# Status ideas for very forward physics measurements in ALICE 3

Rainer Schicker

diff PAG meeting, july 15, 2021

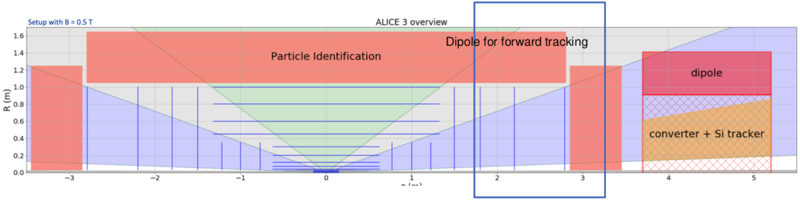
# ALICE 3 Magnet systems

- ALICE 3 workshop, june 14 -18, 2021
  workshop next generation heavy-ion exper. for LHC Run 5
  https://indico.cern.ch/event/1033104/
- W.Riegler, Detector layout and tracker optimisation, slide 33

## LOI reference Layout

Tracker services and service/support structure topology will be studied as from now to refine tracker performance.

What else should be studied/integrated/designed/cost-estimated for the LOI in the next 4 months ?




1) Magnet Systems
2) Barrel TOF1, 2 + RICH
3) Forward TOF + RICH
4) ECAL/Preshower
5) Muons

# ALICE 3 IRIS tracker

- W.Riegler, Detector layout and tracker optimisation, slide 8

**Iris tracker, 3 layers**

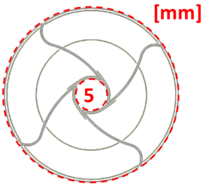
3 layers close to the IP.

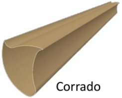
$X_0$(Si) = 93.7mm
$X_0$(Be) = 352.8mm = 3.77 $X_0$(Si)

50µm Si = 0.53 ‰ $X_0$
150µm Be = 0.43 ‰ $X_0$

→ assume 1 ‰ $X_0$ per layer (ITS2, now 3 ‰ $X_0$ for inner barrel)
→ Present Iris Tracker $r_0$=5mm, $r_1$=15mm, $r_2$=25mm

Optimization would assume $r_0$=5mm, $r_1$=12mm, $r_2$=30mm.




Module structure
- 0.1- 0.15mm Aluminum foil welded and formed (similar process done at CERN with Al bellow 0.2mm- R&D)
- 0.1-0.15 Beryllium foil formed and joined (at the limit of present technology - R&D)
- Al-Be material (AlBemet®)(R&D)
- Beryllium 3d printed (few application in aerospace industry, different geometries –R&D)
- Carbon Composite?

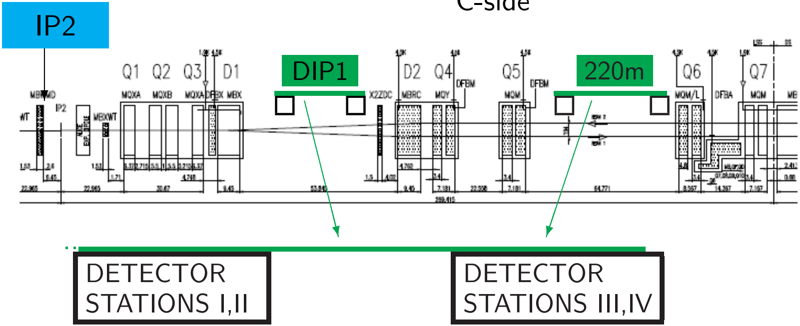
9/3/20 8

- IRIS tracker min. distance to beam $r_0 = 5$ mm
- put (IRIS) trackers (very) far away from the IP to measure very forward scattered particles?

