On using **leading hadron** and **clusters of charged particles** to reconstruct **parton** kinematics

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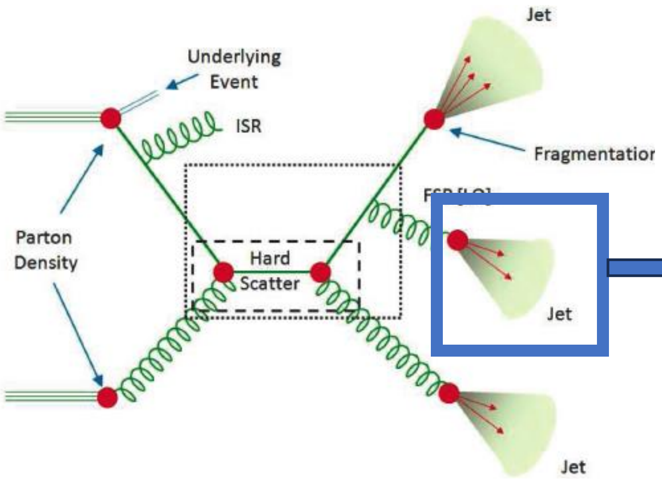
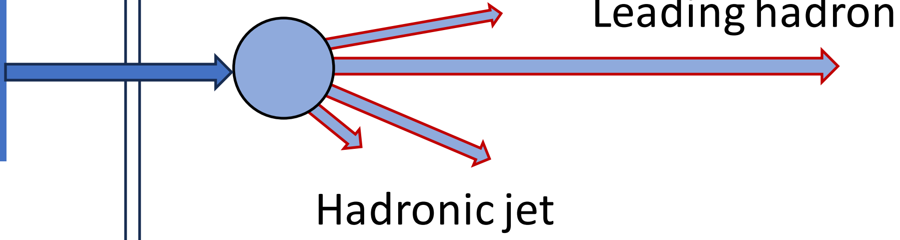
From the final state to the hard process...



$$\sigma^{pp\to hX} \propto \hat{\sigma} \otimes PDF \otimes PDF$$

At large distances, the interaction is divided into **hard** (calculated perturbatively) and **soft** (obtained from the experiment) terms.



Information about parton can be obtained by analyzing the hadronic final state with:

- selecting the **leading hadron** (COMPASS, E609);
- reconstructing **hadronic jets** (CMS, ATLAS).

Purposes

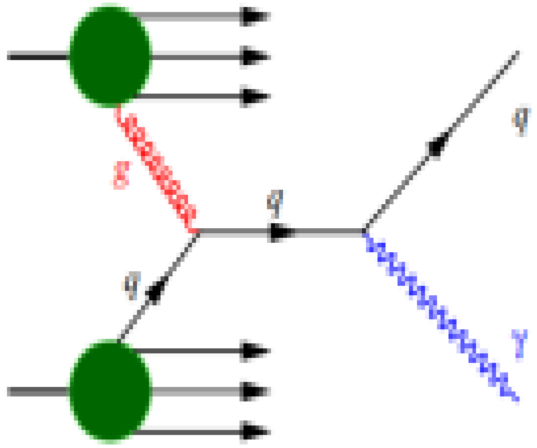
1. For **proton-proton collisions** at the COM frame energy 27 GeV (the main energy of pp-interactions SPD@NICA) in events with large transverse momentum transfer (pT > 3 GeV/c), to study **the possibility of reconstruction** and **the quality of reconstruction** of the **kinematics** of a hard subprocess using:

- charged jets;
- leading hadrons.

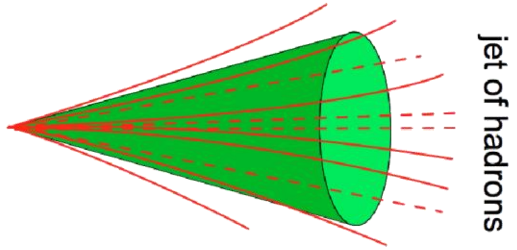
2. Compare two approaches in the energy range from 10 to 200 GeV.

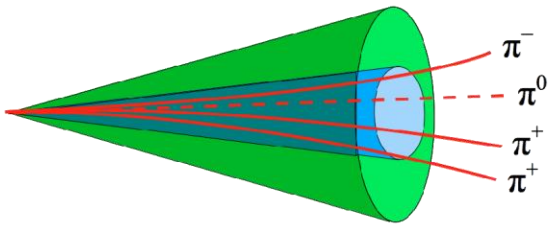
Methods and main points

- The **parton kinematics reconstruction** was studied **by using** gamma+1jet case (gluon-Compton scattering subprocess)
- The **PYTHIA 8** event generator was used to generate pp interactions
- The ***kT*-algorithm** of hadron sequential algorithms was used as the main algorithm for jet selection
- To obtain the main results, **the pp collisions at energy 27 GeV was used**, and for comparison, an energy range of 10 – 200 GeV was used



$$d_{ij} = R_{ij}^2 \min(k_{T,i}^2, k_{T,j}^2)$$

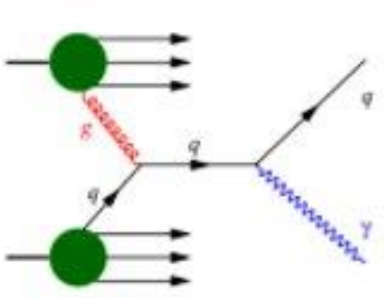




Event selection

Event simulation setup:

- $qg \rightarrow \gamma q$
- $\sqrt{s} = 27$ GeV
- $p_T^{\gamma} > 3$ GeV$/c$
- $p_T^{q} > 3$ GeV$/c$



- Initial state radiation
- Final state radiation
- Primordial partonic kT

Jet requirements:

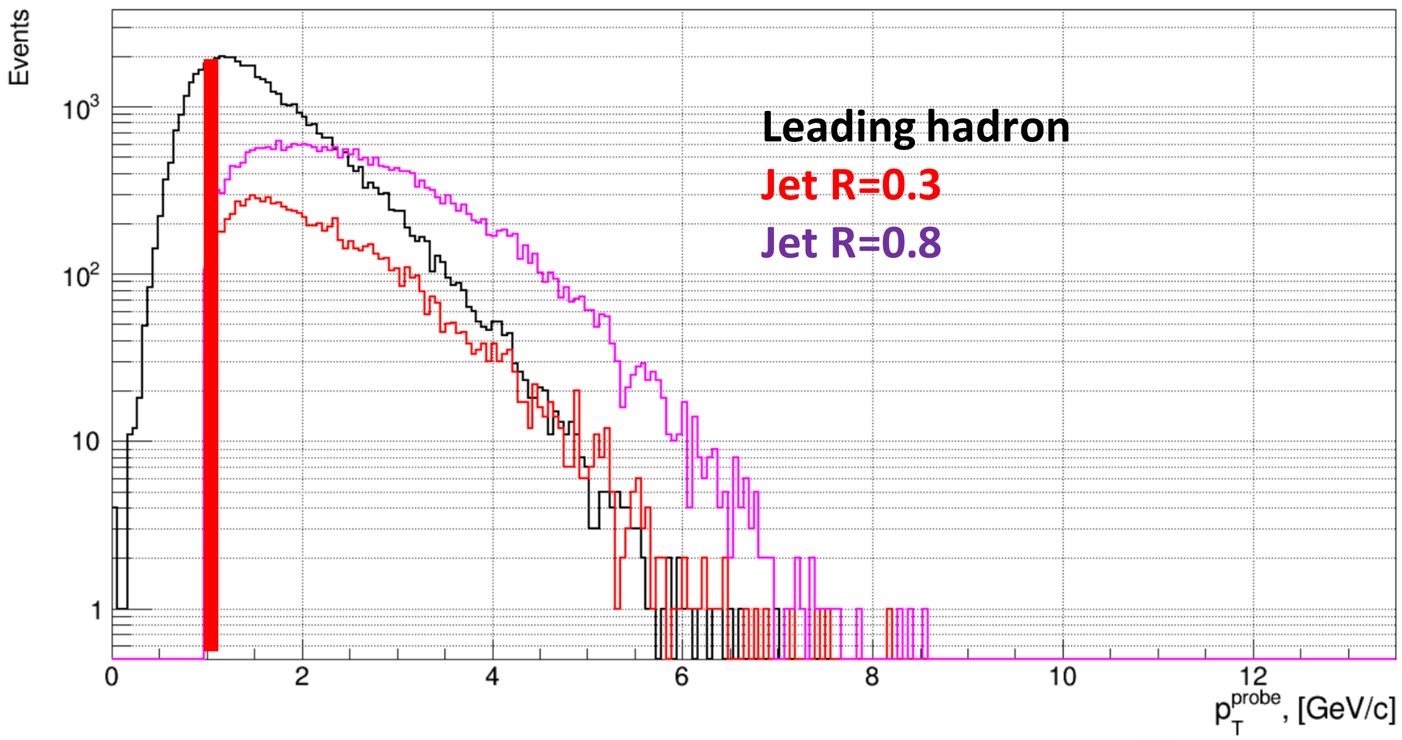
- charged particles only
- *kT*-algorithm

