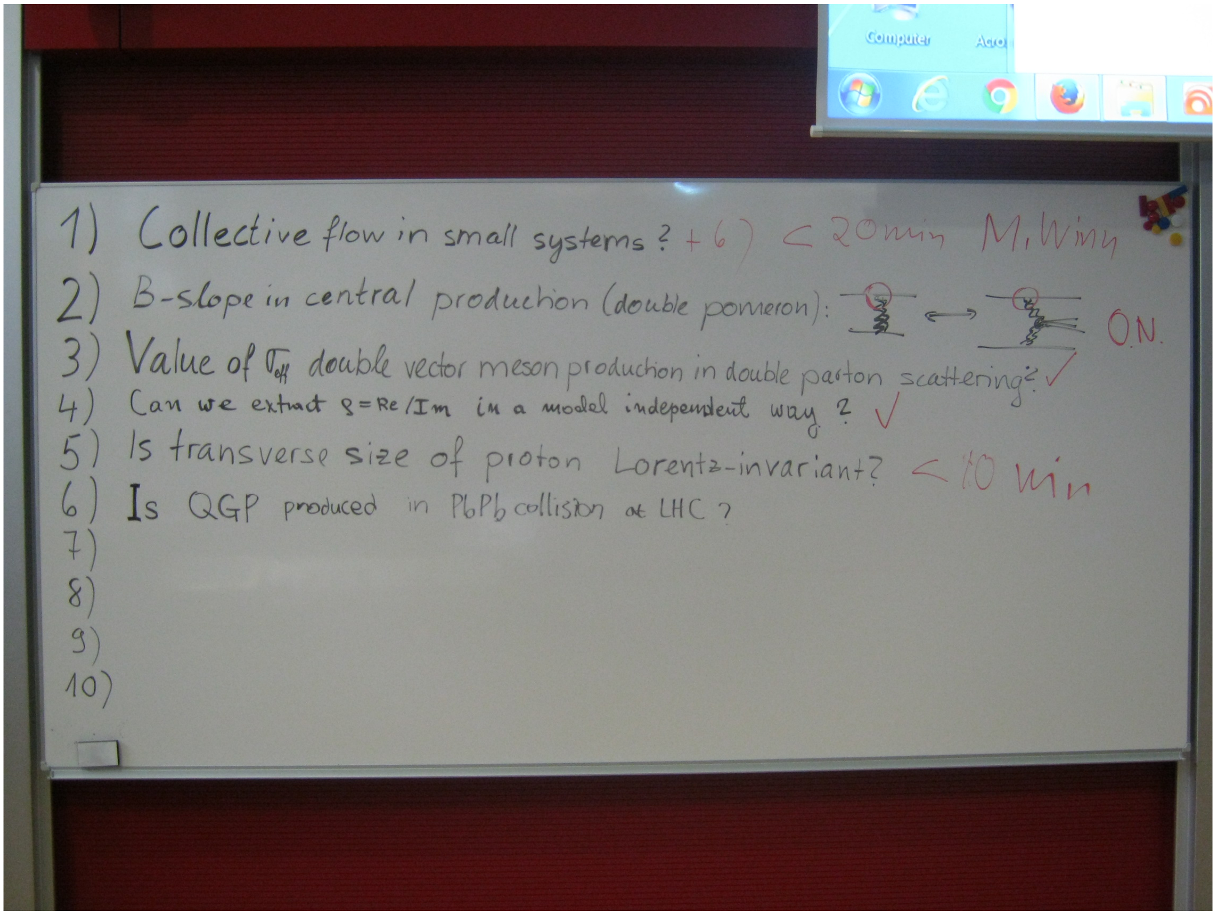
Discussion Session WE-School Bad Honnef, Sept 30, 2017



1. Collective flow in small systems?
2. B-slope in central production (double pomeron)?
3. Value of σ_{eff} double vector meson production in double parton scattering?
4. Can we extract $\rho = \mathcal{R}\mathrm{e}/\mathcal{I}\mathrm{m}$ in a model-independent way?
5. Is transverse size of proton Lorentz-invariant?
6. Is QGP produced in PbPb collision at LHC?