# Location of detectors

- strategy: Measure straight sections of tracks, particle ID

C-side




- particle ID: protons, pions and kaons
  (plus pion and kaon decays to $\mu, e, \nu, \bar{\nu}, (\pi^0)$)
  $\rightarrow$ PID needed for protons, pions, kaons, muons, electrons
  $\rightarrow$ Transition Radiation detector?
  $\rightarrow$ elmagn./hadronic calorimeter?
  $\rightarrow$ zero degree calorimeter for $\pi^0$?

# ALICE 3 Forward Measurements

- Tagging of forward protons (pions, kaons) in pp-collisions
  $\rightarrow$ measure the proton scattering plane
  $\rightarrow$ map t-dependence of process, transition soft to hard scale
  (Mandelstam variable t, 4-momentum transfer to the proton)
  - Odderon search in pp $\rightarrow$ p$\phi$p
  - t-transfer to proton as glueball filter in CEP
  - diffractive excitations of proton
  - vorticity in pp $\rightarrow$ pp $\Lambda\bar{\Lambda}$
  - dip in pp-elastic scattering cross section $d\sigma/dt$
  - establish exclusivity of CEP production (background reduction)

- Cross section $\gamma p$ in pA-collisions
  - ALICE 3 workshop talk Otto Nachtmann: High energy diffractive processes without and with soft-photon radiation

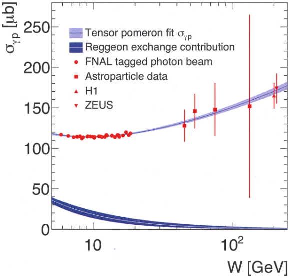
# Cross section $\gamma p$ in pA collisions

- ALICE 3 workshop, Otto Nachtmann, slide 6,7

6

- photo production and low x DIS,
  Britzger, Ewerz, Glazov, O.N., Schmitt, PRD 100 (2019) 114007.

In this paper we could show that a vector pomeron decouples completely in the total photoabsorption cross section and in the structure functions of DIS. In contrast, with the tensor pomeron we get excellent fits. I show this for the case of $\sigma_{tot}(\gamma p)$ for real photons.




We hope that ALice 3 will be able to measure $\sigma_{\gamma p}$ at even higher W in ultraperipheral Ap collisions.

# BACKUP

# Odderon search in pp $\rightarrow$ p$\phi$p

- ALICE 3 workshop talk Otto Nachtmann: High energy diffractive processes without and with soft-photon radiation, slide 9

In my opinion CEP reactions deserve detailed studies with the new detector, which is studied here, for the LHC. Let me just mention the good possibilities to search for odderon effects in CEP of single $\phi$ and double $\phi$ final states X. The $\phi$'s come out at low $p_T$ and their $K^+$, $K^-$ decay products are then also at low $p_T$. If I understand it correctly, this is the region where the new detector will have high sensitivities.

# Odderon search in pp → p$\phi$p

- workshop talk Otto Nachtmann, slide 10

10

3 The reaction $pp \longrightarrow p\phi p$ and the odderon

This reaction was first suggested for an odderon search in A. Schäfer, L. Mankiewicz, O.N., Phys. Lett. B 272 (1991) 419.

Now we have studied it with our tensor-pomeron model in P. Lebiedowicz, A. Szczurek, O.N., Phys. Rev. D 101 (2020) 094012.