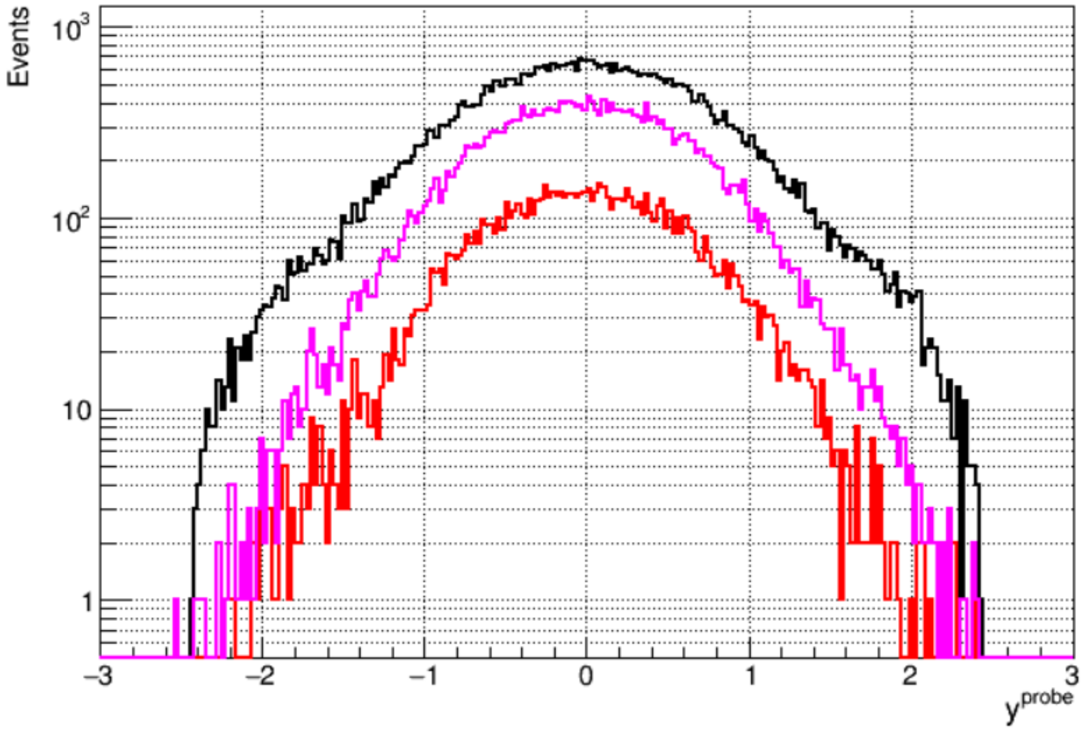
- $p_T^{jet} > 1$ GeV$/c$
- $p_T^{hadr} > 0.25$ GeV$/c$
- $N_{ch}^{jet} \geq 2$ hadrons
- $R = \sqrt{\Delta\phi^2 + \Delta\eta^2} = 0.3$ (narrow jet)
- $R = \sqrt{\Delta\phi^2 + \Delta\eta^2} = 0.8$ (wide jet)
- $|\eta_{hadr}| < 2.44$ (acceptance)

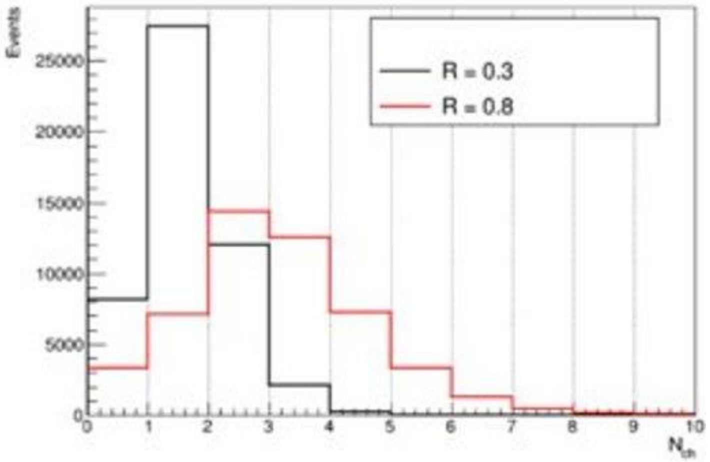
Leading hadron requirements:

