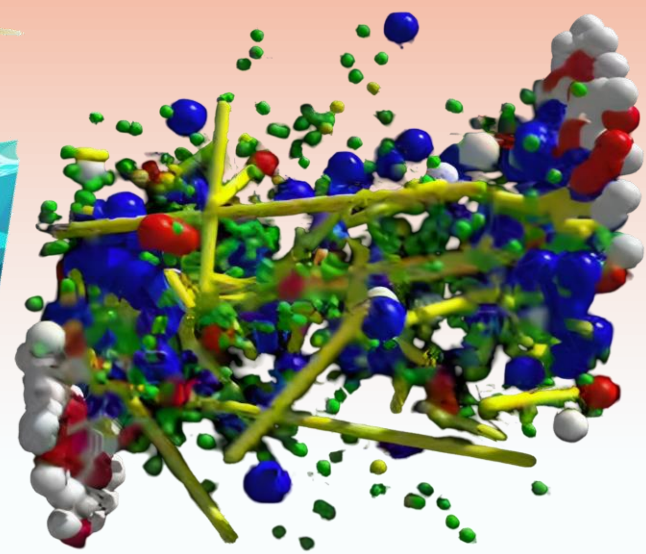
Dániel Kincses, Márton Nagy, Máté Csanád,
ELTE Eötvös Loránd University, Budapest

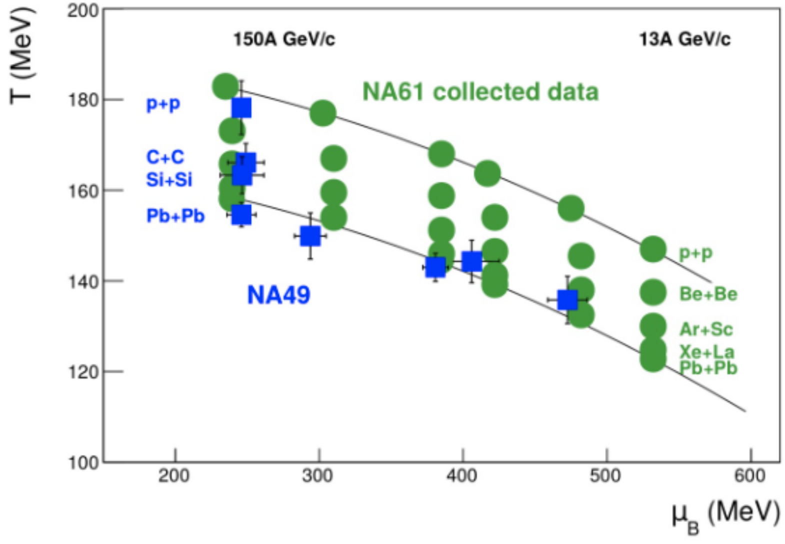
Based on
arXiv:2409.10373

What is common between marine predators, albatrosses, bacteria, climate change, and heavy-ion collisions?

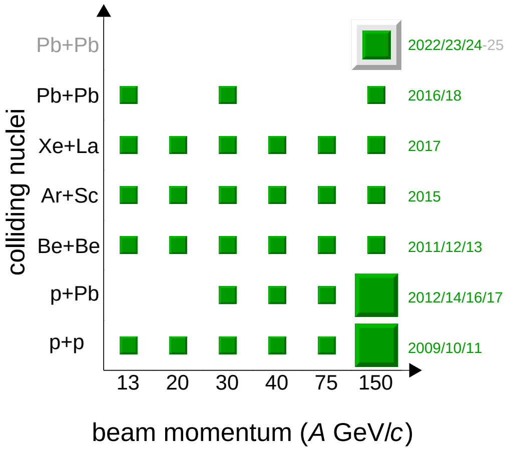
Check out my poster
and find out!

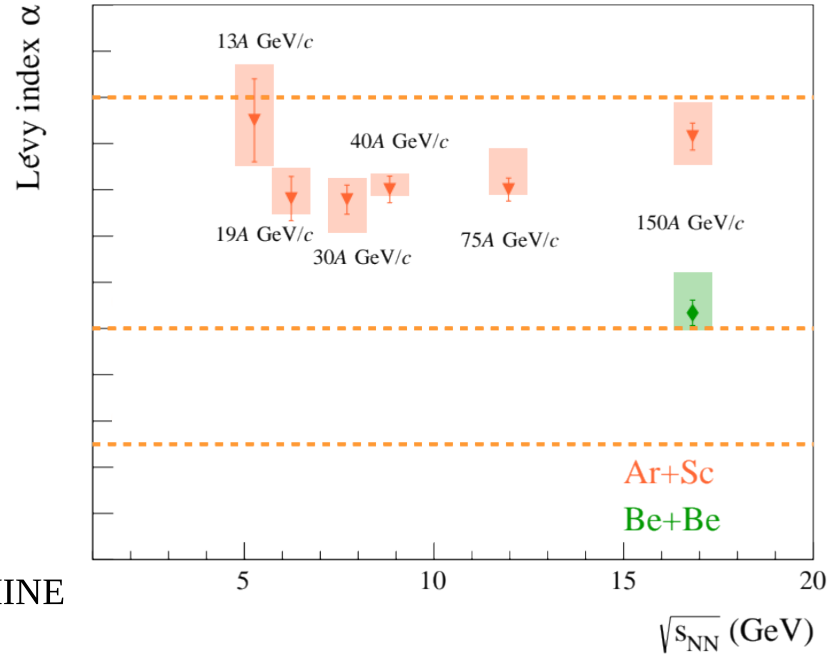


Energy scan results with Lévy type femtoscopy at NA61/SHINE



- Source often assumed to be Gaussian
  - Experimental results show otherwise might bring new, interesting physics
- Is the particle emitting source Gaussian or not?
- Are there signs indicating a critical point?





Energy scan results with Lévy type femtoscopy at NA61/SHINE

- Source often assumed to be Gaussian
  - Experimental results show otherwise
    might bring new, interesting physics
- Is the particle emitting source Gaussian or not?
- Are there signs indicating a critical point?

You can find out the answers at my poster!

1/2

The aim of the analysis

- Pair source distribution: $D(r,K) = \int S\left(\rho + \frac{r}{2}, K\right) S\left(\rho - \frac{r}{2}, K\right) \mathrm{d}^4\rho$
- Shape of the source function?
- Lévy-stable distribution: generalization of Gaussian
- Shown in many experiments: the shape deviates from Gaussian ($\alpha < 2$)

Why?