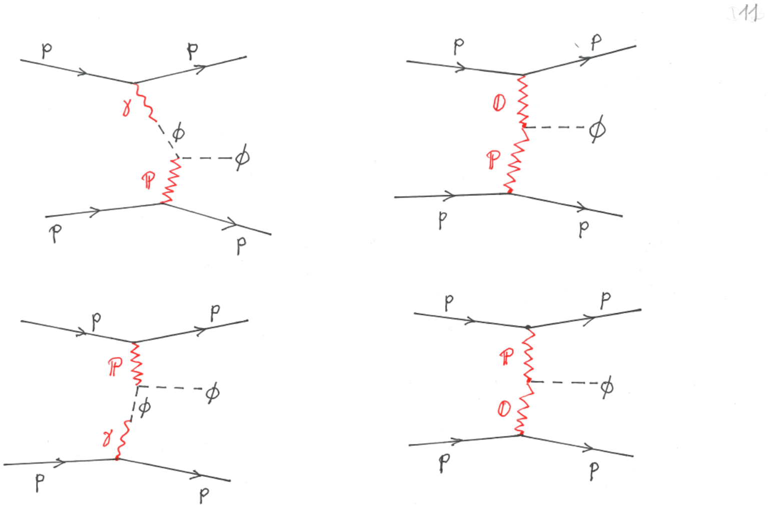
At high energies the main diagrams contributing are $\gamma\mathbb{P}$ and $\mathbb{O}\mathbb{P}$ fusion, giving a $\phi$. The $\phi$ can be identified e.g. by its $K^+K^-$ or $\mu^+\mu^-$ decays.

$$p(p_a) + p(p_b) \longrightarrow p(p_1) + \phi(p_{34}) + p(p_2)$$

$$\phi(p_{34}) \longrightarrow K^+(p_3) + K^-(p_4),\quad \mu^+(p_3) + \mu^-(p_4)$$

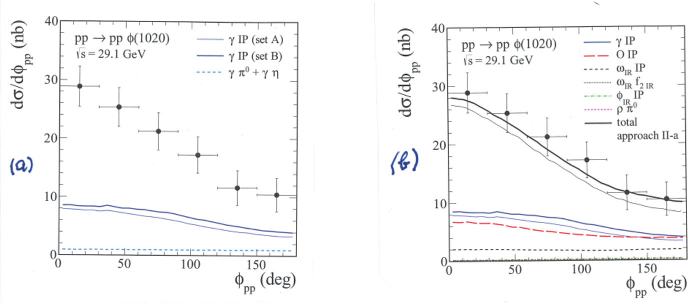
# Odderon search in pp → p$\phi$p

- workshop talk Otto Nachtmann, slide 11



# Odderon search in pp → p$\phi$p

- workshop talk Otto Nachtmann, slide 12




Distributions in $\phi_{pp}$ the azimuthal angle between the outgoing protons.
Comparison of the model with the WA102 data on $\phi$ meson CEP, (a) without an odderon contribution, (b) with an odderon contribution. The total cross section is $\sigma_{exp}(pp \to pp\phi) = (60 \pm 21)$ nb at $\sqrt{s} = 29.1$ GeV.
(A. Kirk, Phys. Lett. B 489 (2000) 29)

# Odderon search in pp → p$\phi$p

- workshop talk Otto Nachtmann, slide 14

14

Now we extrapolate to LHC energies.
Can we distinguish $\gamma$ and $\mathbb{O}$ exchange?

- $\mathbb{O}$ exchange gives $\phi$ mesons with larger $p_\perp$ than $\gamma$ exchange.
- $\mathbb{O}$ exchange gives $\phi$ mesons with preferential longitudinal polarisation in beam direction, $\gamma$ exchange produces preferentially transversely polarised $\phi$'s.

These polarisation difference can be seen in the decay
$\phi \longrightarrow K^+ K^-$.

# Glueball filter

- F.Close, A.Kirk, A Glueball-$q\bar{q}$ Filter in Central Hadron Production, Phys.Lett.B 397 (1997) 333, $(dP_T = |\vec{p}_T^{out}(A) - \vec{p}_T^{out}(B)|)$
- A.Kirk, Resonance production in central pp collisions at the CERN Omega Spectrometer, Phys.Lett. B489 (2000) 29, hep-ph/0008053