$p_T > 1$ GeV$/c$
$|\eta| < 2.44$

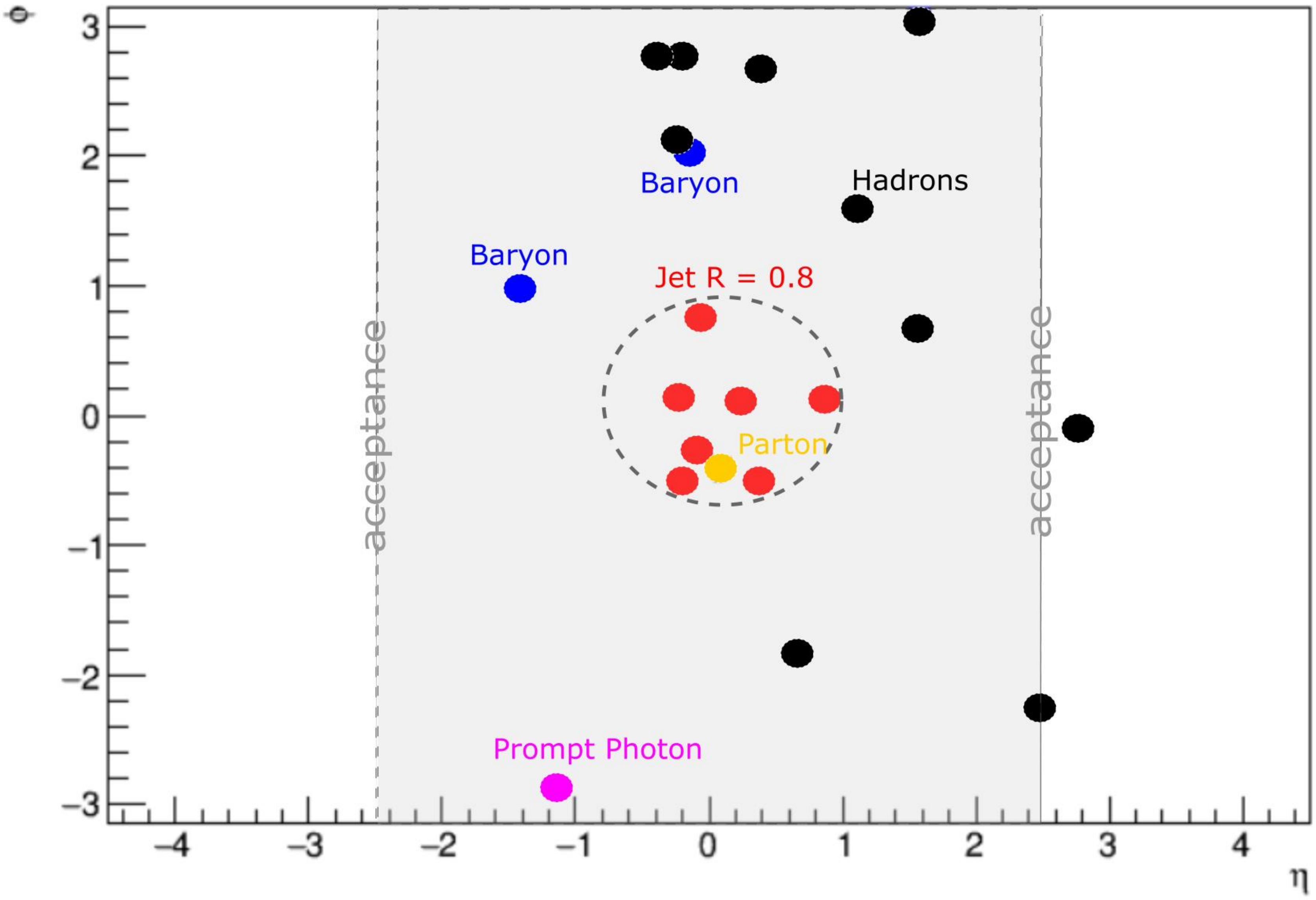
Main characteristics







Event example

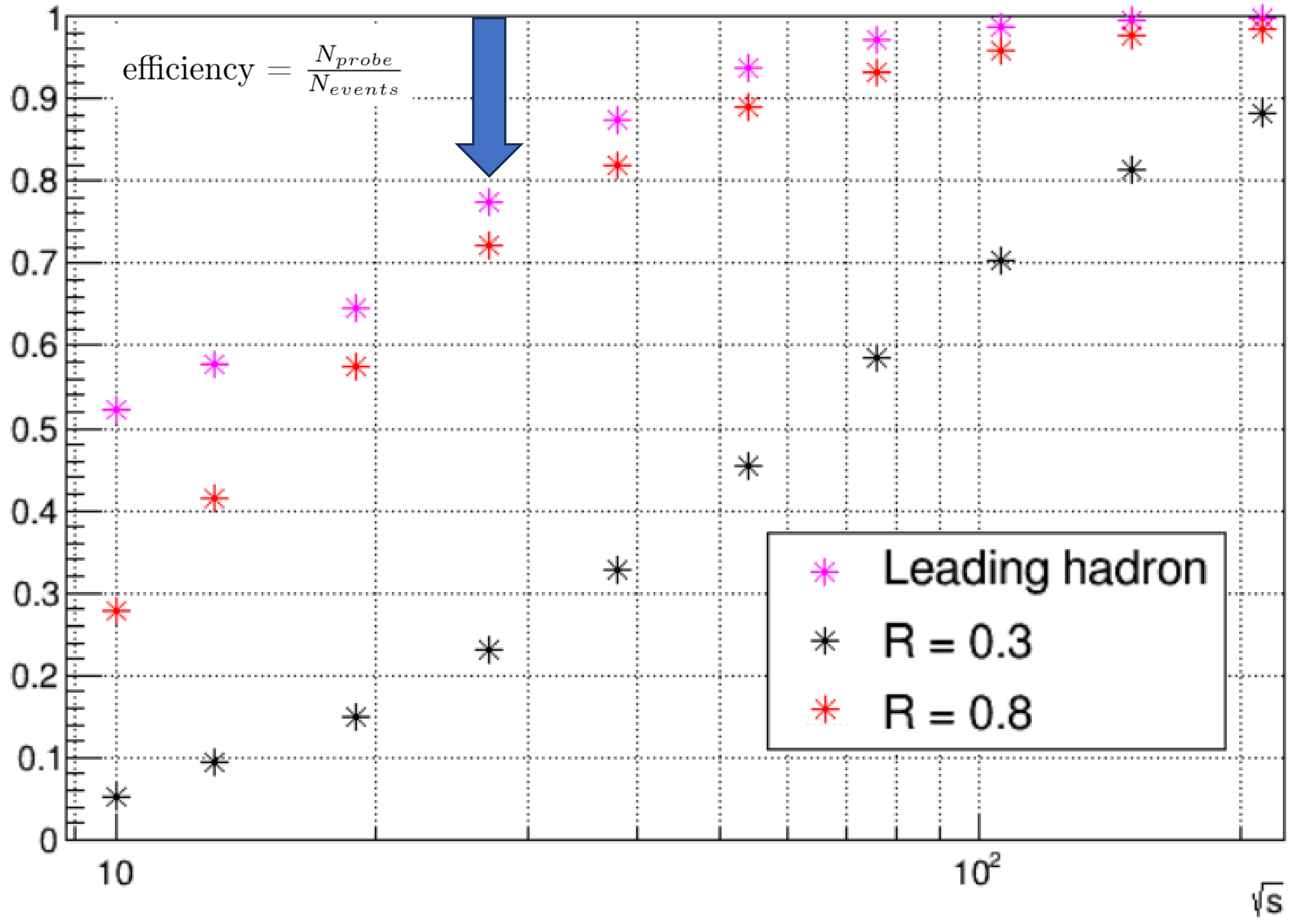


Comparison criteria

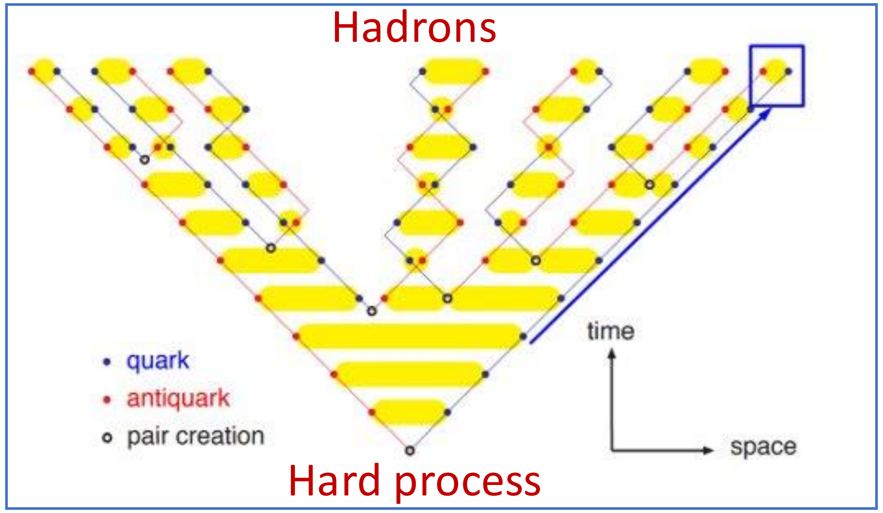
- Efficiency of jet reconstruction and selection of the leading hadron
- The probability of the correct association of the jet and the leading hadron with the parton in a hard process
- Accuracy of parton angle reconstruction
- Accuracy of parton energy reconstruction