One possible reason:

Elastic scattering dominated anomalous diffusion:

smaller cross-section → larger mean free path → heavier power-law tail → $\alpha(\mathrm{K})<\alpha(\pi)$

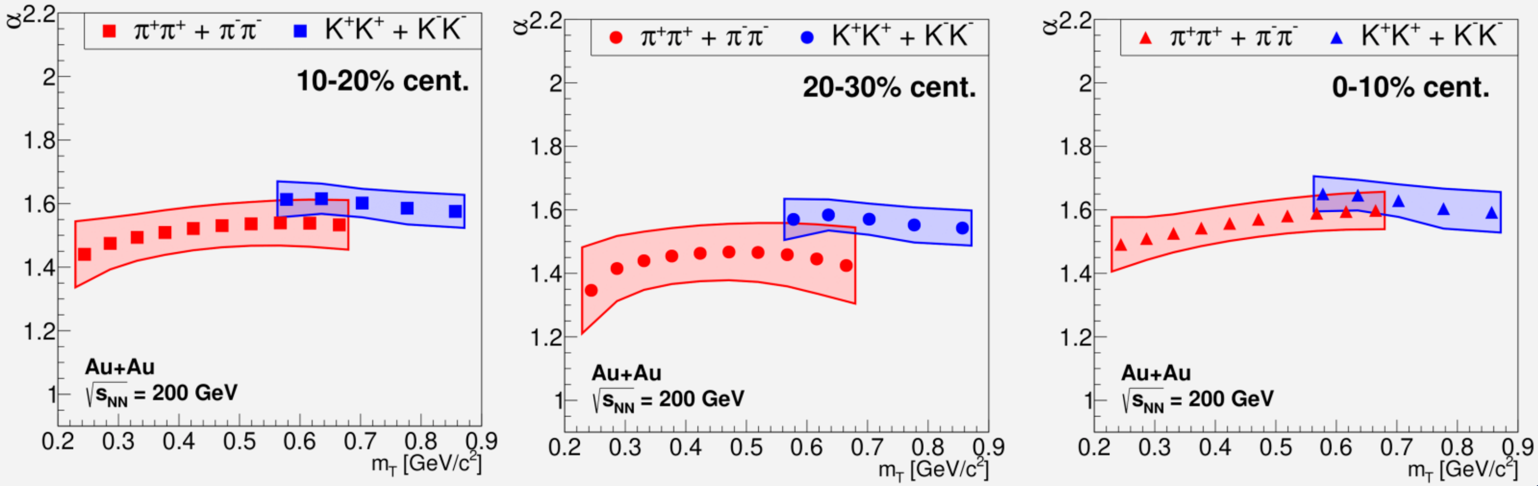
M. Csanád, T. Csörgő, M. Nagy, Braz.J.Phys. 37 (2007) 1002
Humanic, Int.Jour.Mod.Phys. E 15 (2006) 197

Relation?

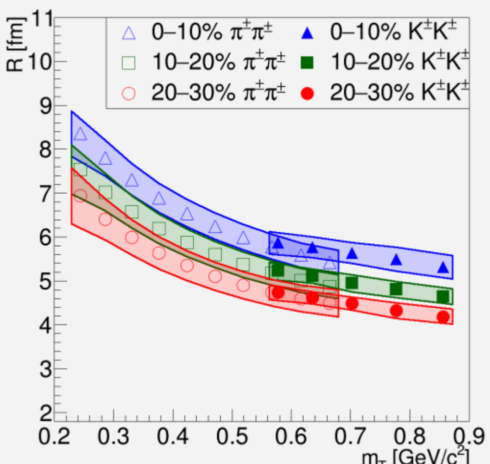
$\alpha(\mathrm{K}^\pm)$ ⟺ $\alpha(\pi^\pm)$

EPOS results

Parameter α



Parameter R



Conclusion

- Observation: $\alpha(\pi) \leq \alpha(K)$; approximately species-independent
- Unlike expectation for elastic scattering dominated Lévy walk
- Likely due to resonance decays

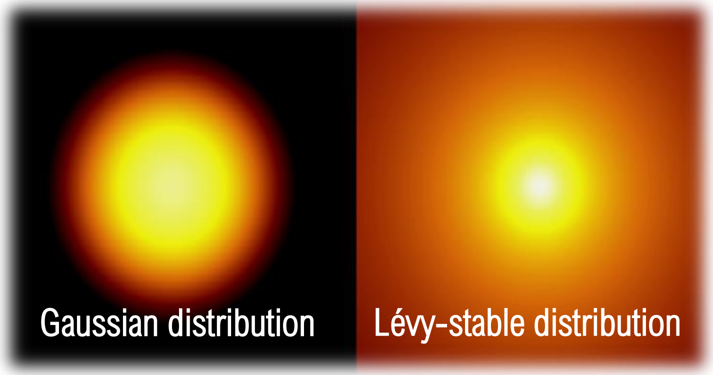
} α

- Usual decrease with mT due to collective flow
- Approximate m_T scaling holds
- Same source for pions and kaons, even after decays and scattering?

} R

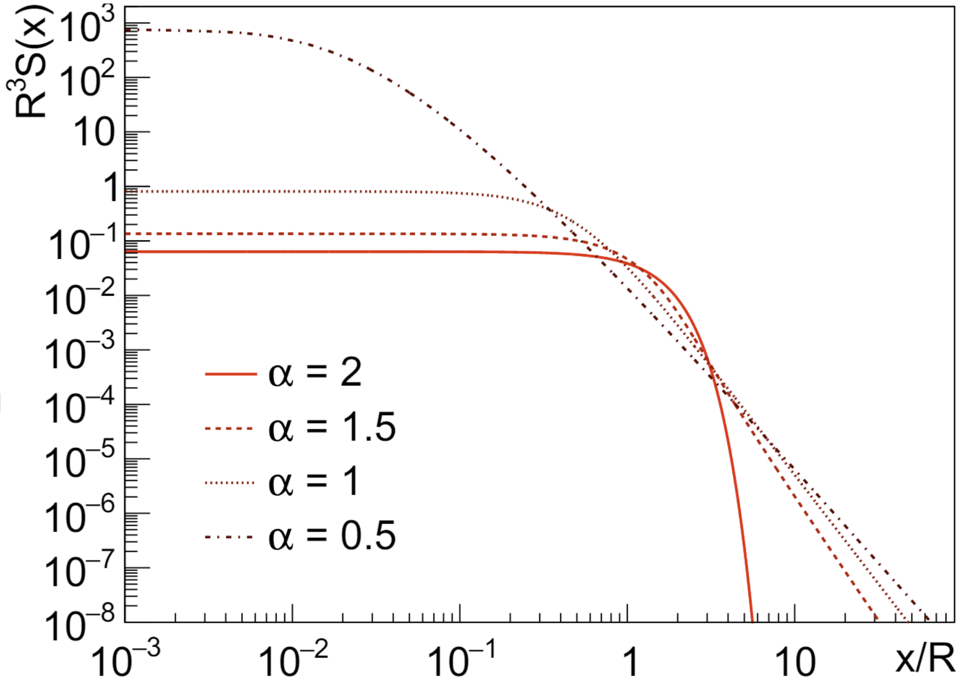
3D pion source images in 200 GeV Au+Au collisions with EPOS