Question 1: Collective flow in central systems?
Answer by Michael Winn:

Q1: Collectivity in “small” systems?

See slide p. 30, LHCb talk and references therein (blue references are links).

Experimental situation in short:

1) same hydrodynamic codes as in PbPb can be applied also here to describe multi-particle correlations although already beyond “normal” applicability limit
2) hadronisation chemistry also approaches smoothly PbPb situation
3) relevant scale is multiplicity; apparently independent of size of colliding objects

Ideas:

1)some theory ideas about hydrodynamics away from standard application limits, e.g. Paul Romatschke in recent series of contributions, e.g. in arXiv:1704.08699v2

2) Original motivation to look at these correlation phenomena in high multiplicity pp related to dense gluonic system first seen in high-multiplicity pp by CMS (Moriond 2011: Dusling: “first discovery” at the LHC)
→ This explanation and/or more generic interference explanations not outruled by experimental data

Current conclusion: description via hydrodynamics might not be unique/appropriate and/or hydro might be applicable beyond locally thermalised system

→ need to lift this ambiguity/duality, if possible
→ at the same time:

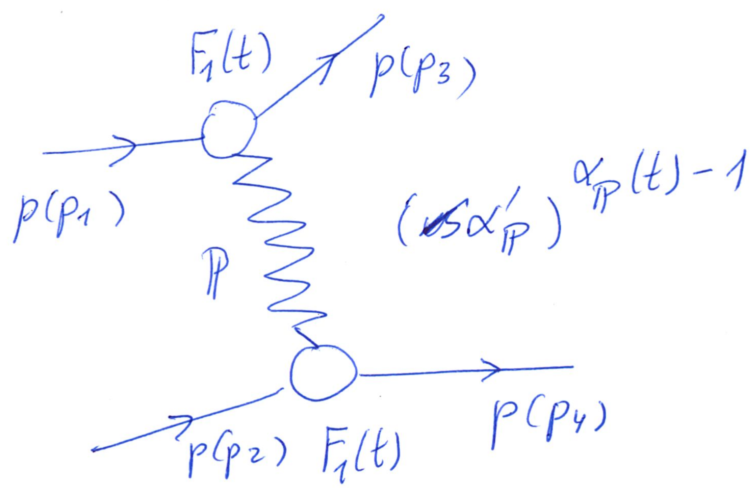
step back and think what will be the consequences for the attempts to extract QGP phase properties (T, transport quantities) in the strongly interacting matter paradigm at RHIC/LHC from nucleus-nucleus collisions

Question 2: B-slope in central production (double pomeron)?
Answer by Otto Nachtmann:

Remarks on the B parameters in elastic scattering and central production

(O. Nachtmann)

elastic scattering:



$$\alpha_{\mathbb{P}}(t) = 1 + \varepsilon_{\mathbb{P}} + \alpha'_{\mathbb{P}}\, t ,$$

$$s = (p_1 + p_2)^2 , \quad t = (p_1 - p_3)^2 .$$

$$\frac{d\sigma_{el}}{dt} \propto \left(F_1(t)\right)^4 \left(s\alpha'_{\mathbb{P}}\right)^{2\alpha_{\mathbb{P}}(t)-2}$$