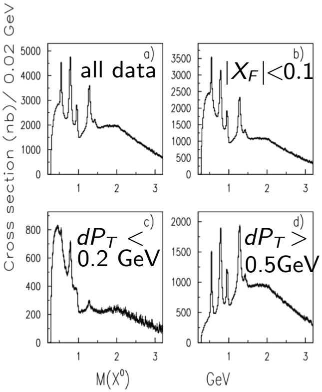



Fig. 1, d$\sigma/dM(\pi\pi)$

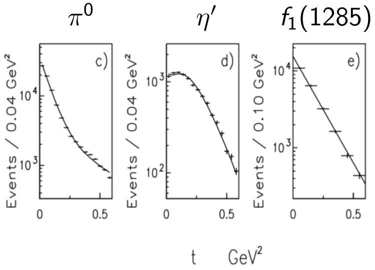



Fig. 2, $|t|$ distributions

# Glueball filter

- A.Kirk, Resonance production in central pp collisions at the CERN Omega Spectrometer, Phys.Lett. B489 (2000) 29, hep-ph/0008053

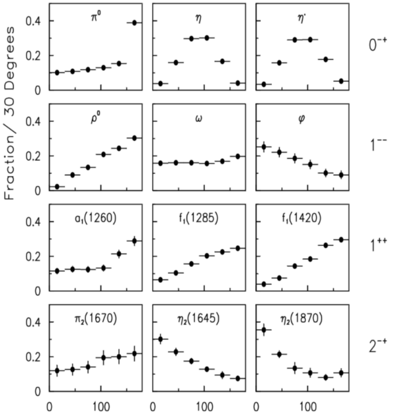



Fig. 4 $\varphi$ Degrees

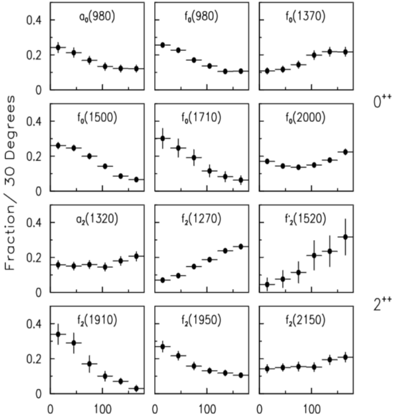
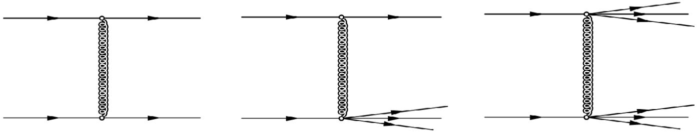



Fig. 5 $\varphi$ Degrees

azimuthal angle $\varphi$ between outgoing protons

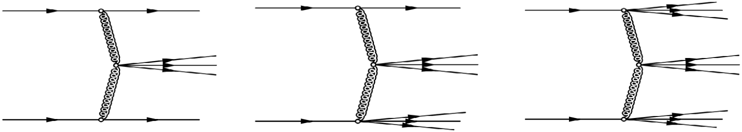
# Diffractive proton excitations

elastic/ inelastic scatter.



elast. scattering | single diff. diss. | double diff. diss.

central prod.

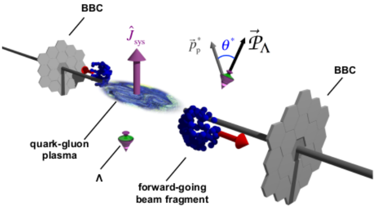


central prod. | central prod./single diss. | central prod./double diss.

- pions, kaons emitted from source moving with beam rapidity have different long. momentum → different magn. rigidity
  *Identify proton diffractive excitations?*
  *Measure single/double diffractive dissociation?*

# Vorticity in pp $\to$ pp $\Lambda\bar{\Lambda}$

- STAR coll., Global $\Lambda$ hyperon polarization in nuclear collisions, Nature **548** (2017) 62-65
- Evidence for the most vortical fluid




STAR at RHIC

- Ayala et al., *The rise and fall of $\Lambda$ and $\bar{\Lambda}$ global polarisation in semi-central heavy-ion collisions at HADES, NICA and RHIC energies from the core-corona model*, arXiv:2106.14379
  $\to$ Calculation of rate of $\Lambda$'s in the core and the corona, energy dependence, global polarisation
- *reference measurement at LHC energy, pp $\to$ pp $\Lambda\bar{\Lambda}$?*