Emese Árpási
Eötvös Loránd University, Budapest



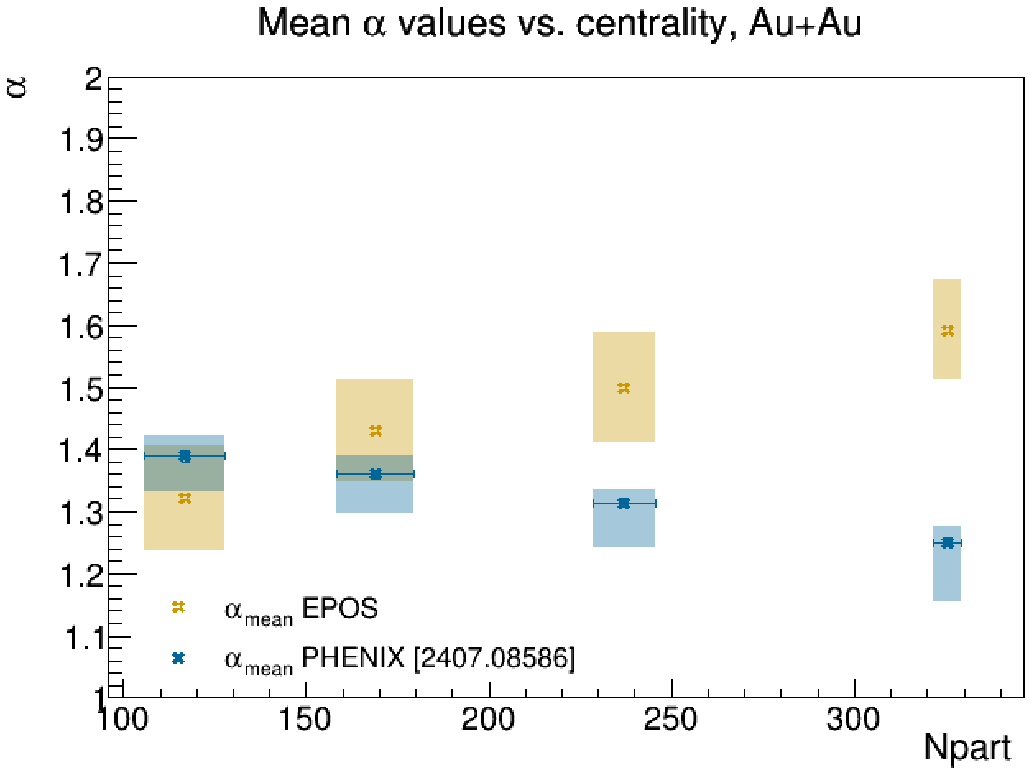
- Lévy shape of the pion source function seen in many experiments
- Motivation: does the Lévy shape show up in 3D too?
  → check in EPOS!
- $\sqrt{s_{NN}}$ = 200 GeV Au+Au collisions generated by the EPOS program package
- Event-by-event and 3-dimensional investigation of the pion pair-source
- $D(r)$ pion pair source function fitted with Lévy distribution

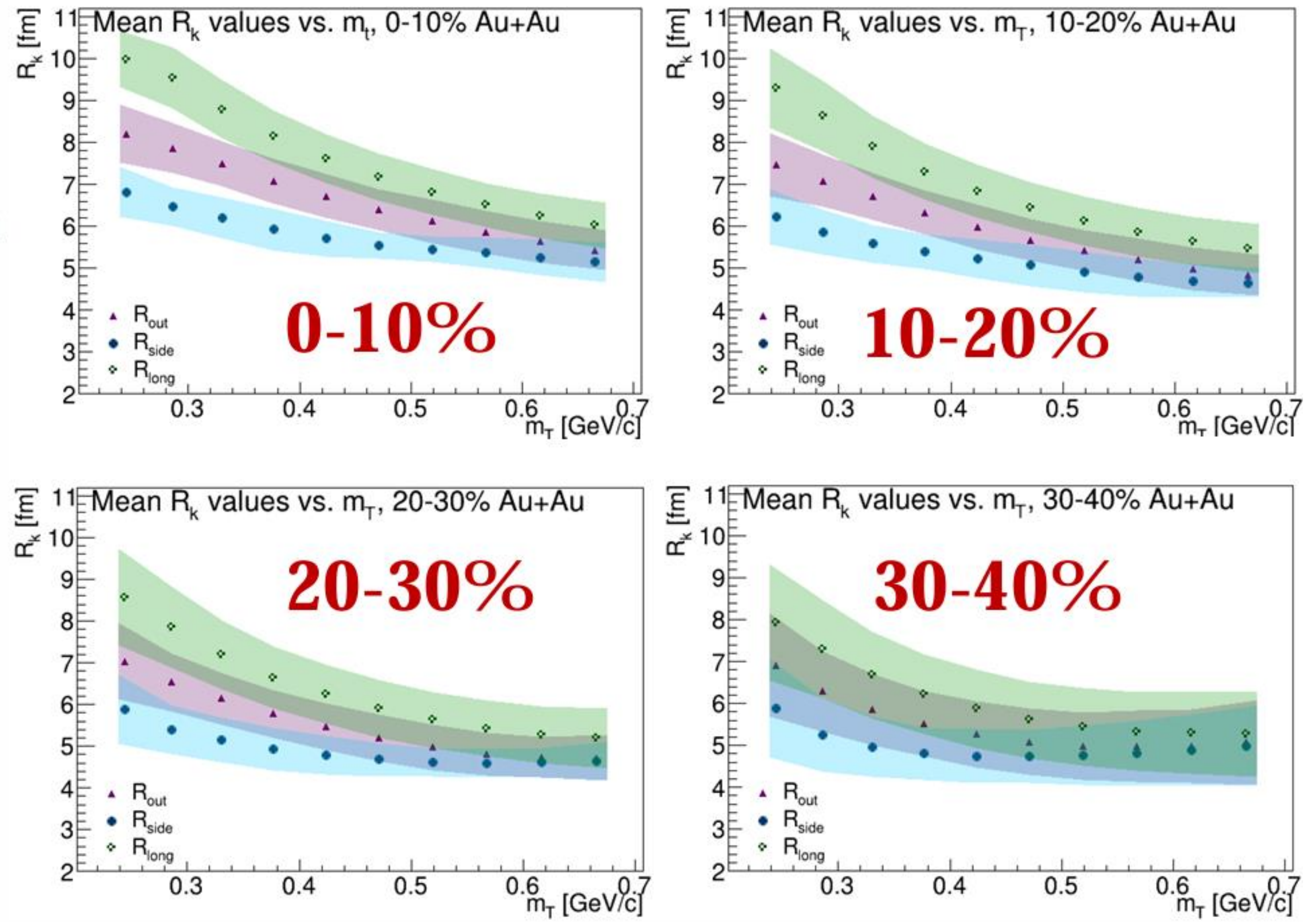
$$D(r) = \mathcal{L}\left(r, 2^{\frac{1}{\alpha}} R_{out}, 2^{\frac{1}{\alpha}} R_{side}, 2^{\frac{1}{\alpha}} R_{long}, \alpha\right)$$



Results

- ➢Source shape described well by 3D Lévy-stable distributions on an event-by-event basis
- ➢Parameters compared to new final PHENIX angle-averaged results



