			30	5.1
5.0	4.9	18	50	4.9
			100	9.8
			30	2.9
13.53	13.5	51	50	1.8
			100	3.6
			30	1.1

The SPD solenoid field is of **1 T for all energies**

Luminosity reduction due to displacement (Δz_c) of IP from the SPD center

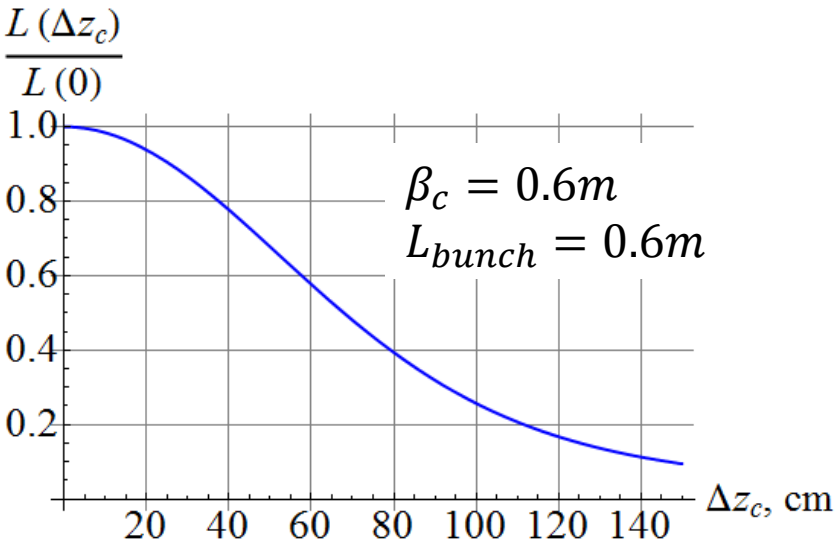


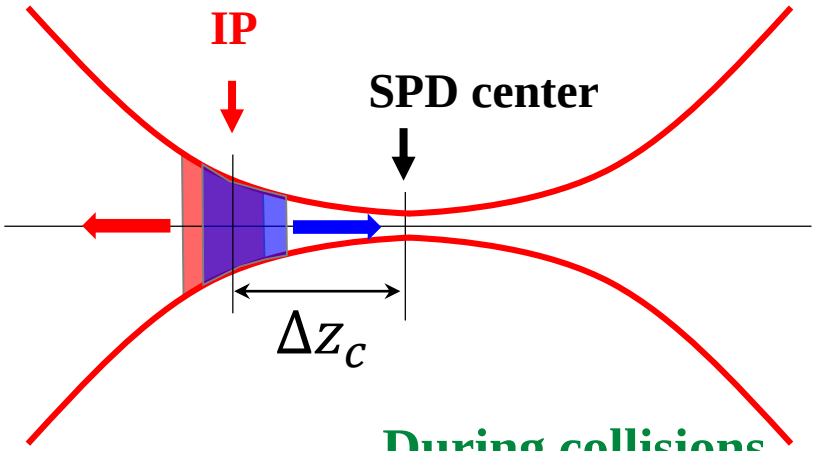
Before collisions



During collisions

IP is displaced from the SPD center





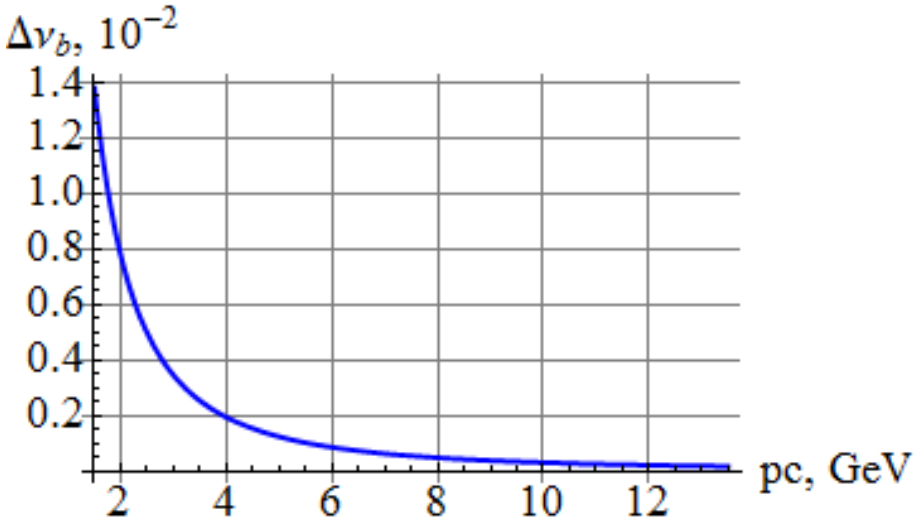
During collisions

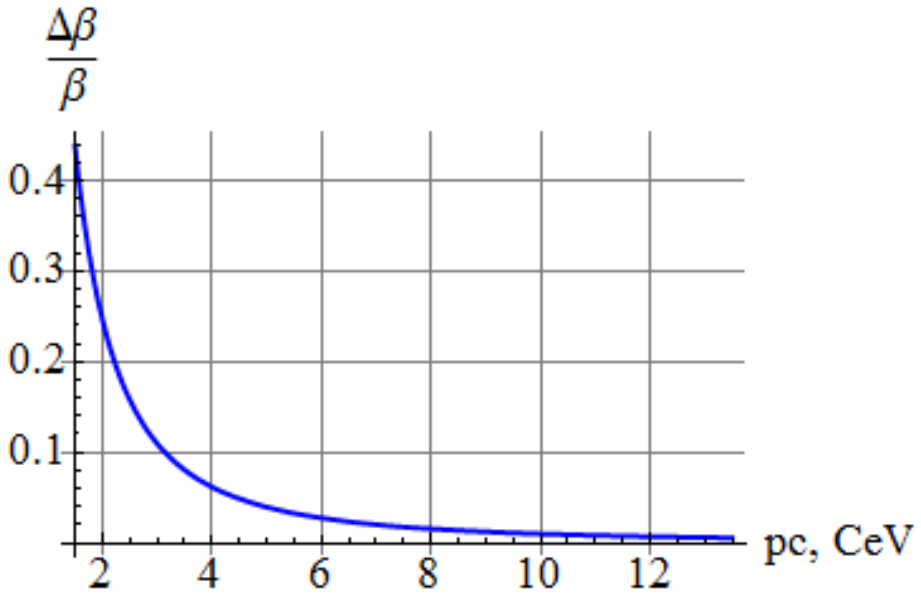