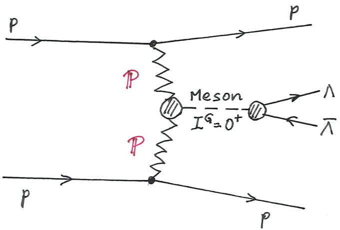
# Cross section pp → pp $\Lambda\bar{\Lambda}$

- presentation O.Nachtmann, diff PAG meeting, 2018
- $\Lambda\bar{\Lambda}$ resonance production

15

## 3.1 Resonance production

CEP of $\Lambda\bar{\Lambda}$ by pomeron - pomeron fusion can occur via a charge conjugation $C = +1$ resonance with $I^G = 0^+$.




Mesons with $I^G \neq 0$ can be produced by subleading exchanges, $\mathbb{P}\,\omega_R$, … . These should be suppressed at LHC.

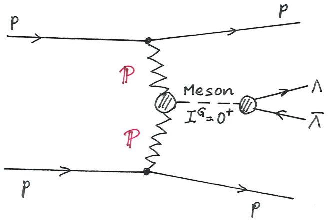
# Cross section pp → pp $\Lambda\bar{\Lambda}$

- presentation O.Nachtmann, diff PAG meeting, 2018
- $\Lambda\bar{\Lambda}$ continuum production

15

### 3.1 Resonance production

CEP of $\Lambda\bar{\Lambda}$ by pomeron - pomeron fusion can occur via a charge conjugation $C = +1$ resonance with $I^G = 0^+$.




Mesons with $I^G \neq 0^-$ can be produced by subleading exchanges, $\mathbb{P}\,\omega_{\mathbb{R}}, \ldots$. These should be suppressed at LHC.

- Calculation $\sigma(pp \to pp\,\Lambda\bar{\Lambda})$ in planning (priv.comm. O.Nachtmann)

# Elastic cross section $d\sigma/dt$ (pp $\rightarrow$ pp)

- TOTEM coll., *Elastic differential cross-section measurement at $\sqrt{s}$ = 13 TeV by TOTEM*, arXiv:1812.08283

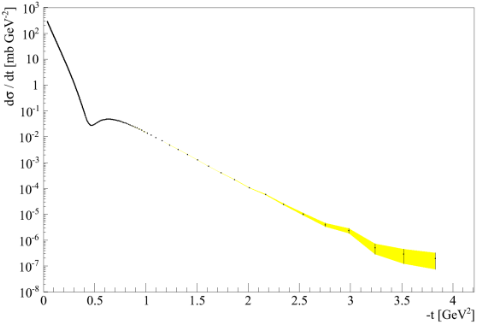



**Fig. 8:** (color) Differential elastic cross-section $d\sigma/dt$ at $\sqrt{s} = 13$ TeV. The statistical and $|t|$-dependent correlated systematic uncertainty envelope is shown as a yellow band.

- TOTEM data for -t $<$ 4 GeV$^2$ (acceptance limited)

# Elastic cross section $d\sigma/dt$ ($pp \to pp$)

- the 1st minimum (dip) universal feature of elastic scattering cross section, location of dip is energy dependent