Efficiency of jet reconstruction and selection of the leading hadron

- the highest probability is to select the leading hadron *(in events at an energy of 27 GeV)*;
- at low energies, it is much more efficient to use leading hadrons
- at high energies, the efficiency of the jets is about 100%

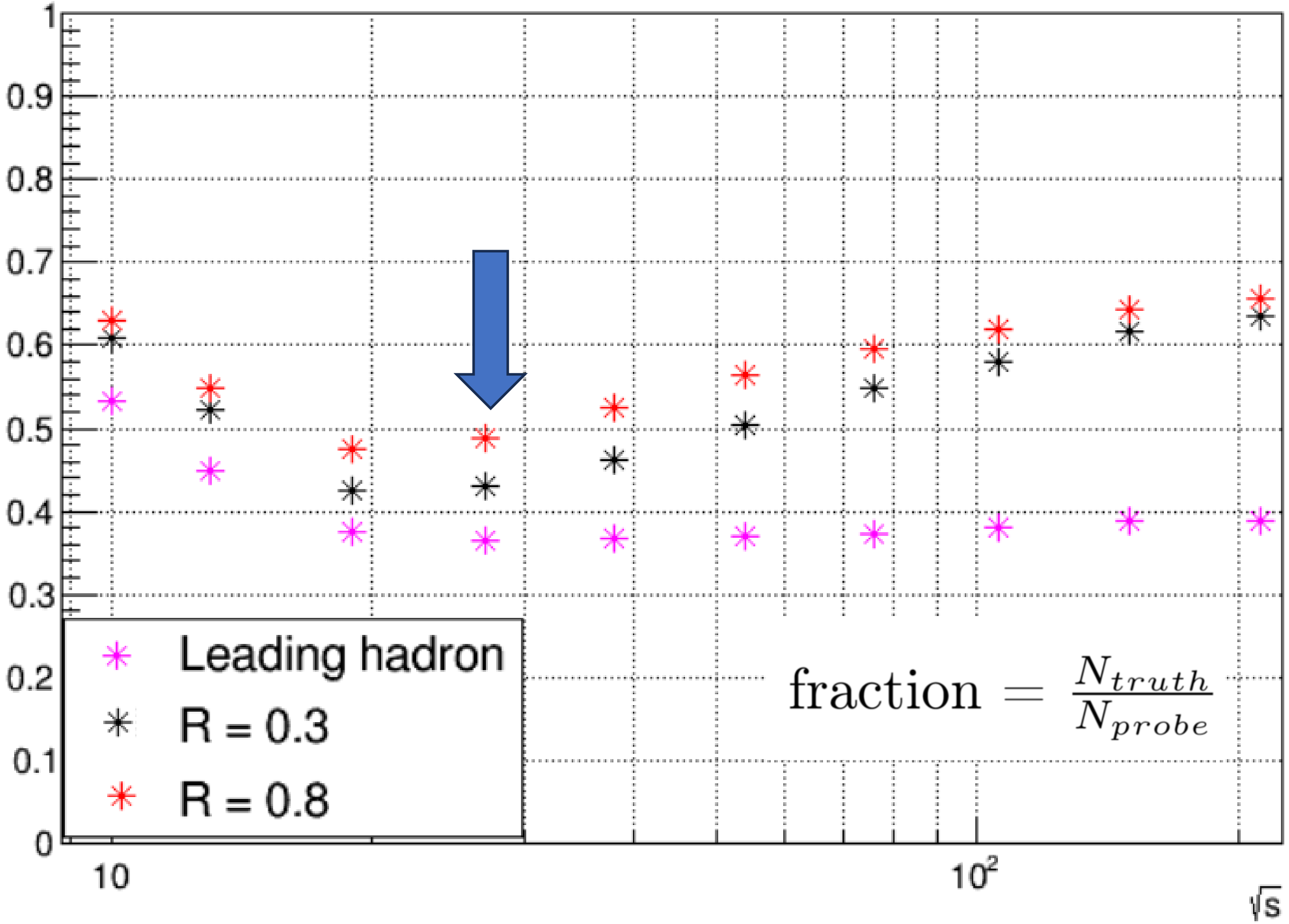


The probability of the correct association of the jet and the leading hadron with the parton in a hard process

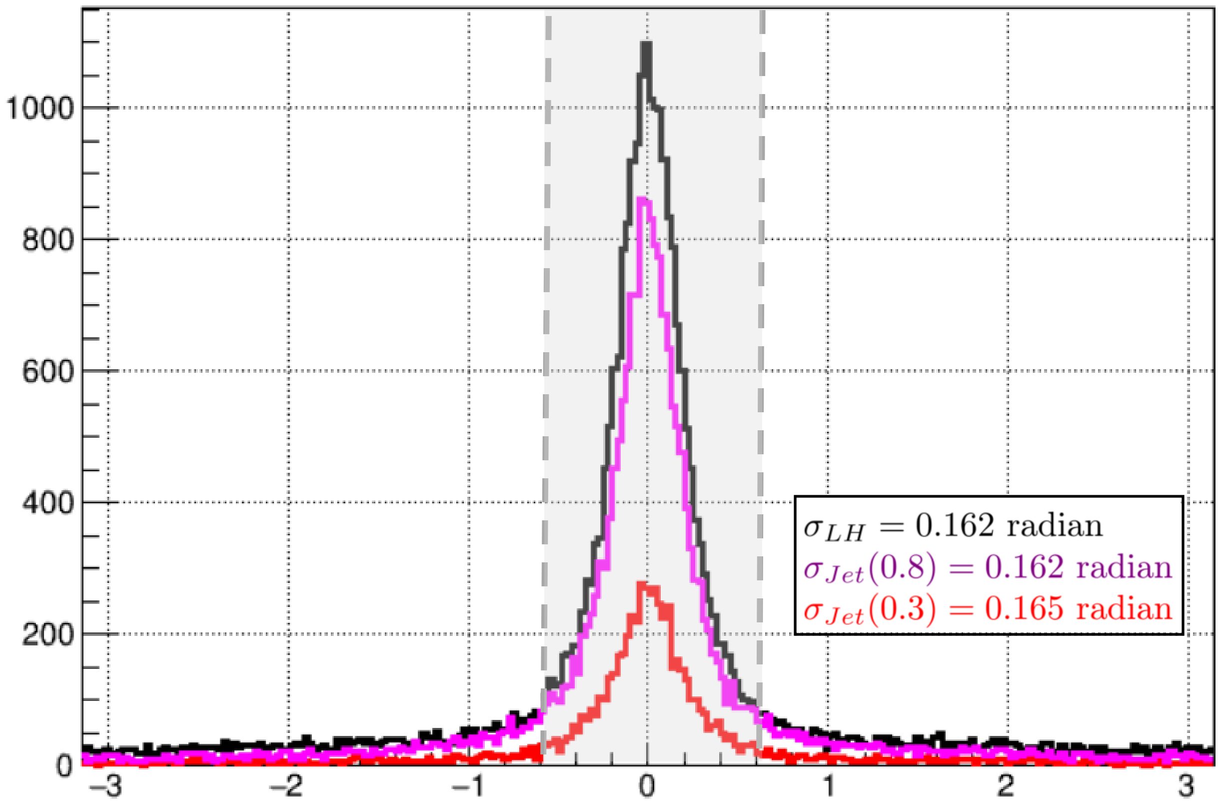


The process of a quark produced in a hard process tracking from parton level to the hadron level based on generator information.