Summary

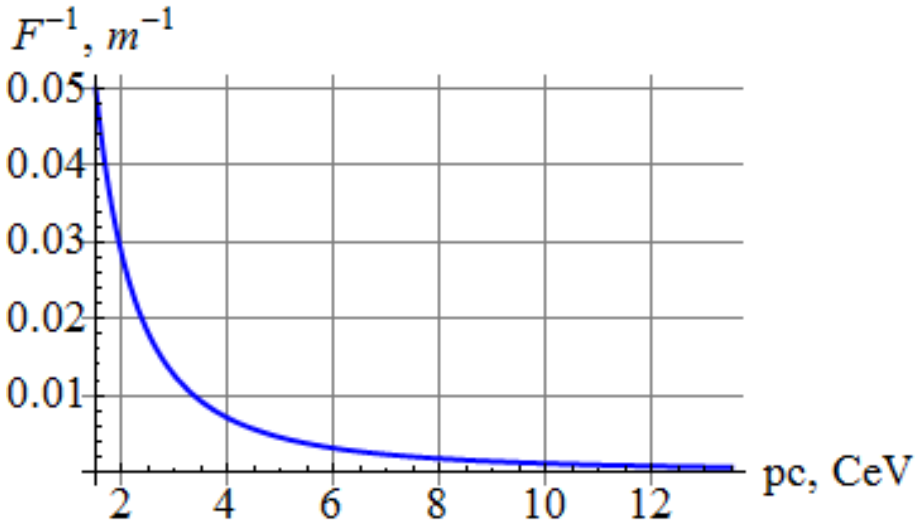
- For transverse spin orientations, the angle between the spin directions of the colliding bunches will increase with the displacement of IP from the SPD center.
- In the existing optics of the NICA collider with a bunch length of 0.6 m, luminosity decreased about 5 times when the IP displacement from the SPD center is 1 meter.
- Development of a system for stabilization of the IP at the SPD center is required.