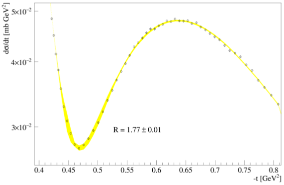


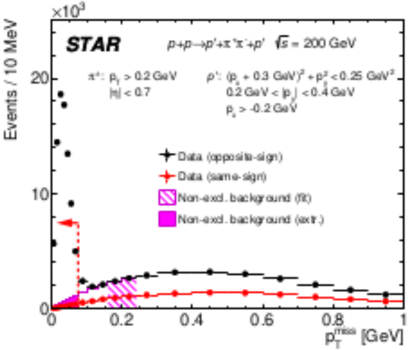

**Fig. 11:** The diffractive minimum has been observed with high significance at 13 TeV. The uncertainty on the points is the statistical uncertainty, while the yellow band shows the full uncertainty, including the systematic part. The dip position has been found to be $|t_{dip}| = (0.47 \pm 0.004^{stat} \pm 0.01^{syst})$ GeV$^2$ and the differential cross section ratio between the second maximum and the minimum is $R = 1.77 \pm 0.01^{stat}$.

- many models on the market to explain features of elastic pp scattering and their energy dependence
- elastic pp scattering and its energy dependence not understood at a fundamental level, many open issues
- future pp elastic scattering measurements for $|t| > 4$ GeV$^2$?
  for $\mathcal{L} = 200$ pb$^{-1}$ $\to$ meas. up to $|t| \sim 5$ GeV$^2$, stat. uncer. $\sim 15\%$

# Background in central exclusive production

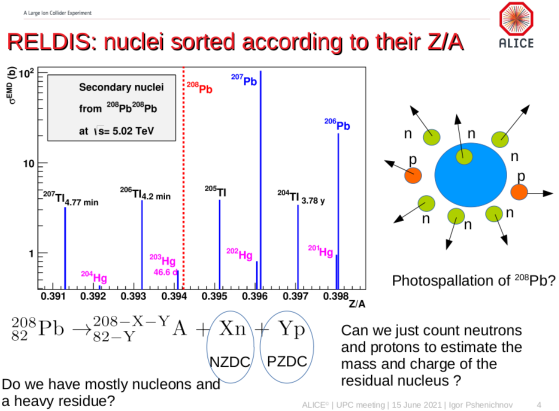
- measure central system and two outgoing protons
- total transverse momemtum $\sim 0$
- R.Sikora, *Recent results on Central Exclusive Production with the STAR detector,*

  *Int. Workshop on Deep-Inelastic Scattering (DIS)*, 12-16 april, 2021



# Nuclear fragments in ultraperipheral reactions

- presentation I.Pshenichnov, 15 june, UPC meeting




- fragments have different magnetic rigidity, can they be tagged?
- measure forward neutrons, protons, pions in coincidence?

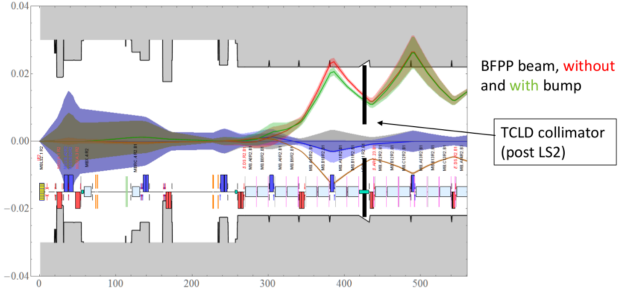
# Fragments in peripheral and semi-central AA reactions

- spectator fragments in peripheral and semi-central AA collisions have different magn. rigidity, can they be tagged?
- Study correlation of fluctuations at mid-rapidity to fluctuations of fragment composition
- Study correlation of fluctuations between the two beam fragments

# Secondary beams at IP2

- J.Jowett, Colliding Heavy Ions at the LHC, TUXGBD2, IPAC'18, Vancouver, 2018

## Orbit bumps alone are not effective for ALICE




- IR2 has different quadrupole polarity and dispersion from IR1/IR5
- Primary BFPP loss location is further upstream from connection cryostat
- Solution is to modify connection cryostat to include a collimator to absorb the BFPP beam – **to be ready for LS2 installation**
- With levelled luminosity in ALICE, quenches were not seen in 2015

# Secondary beams at IP2

- J.Jowett, Colliding Heavy Ions at the LHC, TUXGBD2, IPAC'18, Vancouver, 2018