- at low energies, the probability that the leading hadron contains a quark of a hard process is comparable to jets;
- at high energies, the leading hadron is significantly less associated with a quark

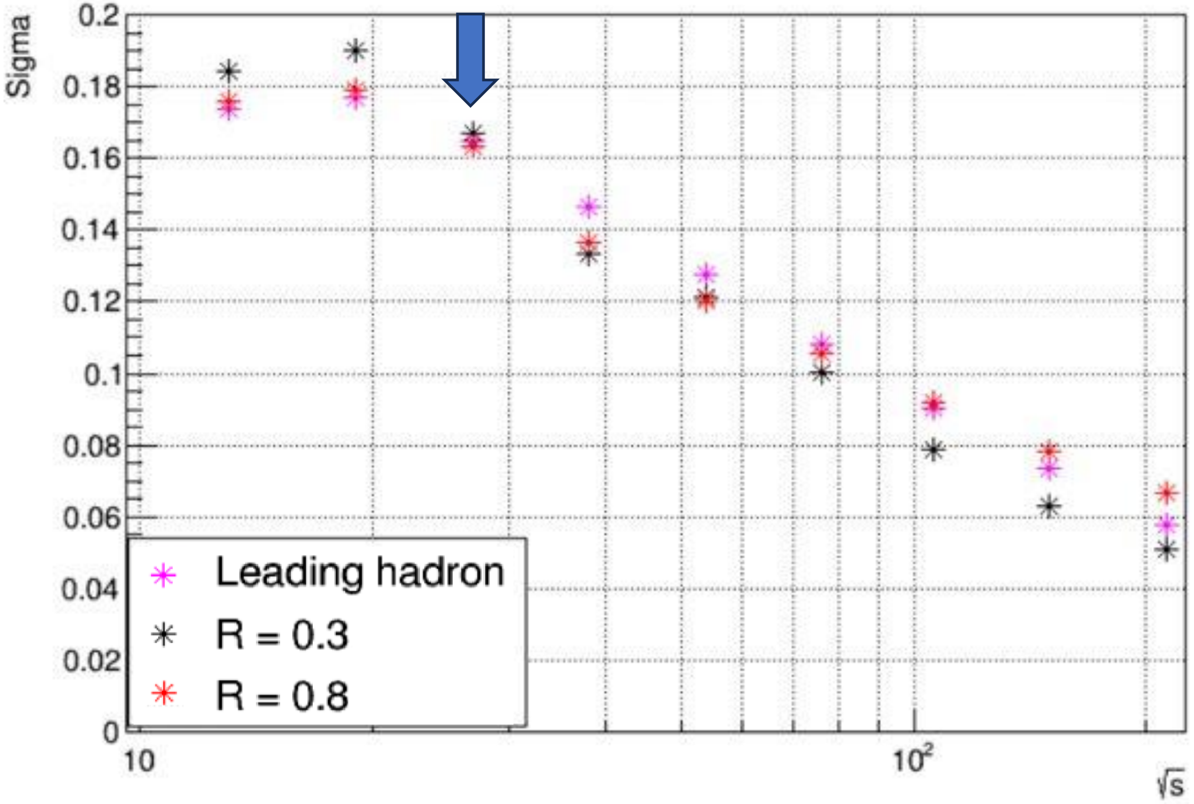


Accuracy of parton angle reconstruction



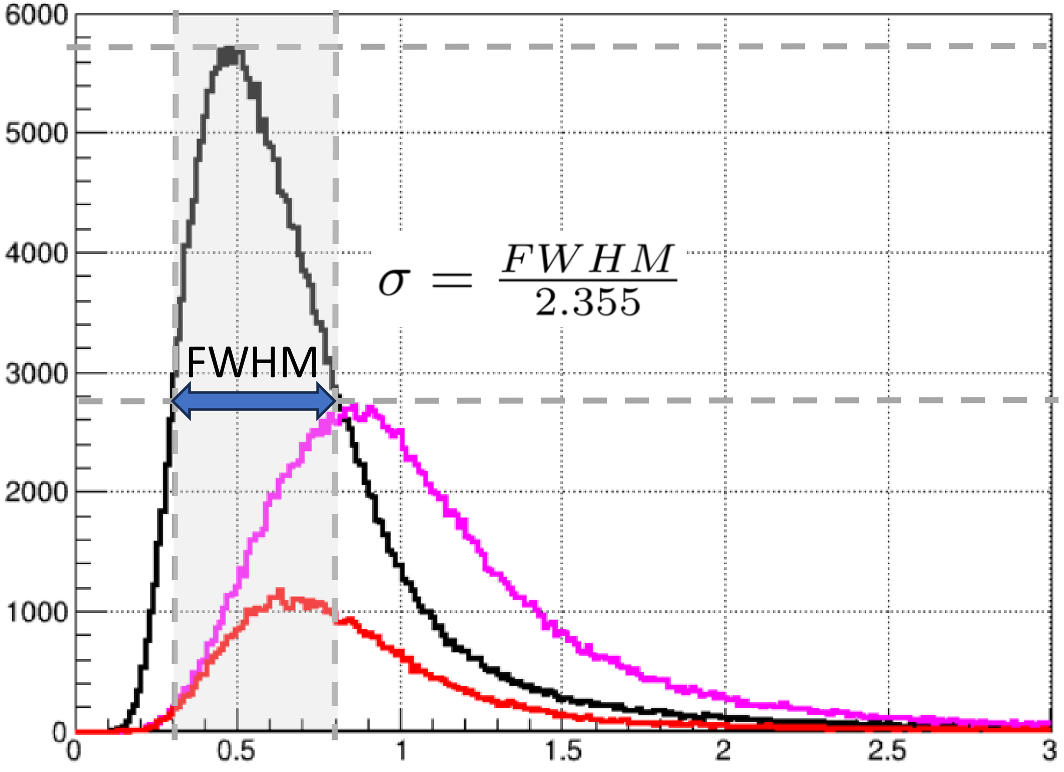
The angle (in the azimuthal plane) between the direction of the parton momentum and:

- jet axis;
- the direction of the momentum of the leading hadron.