Thank you for your attention!

Orbital parameters







Spin deviation from the vertical due to the displacement of collisions from the SPD center. Deuterons

E, GeV	pc, GeV	$B\rho$, T ·m	F_{sol}, m	z_0, m	Ψ, grad
1.5	2.34	7.8	49	0.5	3.1
				1.0	6.3
				0.3 (half bunch)	1.9
3.0	5.70	19.0	289	0.5	1.3
				1.0	2.6
				0.3	0.8
6.0	11.85	39.5	1248	0.5	0.6
				1.0	1.2
				0.3	0.4

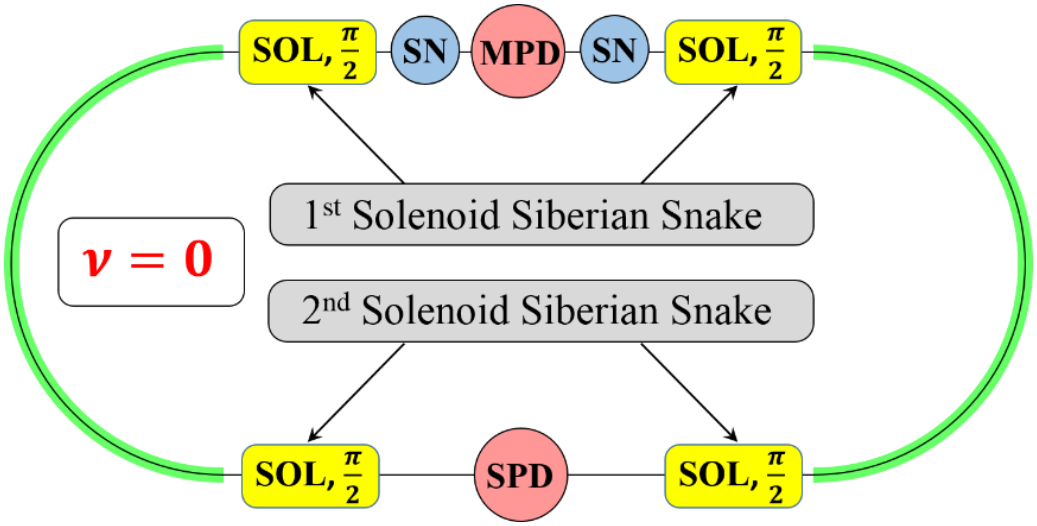
F_{sol} is a focus of the solenoidal lens

The SPD solenoid field is of 1 T for all momenta

Spin deviation from the vertical due to the displacement of collisions from the SPD center. Protons

E, GeV	pc, GeV	$B\rho$, T ·m	F_{sol}, m	z_0, m	Ψ, grad
1.5	1.17	3.9	12	0.5	20.5
				1.0	41
				0.3 (half bunch)	12.3
3.0	2.85	9.5	72	0.5	8.4
				1.0	16.8
				0.3	5.1
5.0	4.91	16.4	215	0.5	4.9
				1.0	9.8
				0.3	2.9
13.5	13.47	44.9	1612	0.5	1.8
				1.0	3.6
				0.3	1.1

Spin Transparency (ST) mode in the NICA collider



SOL, $\frac{\pi}{2}$ Solenoids for providing ST mode:

BL = 1÷25 T·m (***protons***),

BL = 3÷80 T·m (***deuterons***)

SN Spin Navigator based on weak solenoids

The polarization control scheme allows one:

- to provide the longitudinal or the transverse polarizations at SPD/MPD (SN)
- to maintain polarization up to 70% during the lifetime of the beams (Snakes)
- to operate with polarized beams at any energy (maximum energy is defined by snake field integrals)
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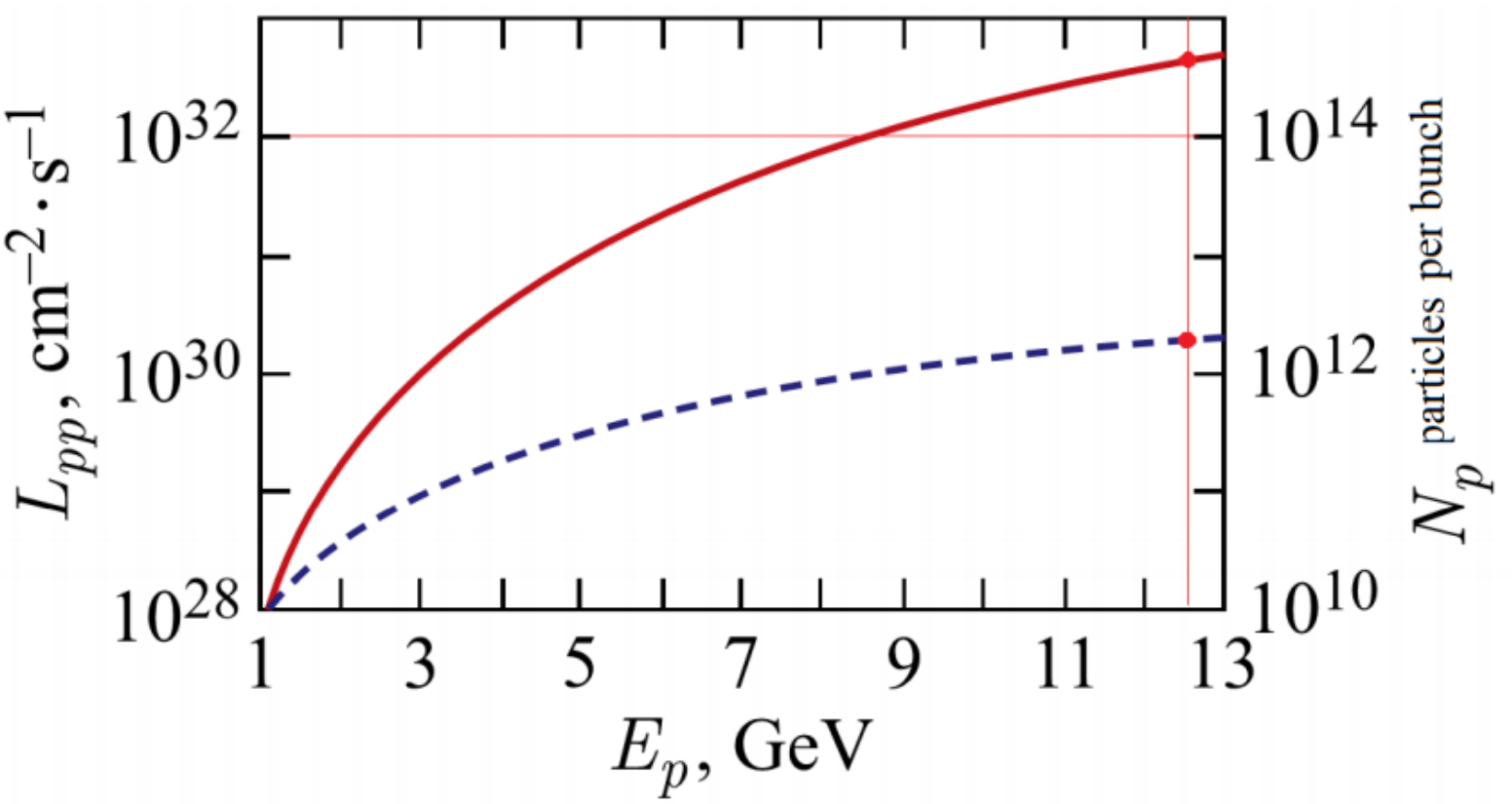
Luminosity



Normalized dependence of the luminosity L_{pp} (the red curve and the left scale) and the beam intensity N_p (the blue curve and the right scale) on the proton kinetic energy in the p-p-collision