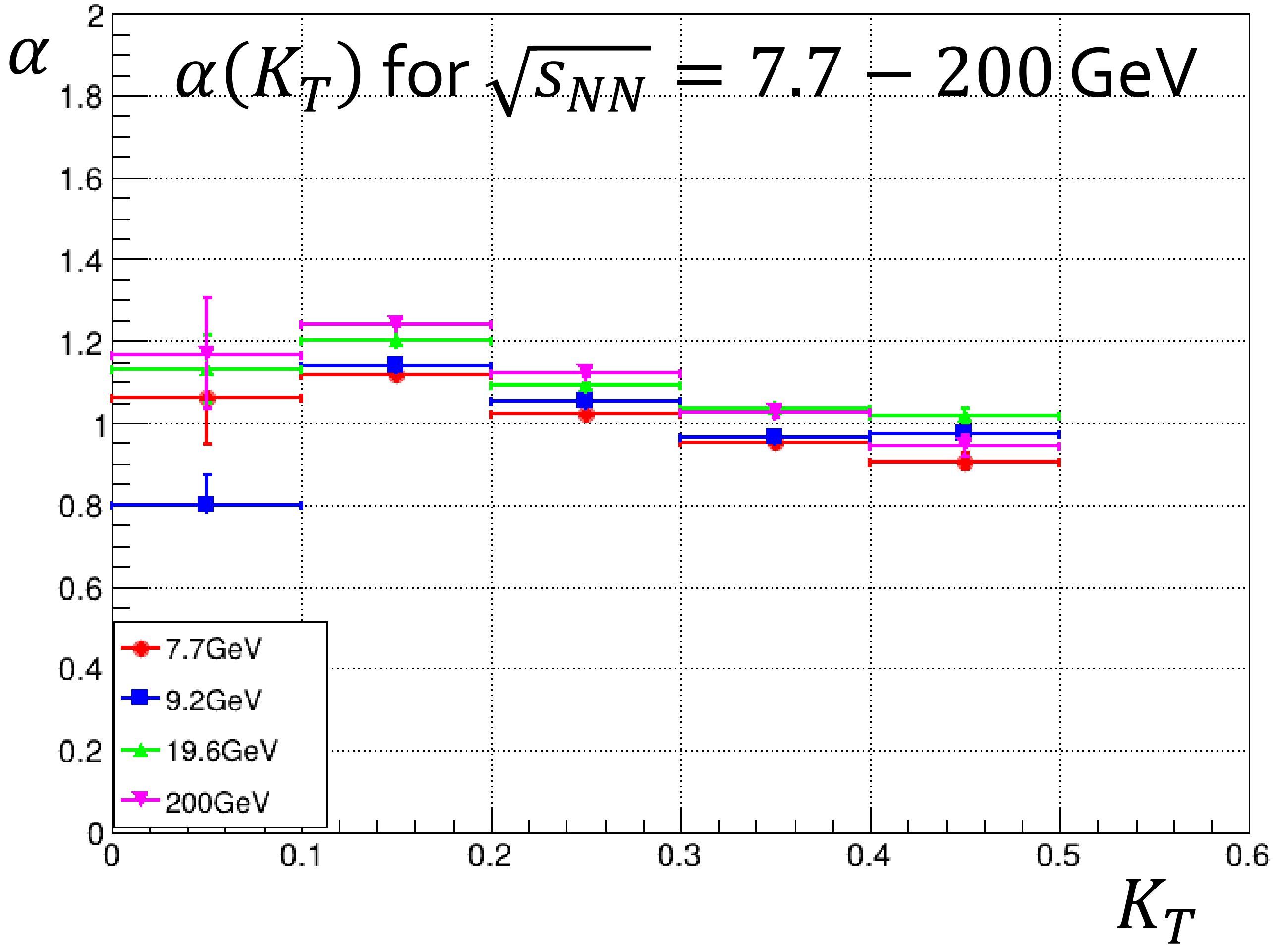


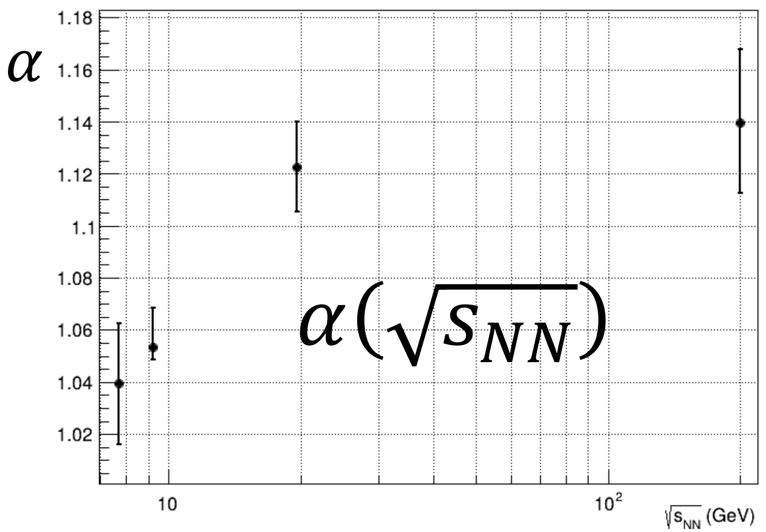
PION EMISSION SOURCE WITH EPOS4

M. Molnár (Eötvös University)

Shape of pion emission source versus $\sqrt{s_{NN}}$

- Analysis done before in EPOS3 (see talks by E. Árpási, L. Kovács, D. Kincses, M. Csanád)
- EPOS4 includes different hadronization
- First preliminary results out: from 7.7 to 200 GeV
  - Slight dependence on K_T
  - To check: fits from event-averaged data
- Collision energy dependence interesting





Elliptic flow of deuterons in heavy-ion collisions

Tomáš Poledníček[a], Boris Tomášik[a,b]

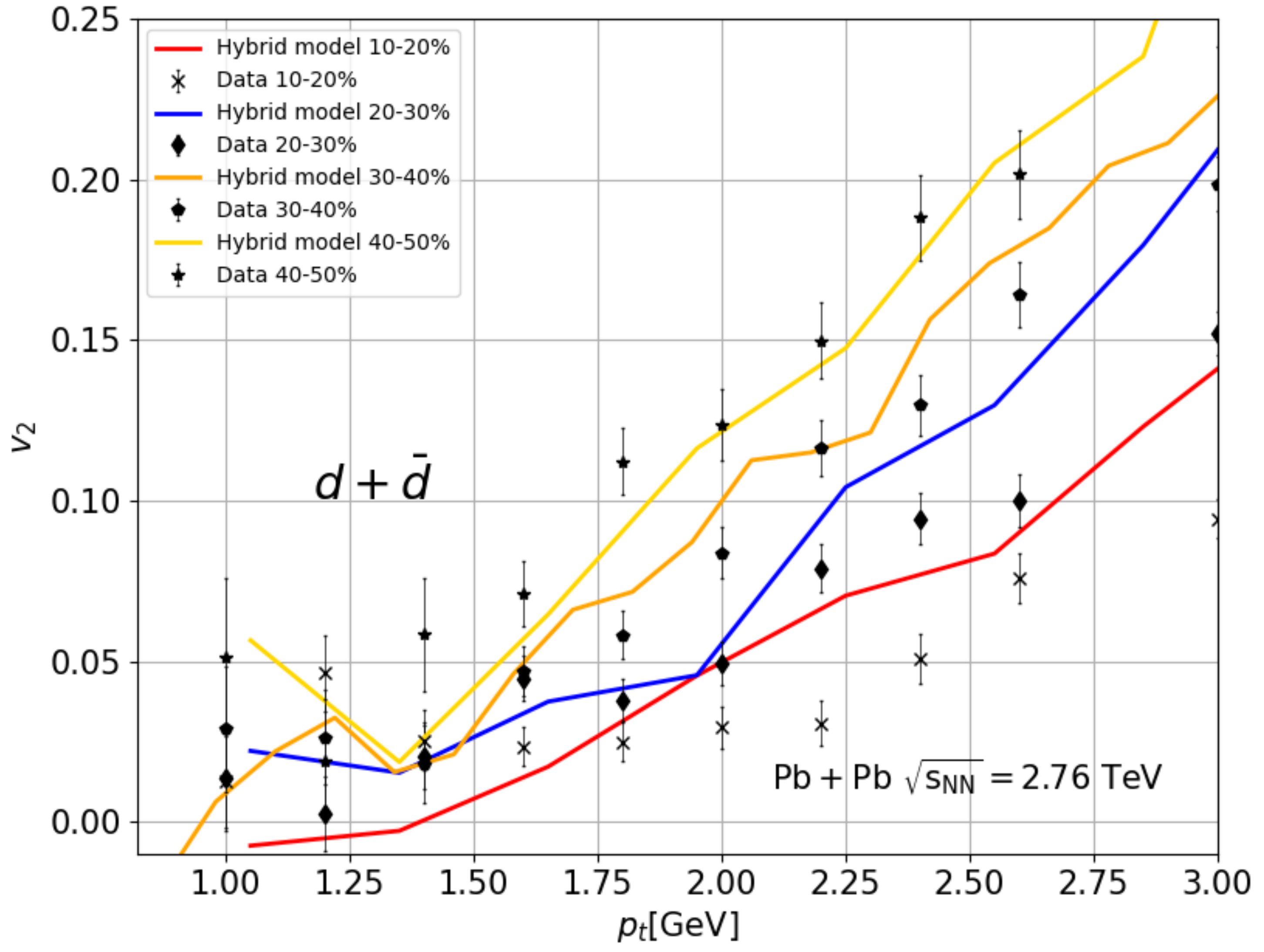
[a]*Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague, Czech Republic*
[b]*Univerzita Mateja Bela, Banská Bystrica, Slovakia*