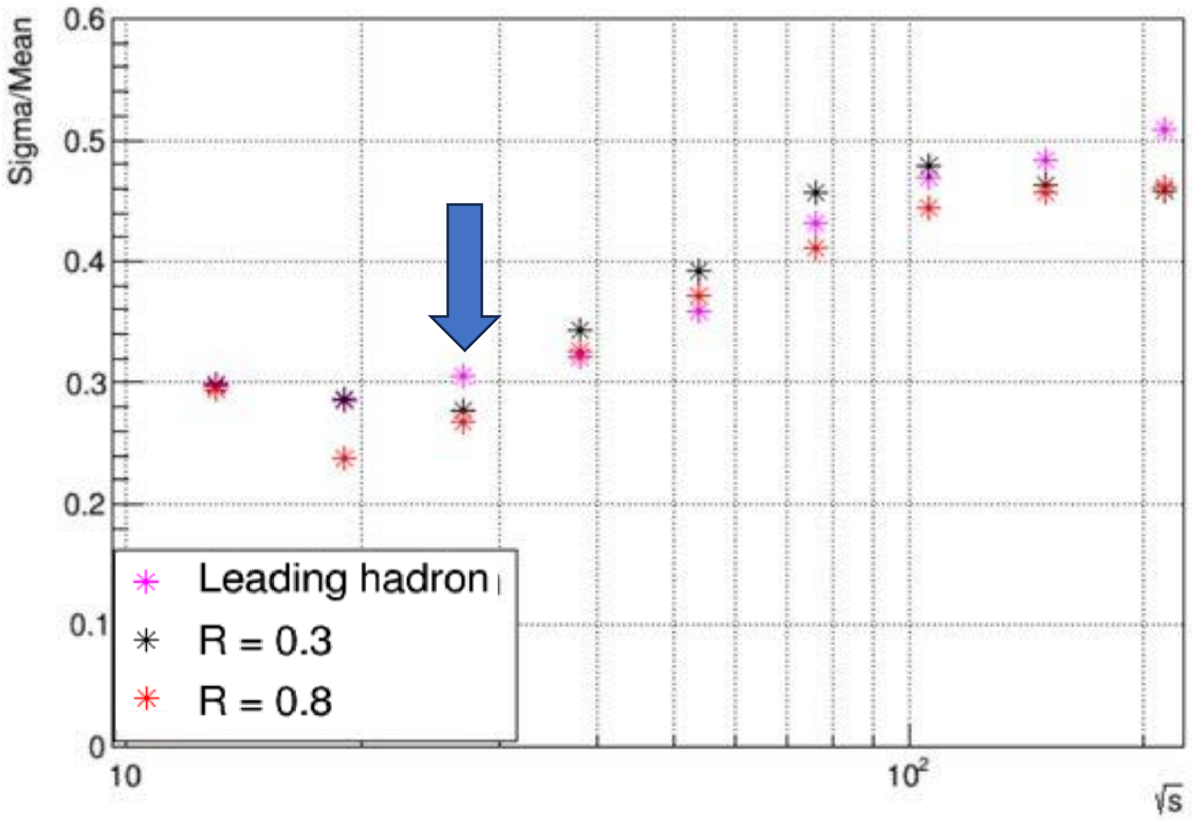


Uncertainty of the parton momentum direction reconstruction for leading hadrons and jets

Accuracy of parton energy reconstruction



The ratio of parton energy and:
- jet energies ("narrow cone" and "wide cone");
- energy of the leading hadron.



Relative uncertainty of the reconstruction of the parton energy for the leading hadron and jet.

Conclusions

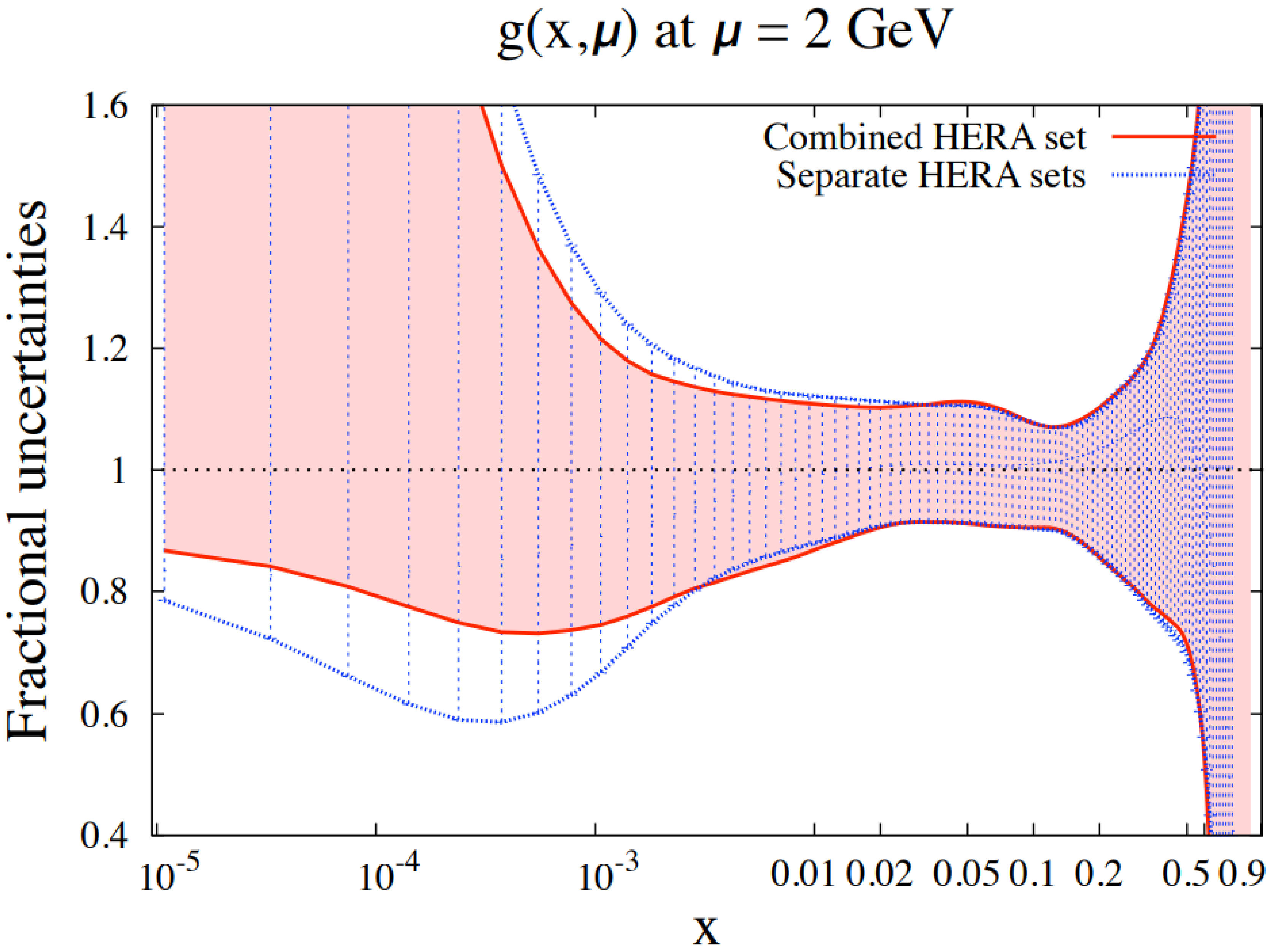
For proton-proton collisions with an energy in the center of mass system 27 GeV in events with large transverse momentum transfer ($pT > 3$ GeV/c) the efficiency and accuracy of reconstruction the kinematics of a hard subprocess are studied using:

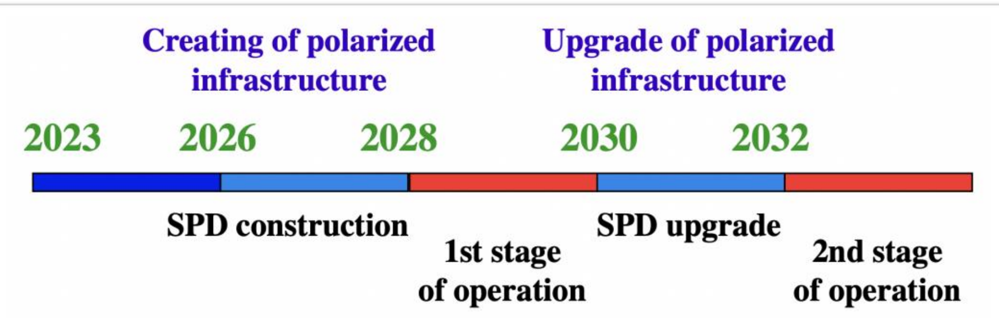
- charged jets
- leading hadrons.