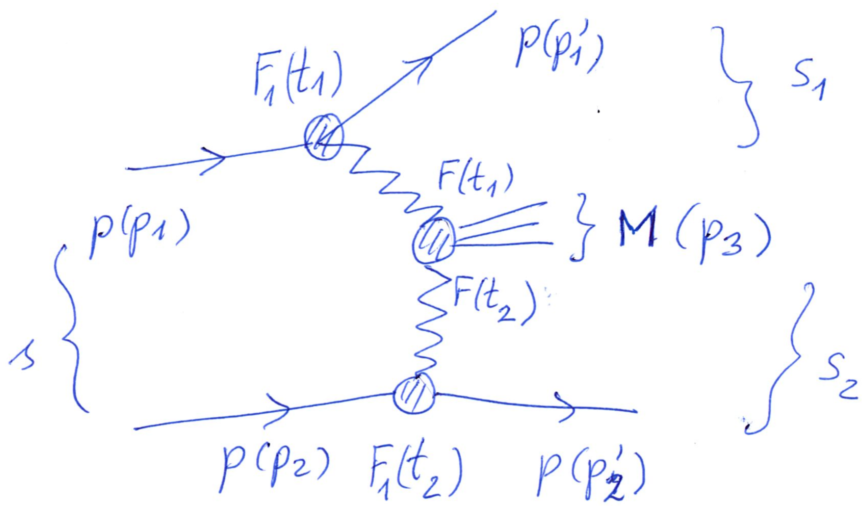
$$B_{el} = \frac{d}{dt}\left(\ln \frac{d\sigma}{dt}\right)\bigg|_{t=0}$$

$$= \frac{d}{dt}\left\{4 \ln F_1(t) + (2\alpha_{\mathbb{P}}(t)-2)\ln(s\alpha'_{\mathbb{P}})\right\}\bigg|_{t=0}$$

$$= 4\frac{d}{dt}\ln F_1(t)\bigg|_{t=0} + 2\alpha'_{\mathbb{P}}\ln(s\alpha'_{\mathbb{P}})$$

$\ln s$ term leads to shrinkage of the diffraction peak

Central exclusive production:



$$s = (p_1 + p_2)^2,$$

$$s_1 = (p_1' + p_3)^2, \qquad s\, m_M^2 \cong s_1 s_2,$$

$$s_2 = (p_2' + p_3)^2,$$

$$t_1 = (p_1 - p_1')^2, \quad t_2 = (p_2 - p_2')^2.$$

Amplitude $\propto F_1(t_1)\, F_1(t_2)\, F(t_1)\, F(t_2)$

$$(s_1 \alpha_{I\!P}')^{\alpha_{I\!P}(t_1)-1} \, (s_2 \alpha_{I\!P}')^{\alpha_{I\!P}(t_2)-1},$$

$\Longrightarrow$

$$\frac{d^2\sigma}{dt_1\, dt_2}(t_1, t_2)$$

$$B_1 = \frac{\partial}{\partial t_1} \ln \frac{\partial^2 \sigma}{\partial t_1 \partial t_2}(t_1, t_2) \Big|_{t_1 = 0,\, t_2 = 0}$$

$$= 2 \frac{d}{dt_1} \ln F_1(t_1) \Big|_{t_1 = 0} + 2 \frac{d}{dt_1} \ln F(t_1) \Big|_{t_1 = 0}$$

$$+ 2 \alpha'_{I\!P} \ln(s_1 \alpha'_{I\!P}) \,,$$

$$B_2 = \frac{\partial}{\partial t_2} \ln \frac{\partial^2 \sigma}{\partial t_1 \partial t_2}(t_1, t_2) \Big|_{t_1 = 0,\, t_2 = 0}$$

$$= 2 \frac{d}{dt_2} \ln F_1(t_2) \Big|_{t_2 = 0} + 2 \frac{d}{dt_2} \ln F(t_2) \Big|_{t_2 = 0}$$

$$+ 2 \alpha'_{I\!P} \ln(s_2 \alpha'_{I\!P}) \,,$$

B_1 and B_2 depend on $\ln s_1$

resp. $\ln s_2$

$$B_1 + B_2 - B_{el} =$$

$$4 \frac{d}{dt} \ln F(t) \Big|_{t=0}$$

$$+ 2\alpha'_{\mathbb{P}} \ln \frac{s_1 s_2 \alpha'^2_{\mathbb{P}}}{s \alpha'_{\mathbb{P}}}$$

$$= 4 \frac{d}{dt} \ln F(t) \Big|_{t=0}$$

$$+ 2\alpha'_{\mathbb{P}} \ln (m_M^2 \alpha'_{\mathbb{P}})$$

independent of s_1, s_2, s !