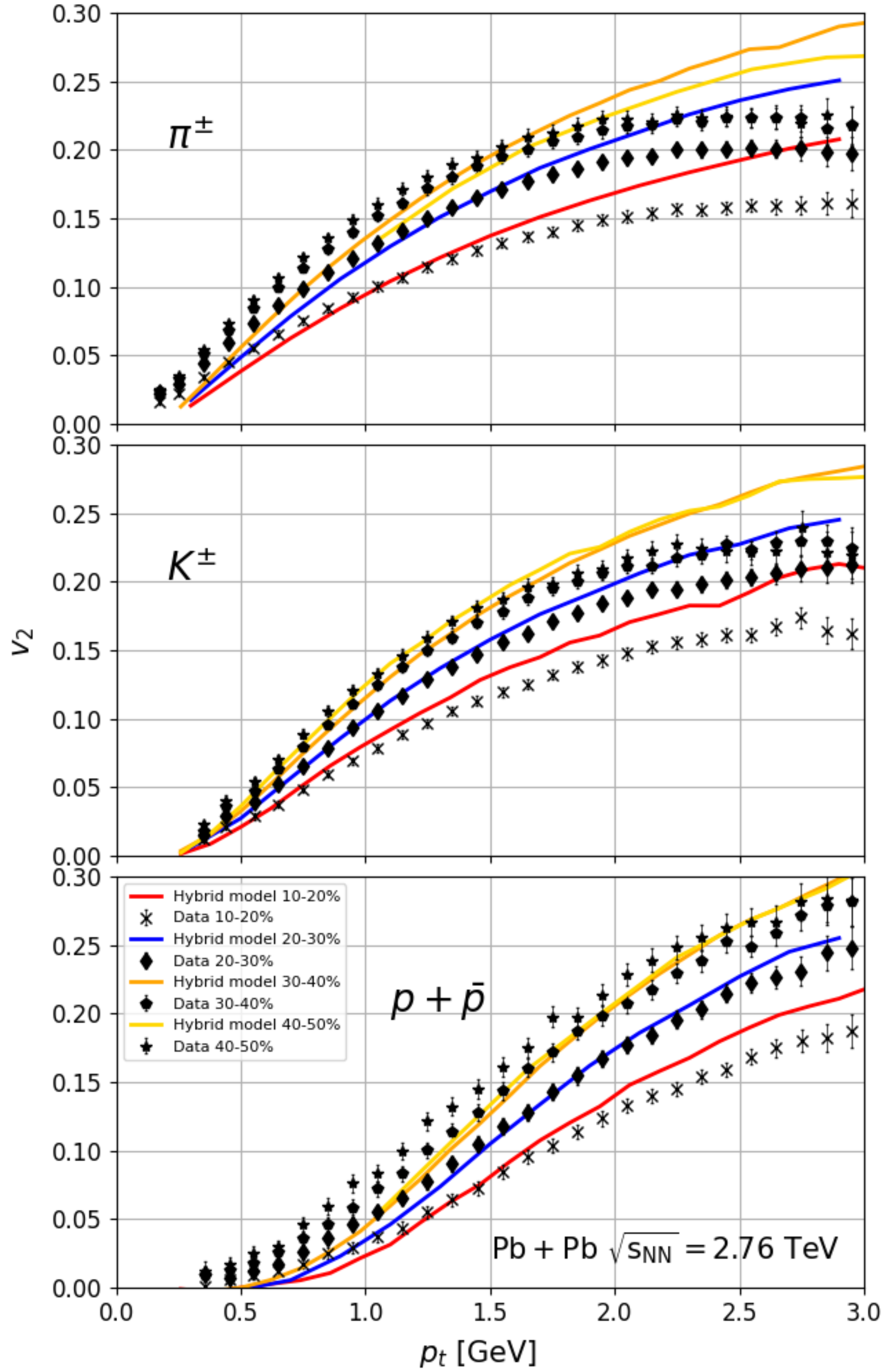
CTU CZECH TECHNICAL UNIVERSITY IN PRAGUE

MATEJ BEL UNIVERSITY

Key Insights and Results

- **Hybrid model:**
  - Trento3D - vHLLE - SMASH
  - Initial conditions → QGP evolution → Hadronic phase
- **Tuning of parameters (Trento3D, vHLLE)**
  - Spectra in p_t
  - $v_2(p_t)$ increases with p_t
  - Agreement observed $v_2(p_t)$ for kaons, pions, and protons
  - Centrality effects are captured well by the model
- **Prediction of direct deuterons production**
  - Intermediate p_t discrepancies noted for deuterons
  - First results for coalescence
- **Conclusion and outlook:**
  - The hybrid model demonstrates overall good agreement $v_2(p_t)$ with data, especially for kaons, protons, and pions
  - Outlook:
    - We aim to incorporate explicit coalescence models into the hybrid framework to compare predictions for deuterons





Thermodynamic relations for perfect spin hydrodynamics

Mykhailo Hontarenko

Institute of Theoretical Physics, Jagiellonian University, PL-30-348 Kraków, Poland

02-06.12.2024, 24th Zimányi School, Budapest

based on: W. Florkowski + MH, arXiv:2405.03263 and Z. Drogosz + WF + MH, Phys.Rev.D 110 (2024) 9, 096018

National Science Centre
Poland

The problem to be solved

The usual Israel-Stewart approach with spin uses a phenomenological form of scalar thermodynamic relations multiplied by u^μ, where $\omega_{\alpha\beta} = \Omega_{\alpha\beta}/T$ is the spin polarization tensor, thus, from

$$\varepsilon + P = T\sigma + \mu n + \frac{1}{2}\Omega_{\alpha\beta}S^{\alpha\beta} \tag{1}$$

we obtain

$$S^\mu_{\rm eq} = P\beta^\mu - \xi N^\mu_{\rm eq} + \beta_\lambda T^{\lambda\mu}_{\rm eq} - \frac{1}{2}\omega_{\alpha\beta}S^{\mu,\alpha\beta}_{\rm eq}, \tag{2}$$

$$dS^\mu_{\rm eq} = -\xi\, dN^\mu_{\rm eq} + \beta_\lambda\, dT^{\lambda\mu}_{\rm eq} - \frac{1}{2}\omega_{\alpha\beta}dS^{\mu,\alpha\beta}_{\rm eq}, \tag{3}$$

$$d(P\beta^\mu) = N^\mu_{\rm eq}\, d\xi - T^{\lambda\mu}_{\rm eq}\, d\beta_\lambda + \frac{1}{2}S^{\mu,\alpha\beta}_{\rm eq}d\omega_{\alpha\beta}. \tag{4}$$

where the spin tensor is $S^{\lambda,\mu\nu} = u^\lambda S^{\mu\nu}$. Two problems exists:
1) $S^{\lambda,\mu\nu}_{eq}$ usually has additional terms. 2) If $\omega_{\mu\nu} \sim S^{\mu\nu} \sim \mathcal{O}(\partial^1)$, the spin tensor in (1) should be neglected.