It is shown that in the SPD experiment at a proton collision at 27 GeV:

- it is possible to reconstruct the kinematics of hard processes using only charged particles
- the accuracy of reconstruction the azimuthal angle of direction of the parton is 0.15 radians and the parton energy is about 30%
- using of leading hadrons and jets gives a similar accuracy in reconstructed angles and energies; at the same time, the reconstructed efficiency for leading hadrons is higher (by 6% for $R = 0.8$ and by 50% for $R = 0.3$).

Thank you for your attention


g(x,μ) at μ = 2 GeV
Combined HERA set
Separate HERA sets
Fractional uncertainties
1.6
1.4
1.2
1
0.8
0.6
0.4
10^-5
10^-4
10^-3
0.01
0.02
0.05
0.1
0.2
0.5
0.9
x



Subsystem	Stage	Technology	Materials & components	Electronics
MM-based Central Tracker	1			
SI Vertex Detector				
DSSD option	2			
MAPS option	2			
Straw Tracker	1,2			
ToF	1*,2			
Aerogel	2	New group		
ECAL	1*,2			
Muon (Range) System	1,2			
BBC	1,2			
ZDC	1,2			
Superconducting Magnet	1,2			
DAQ	1,2			
Computing	1,2			
DCS	1,2			
Support & moving system	1,2			

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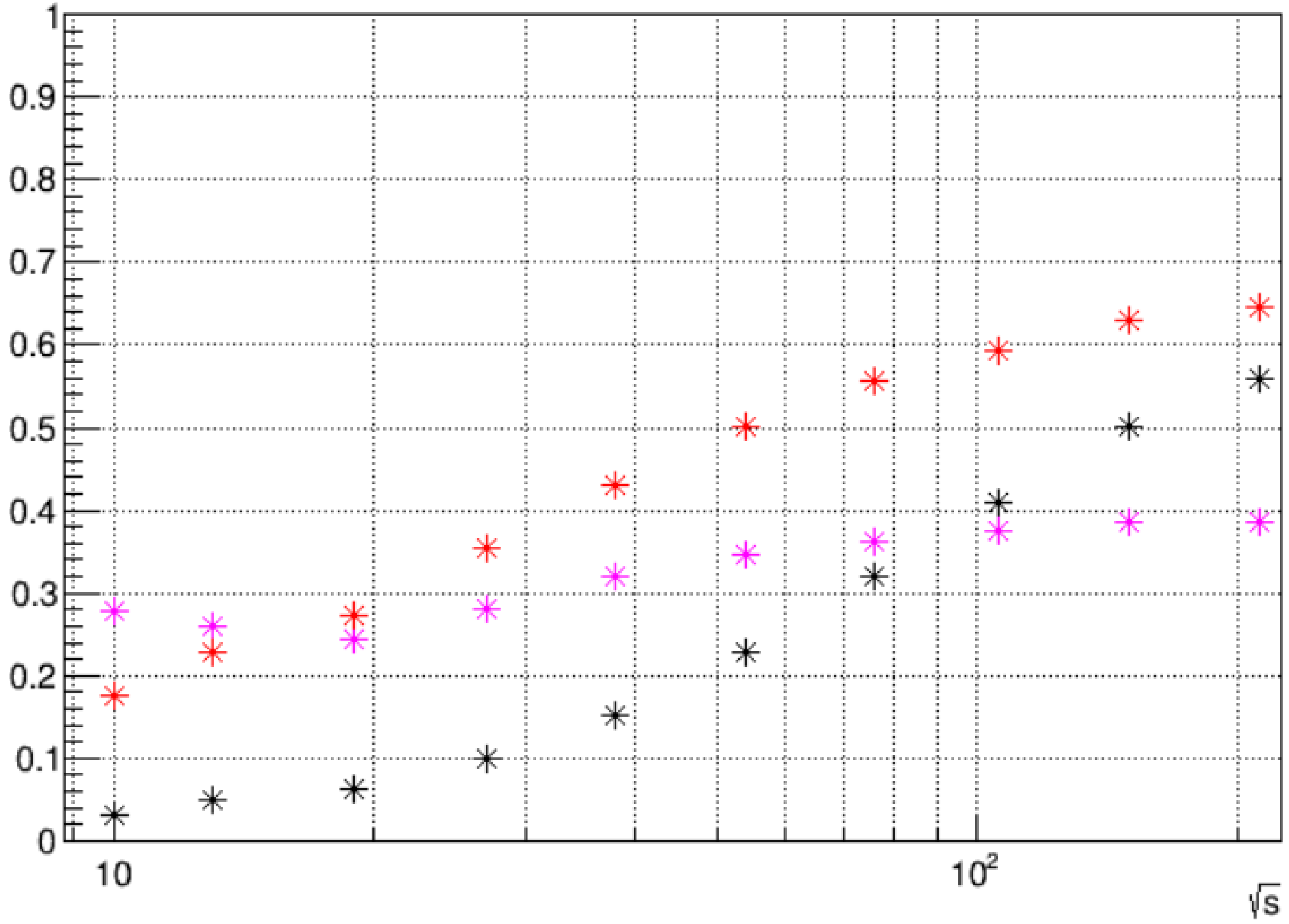
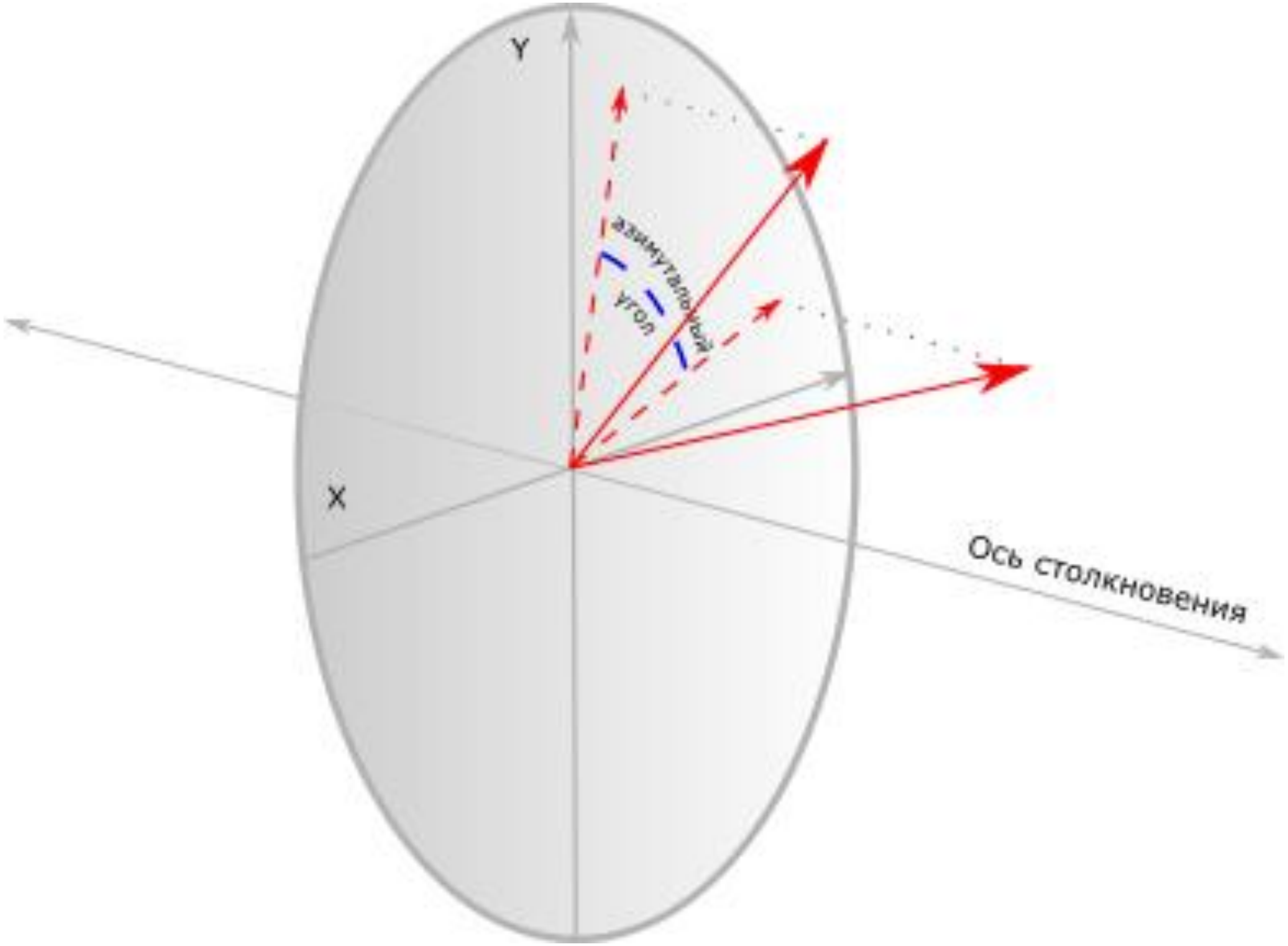
Subsystem	Stage	Main task	Active element	Weight, t	Power, kW	Channels, 10^3
Range System (RS)	I+II	μ-ID	mini drift tubes $Ar:CO_2 70:30$	927	47	130.2
Electromagnetic Calorimeter (ECal)	II	γ detection	Pb/scint.-shashlyk	68	8	23
Time-of-Flight system (TOF)	II	PID	RPC chambers $C_2H_2F_4:C_4H_{10}:SF_6$ 90:5:5	4	4	8.8
Aerogel	II	PID	aerogel	0.1	0.5	0.3
Straw Tracker (ST)	I+II	tracking, PID	straw tubes $Ar:CO_2$ 70:30	0.2	4	30.5
Silicon Vertex Detector (SVD)						
– MAPS	II	vertex, tracking	Si pixels	< 0.1	22	12
– DSSD	II	vertex, tracking	Si strips	< 0.1	2	107.5
Micromegas-based Central Tracker (MCT)	I	tracking	gas chambers $Ar:C_4H_{10}$, 90:10	< 0.1	1	25.6
Beam-Beam Counter (BBC)						
– inner	I+II	polarimetry	MCP	$\ll 0.1$	$\ll 1$	0.1
– outer	I+II	polarimetry, timing	scint.	0.1	0.5	0.3
Zero Degree Calorimeter (ZDC)	I+II	n,γ detection	W/scint.	0.3	2	2
Magnet	I+II			20	23	
Support and transportation system	I+II			80.3		
Top platform (loaded)	I+II			40		
Side platform (loaded)	I+II			100		