Bad Honnef Relation

September 2017

In writing down this simple relation we have made approximations in the kinematics of central exclusive production. A discussion of various central production reactions in the tensor-pomeron approach can be found in the following papers where also many kinematic relations are given.

P. Lebiedowicz, O. N., A. Szczurek:

Annals Phys. 344 (2014) 301

Phys. Rev. D91 (2015) 074023

Phys. Rev. D93 (2016) 054015

Phys. Rev. D94 (2016) 034017

Phys. Rev. D95 (2017) 034036

Question 3: Value of σ_{eff} double vector meson production in double parton scattering?
Answer by Antoni Szczurek:

Please see my talk on double parton scattering on thursday afternoon.

Question 4: Can we extract $\rho = \mathcal{R}\mathrm{e}/\mathcal{I}\mathrm{m}$ in a model-independent way?
Answer by Mario Deile:

Please see my talk on QCD processes in TOTEM on friday afternoon.

Question 5: Is transverse size of proton Lorentz-invariant?
Answer by Chung-I Tan:

The answer is yes and no; it all depends.
The notion of size is well-defined classically. Under Lorentz boost, transverse size does not change. For a proton at rest, it has a classical size, when measured by "weak probe". However, a "probe", quantum mechanically, is a scattering process. Therefore, "static size" of a proton is specified by "low-energy limit", i.e., probe in the long wavelength limit, e.g., experimentally given form factor at zero momentum transfer.
With this understanding, transverse "static size" of a proton, even under Lorentz boost, remains unchanged, with Lorentz contraction in longitudinal direction. However, it is difficult to have "weak probe" when the proton is moving with large momentum.
Quantum mechanically, a low energy photon in the lab frame hitting a high momentum proton leads to high energy scattering in their CM. Due to quantum fluctuations, a proton appears increasingly larger in transverse direction, i.e., total cross section expands. This can be described by a diffusion process, via partonic fluctuations in the QCD vacuum.
The physics involved is non-perturbative. Understanding how this works in QCD has been the challenge of the past, and it remains a puzzle and presents opportunity for the future. In fact, understanding "Pomeron" in QCD non-perturbatively can be considered as trying to answer the question "What is the Size and Shape of Proton?" This is one of the key concerns of high energy scattering in QCD.
Long live the Pomeron !

Question 6:
Is QGP produced in PbPb collision at LHC?
Answer by Michael Winn:

Q6: is there a QGP produced in PbPb collisions at the LHC?

First question to be answered: definition of QGP
→ in order to talk about a phase: local thermal equilibrium required
→ reformulated: is there a locally thermally equilibrated piece of considerable dimension and durations(> 1fm) of strongly interaction matter created in PbPb collisions at the LHC?

Answer:

1) finite extension & duration of strongly interacting volume: yes, otherwise strong jet quenching of multi-GeV probes not explainable, see talk by Davide Caffari for experimental results
2) equilibrium: close to ideal hydrodynamics very successful for a large range of observables in soft sector (p_t spectra, azimuthal correlations v_n, HBT; historic: see Quark Matter '12 plenary of Björn Schenke, see talk Michael Weber at this school) despite many model parameters and crude approximations necessary
3) electromagnetic probes (chiral restoration and T above rapid cross-over from LQCD at mub=0, see T. Galatyuk) from SPS, RHIC and LHC and quarkonium behaviour at the LHC vs. RHIC (Davide Caffari's talk) as well in line
→ fully in line with paradigm of strongly interacting plasma: goal of research field to use collisions as tool to extract phase properties

In addition from theory: explanation for thermalisation at the horizon (see talk Raju Venugopalan)