Our solution

Kinetic theory + proper counting scheme leads to:

$$S^{\mu}_{eq} = \mathcal{N}^{\mu} - \xi N^{\mu}_{eq} + \beta_{\lambda} T^{\lambda\mu}_{eq} - \tfrac{1}{2}\omega_{\alpha\beta} S^{\mu,\alpha\beta}_{eq}, \qquad \mathcal{N}^{\mu} = \coth(\xi)\, N^{\mu}_{eq} \neq P\beta^{\mu},$$

$$dS^{\mu}_{eq} = -\xi dN^{\mu}_{eq} + \beta_{\lambda} dT^{\lambda\mu}_{eq} - \tfrac{1}{2}\omega_{\alpha\beta} dS^{\mu,\alpha\beta}_{eq}, \tag{5}$$

$$d\mathcal{N}^{\mu} = N^{\mu}_{eq} d\xi - T^{\lambda\mu}_{eq} d\beta_{\lambda} + \tfrac{1}{2} S^{\mu,\alpha\beta}_{eq} d\omega_{\alpha\beta}, \tag{6}$$

$$N^{\mu}_{eq} = \bar{n} u^{\mu} + n_t t^{\mu}, \tag{7}$$

$$T^{\mu\nu}_{eq} = \bar{\varepsilon} u^{\mu} u^{\nu} - \bar{P}\Delta^{\mu\nu} + P_k\, k^{\mu} k^{\nu} + P_{\omega}\, \omega^{\mu}\omega^{\nu} + P_t\, (t^{\mu} u^{\nu} + t^{\nu} u^{\mu}). \tag{8}$$

And spin current tensor includes an ortogonal parts to u^{λ}.

$$S^{\lambda,\mu\nu}_{eq} = u^{\lambda} S^{\mu\nu} + smth^{\lambda,\mu\nu}. \tag{9}$$

Boost-invariant spin hydrodynamics with spin feedback effects

Zbigniew Drogosz, Wojciech Florkowski, Natalia Łygan, Radoslaw Ryblewski

arXiv:2411.06154

Natalia Łygan

Institute of Theoretical Physics, Jagiellonian University,
Kraków, Poland

December 5, 2024

UNIWERSYTET JAGIELLOŃSKI W KRAKOWIE

NATIONAL SCIENCE CENTRE POLAND

Our approach to spin hydrodynamics

- **motivation: spin polarization measurements in RHIC**
  1. perfect spin hydrodynamics conserves the spin part of the total angular momentum,
  2. spin-orbit interaction is dissipative (not included here),
  3. two-fold expansion: in the magnitude of $\omega_{\mu\nu}$ and gradients,
  4. my talk: perfect spin hydrodynamics for Bjorken expansion with second-order corrections [1],
- **boost-invariant** and **transversely homogeneous** system with **polarization tensor** decomposed to

$$\omega_{\mu\nu} = k_\mu U_\nu - k_\nu U_\mu + t_{\mu\nu}, \qquad t_{\mu\nu} = \epsilon_{\mu\nu\alpha\beta} U^\alpha \omega^\beta, \tag{1}$$

$$k^\mu = C_{kx} X^\mu + C_{ky} Y^\mu + C_{kz} Z^\mu, \qquad \omega^\mu = C_{\omega z} X^\mu + C_{\omega y} Y^\mu + C_{\omega z} Z^\mu, \qquad t^\mu = V_x X^\mu + V_y Y^\mu + V_z Z^\mu, \tag{2}$$

- calculations with respect to **conservation laws**

$$\partial_\mu N^\mu(x) = 0, \qquad \partial_\mu T^{\mu\nu} = 0, \qquad \partial_\lambda S^{\lambda,\mu\nu} = 0, \tag{3}$$

- **result**: overdetermined system $\Rightarrow$ additional symmetry $\Rightarrow$ mathematically allowed solutions
  1. **longitudinal configuration**

$$\boldsymbol{C}_k = (0, 0, C_{kz}), \qquad \boldsymbol{C}_\omega = (0, 0, C_{\omega z}), \tag{4}$$

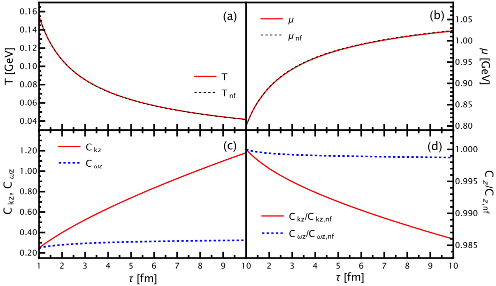
  2. **transverse configuration**

$$\boldsymbol{C}_k = \left(C_{kx}, C_{ky}, 0\right), \qquad \boldsymbol{C}_\omega = \lambda \boldsymbol{C}_k. \tag{5}$$

[1] Extension of work - W. Florkowski, A. Kumar, R. Ryblewski, R. Singh, *Spin polarization evolution in a boost invariant hydrodynamical background*, Phys. Rev. C 99, 044910 (2019), arXiv:1901.09655.

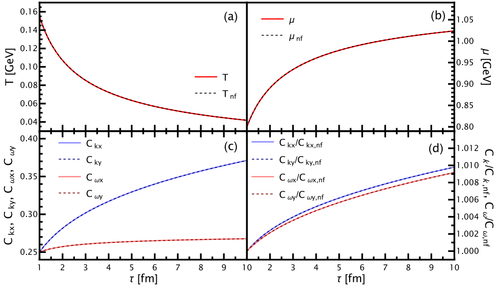
1 Longitudinal configuration

$$C^0_{kz} = C^0_{\omega z} = 0.25$$



2 Transverse configuration

$$C^0_{kx} = C^0_{ky} = C^0_{\omega x} = C^0_{\omega y} = 0.25$$



References

[1] Zbigniew Drogosz, Wojciech Florkowski, Natalia Łygan, Radoslaw Ryblewski, *Boost-invariant spin hydrodynamics with spin feedback effects* (2024), arXiv:2411.06154.

[2] J. D. Bjorken, *Highly relativistic nucleus-nucleus collisions: The central rapidity region*, Physical review D 27, 140 (1983).

[3] W. Florkowski, A. Kumar, R. Ryblewski, and R. Singh, *Spin polarization evolution in a boost invariant hydrodynamical background*, Phys. Rev. C 99, 044910 (2019), arXiv:1901.09655.