https://indico.jinr.ru/event/3750/contributions/20851/attachments/15995/27440/5.%20SPD_NICA_TDR_PAC_JUNE_0.pdf

Эффективность



Азимутальный угол



Азимутальный угол между двумя векторами

Pythia settings

prompt photons

PromptPhoton:qg2qgamma = on
PromptPhoton:qqbar2ggamma = on
PDF:pSet = 15

BeamRemnants:primordialKThard = 1.2

PhaseSpace:mHatMin = 0.
PhaseSpace:pTHatMin = 0.

Random:setSeed = on
Random:seed = 0

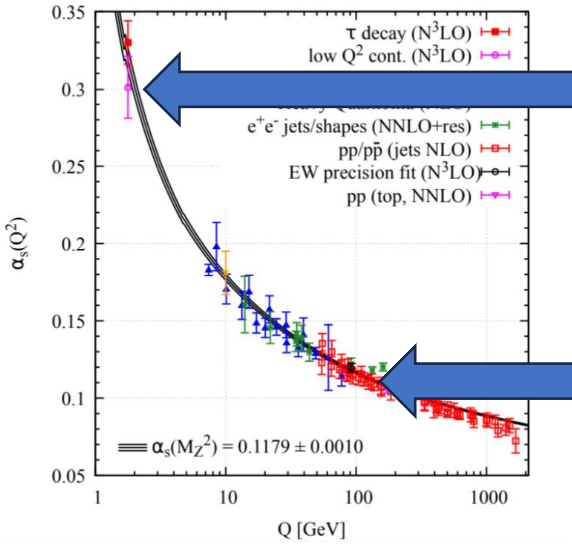
minimum-bias

SoftQCD:all = on
PDF:pSet = 15
BeamRemnants:primordialKT = on
BeamRemnants:primordialKTsoft = 1.1
BeamRemnants:primordialKThard = 1.8
BeamRemnants:halfScaleForKT = 2.0
BeamRemnants:halfMassForKT = 4.0
BeamRemnants:reducedKTatHighY = 0.7
BeamRemnants:primordialKTremnant = 0.4
PhaseSpace:pTHatMinDiverge = 0.5

PhaseSpace:mHatMin = 0.
PhaseSpace:pTHatMin = 0.
Random:setSeed = on

Rymbekova_2020-03.pdf (spd.jinr.ru)

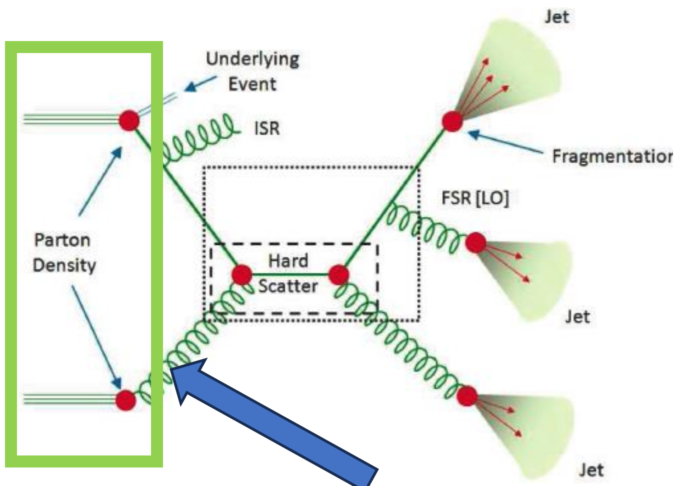
Квантовая хромодинамика



Непертурбативная КХД при малых энергиях (< 1 ГэВ)

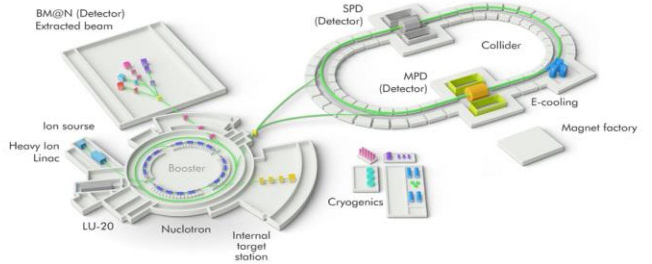
Пертурбативная КХД при больших (>> 1 ГэВ) энергиях

Квантовая хромодинамика -- истинная теория взаимодействия кварков и глюонов.



$$\sigma^{pp\to hX} \propto \hat{\sigma} \otimes PDF \otimes PDF$$

На больших расстояниях взаимодействие делится на жесткую (вычисляемую пертурбативно) и мягкую (получаемую из эксперимента) части.



В настоящее время в ОИЯИ на базе ускорительного комплекса NICA планируется эксперимент SPD для изучения поляризованной и неполяризованной **глюонной структуры протонов** и дейтронов на поляризованных пучках **pp (27 ГэВ)**