[4] W. Florkowski, *Phenomenology of Ultra-Relativistic Heavy-Ion Collisions (2010).*

[5] W. Florkowski and M. Hontarenko, *Generalized thermodynamic relations for perfect spin hydrodynamics* (2024), arXiv:2405.03263.

[6] Z. Drogosz, W. Florkowski, and M. Hontarenko, *Hybrid approach to perfect and dissipative spin hydrodynamics* (2024), arXiv:2408.03106.

Event-activity-dependent beauty-baryon enhancement in simulations with color junctions

arXiv:2408.16447 [hep-ph]

Lea Virág Földvári, Róbert Vértesi and Zoltán Varga

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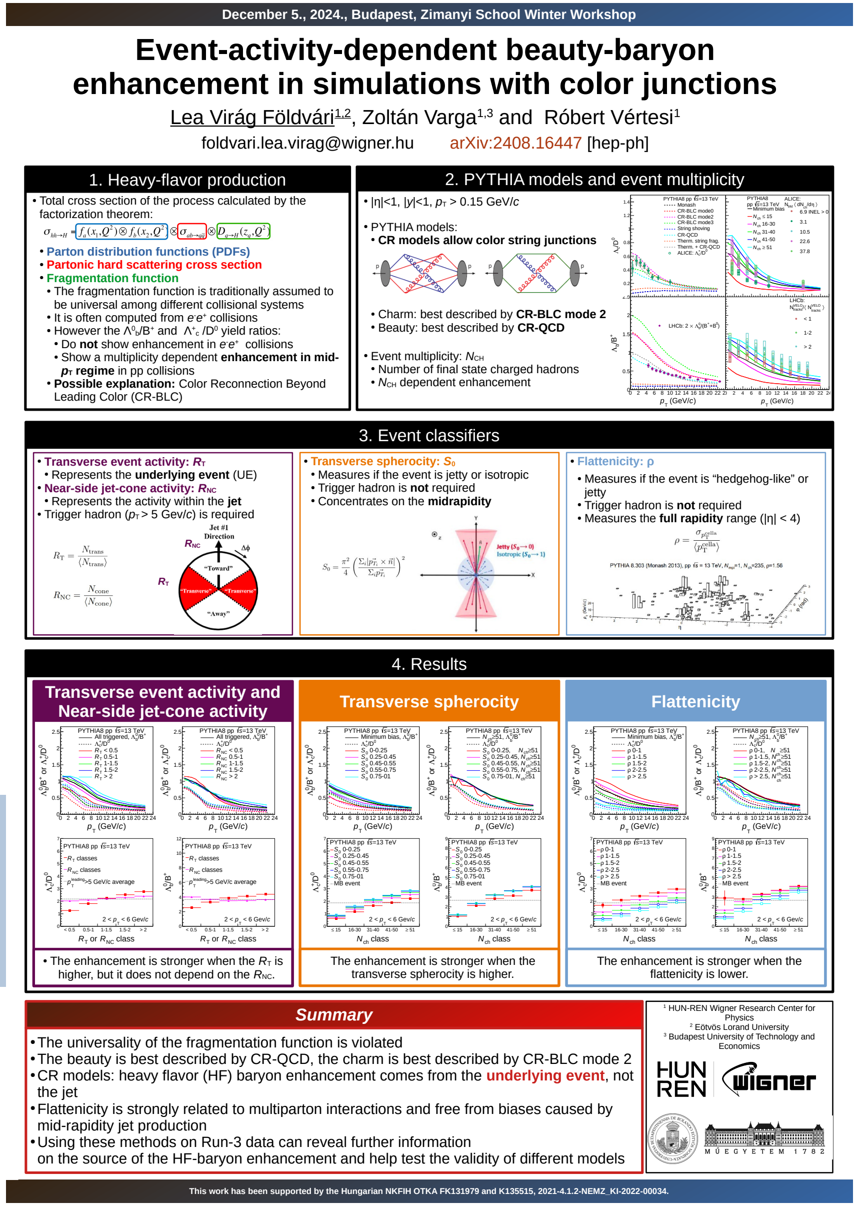

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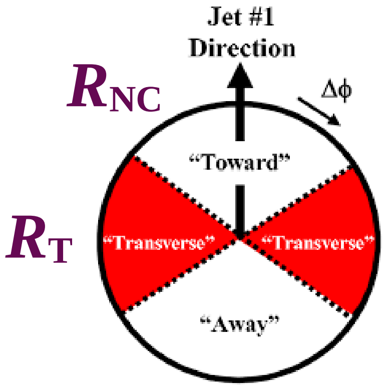
This work has been supported by the Hungarian NKFIH OTKA FK131979 and K135515, 2021-4.1.2-NEMZ_KI-2022-00034.

Event activity classifiers

- **Transverse event activity: R_T**
  - Represents the **underlying event** (UE)
- **Near-side jet-cone activity: R_{NC}**
  - Represents the activity within the **jet**
- Trigger hadron (p_T > 5 GeV/c) is required

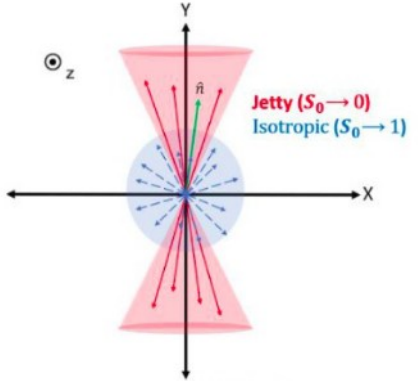
$$R_T = \frac{N_{trans}}{\langle N_{trans} \rangle}$$

$$R_{NC} = \frac{N_{cone}}{\langle N_{cone} \rangle}$$



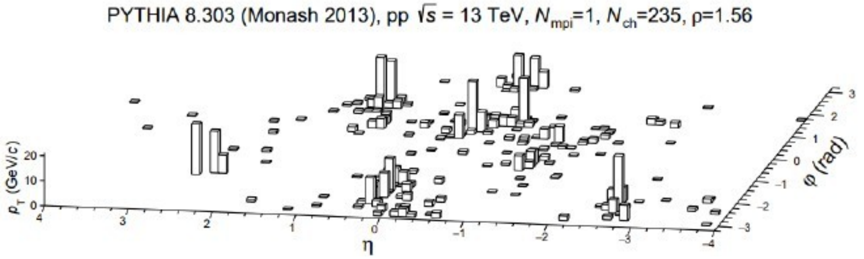
- **Transverse spherocity: S_0**
  - Measures if the event is jetty or isotropic
  - Trigger hadron is **not** required
  - Concentrates on the **midrapidity**

$$S_0 = \frac{\pi^2}{4} \left(\frac{\Sigma_i |\vec{p_{T_i}} \times \vec{n}|}{\Sigma_i p_{T_i}} \right)^2$$



- **Flattenicity: \rho**
  - Measures if the event is "hedgehog-like" or jetty
  - Trigger hadron is **not** required
  - Measures the **full rapidity** range |η| < 4

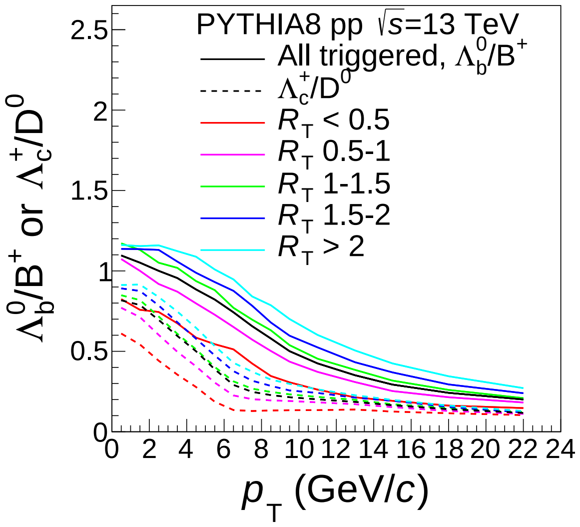
$$\rho = \frac{\sigma_{p_T^{cella}}}{\langle p_T^{cella} \rangle}$$

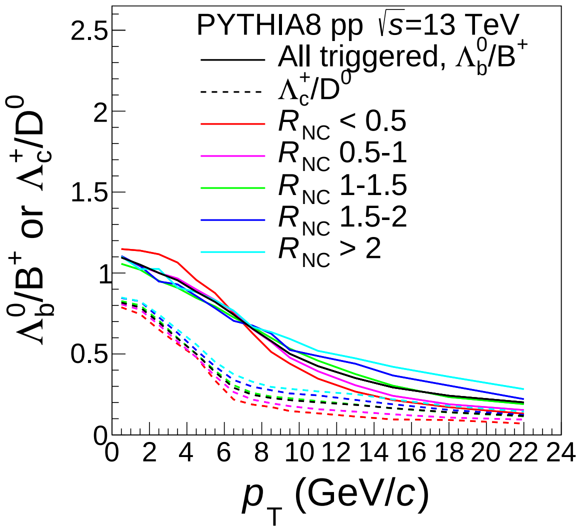


Results

***R_T* and *R_{NC}*:**

- Activity of the jet ↑
  - Enhancement does not change
- Activity of the UE ↑
  - Enhancement ↑

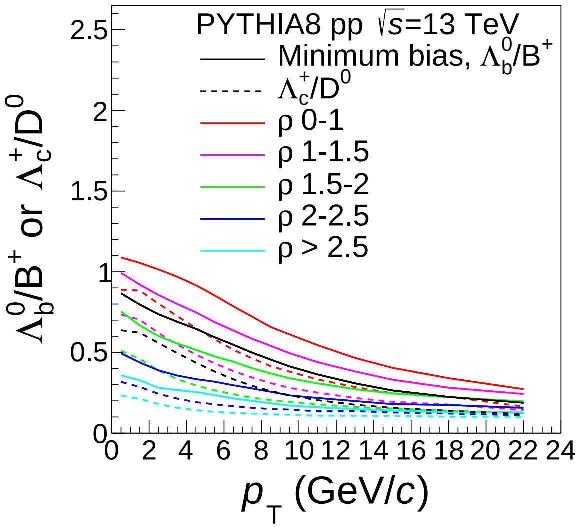


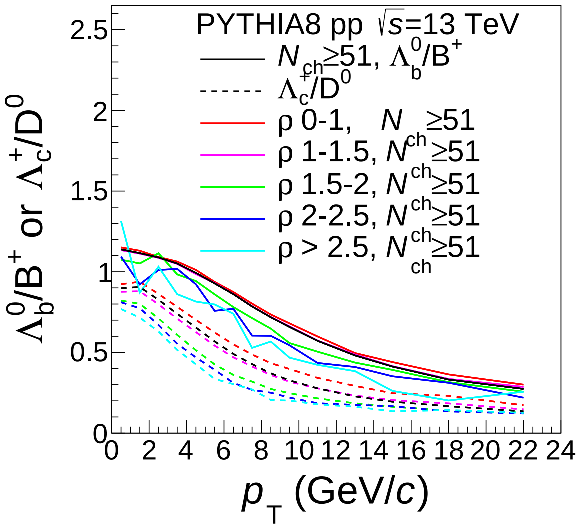


Flattenicity:

- Isotropy ↑
  - Enhancement ↑

➔ **Heavy flavor baryon enhancement comes from the UE**





Review on recent results of *J/ψ* production at STAR

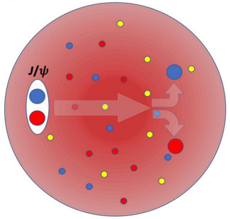
Jitka Mrázková (*for the STAR Collaboration*)

FNSPE, Czech Technical University in Prague

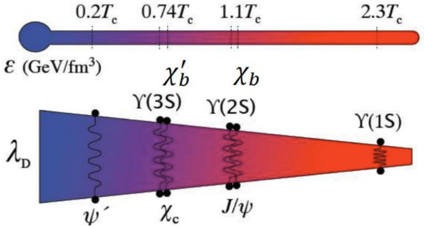
24th ZIMÁNYI SCHOOL WINTER WORKSHOP ON HEAVY ION PHYSICS (December 2-6, 2024)

STAR

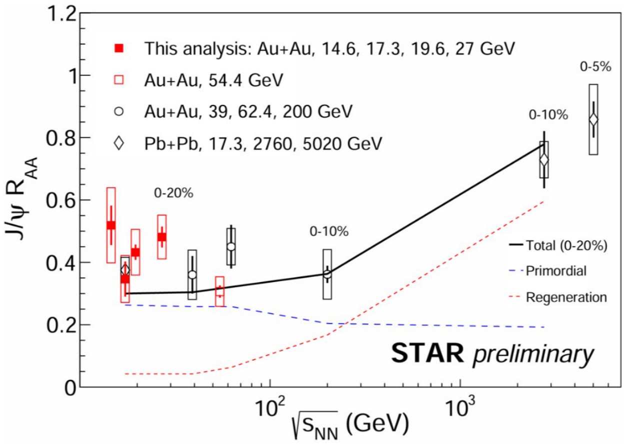
Recent results of *J/ψ* production in A+A



Credit: Q.Yang (STAR)

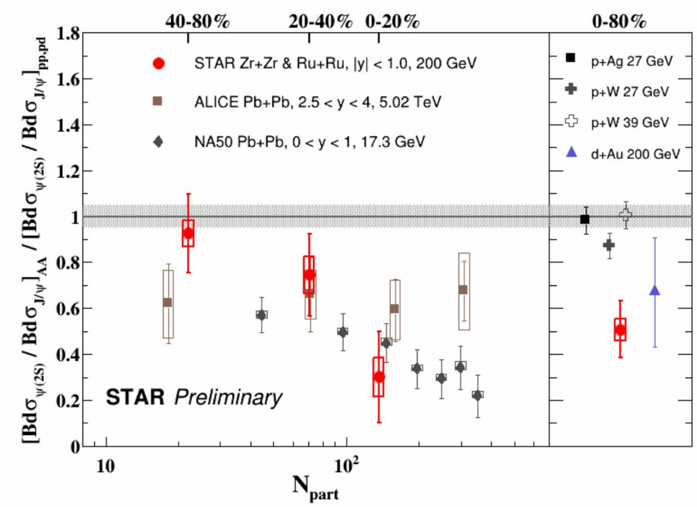


Inclusive *J/ψ* R_{AA}



No significant energy dependence in central collisions within $\sqrt{s_{NN}}$ = 14.6 – 200 GeV

ψ(2S) over *J/ψ* Double Ratio



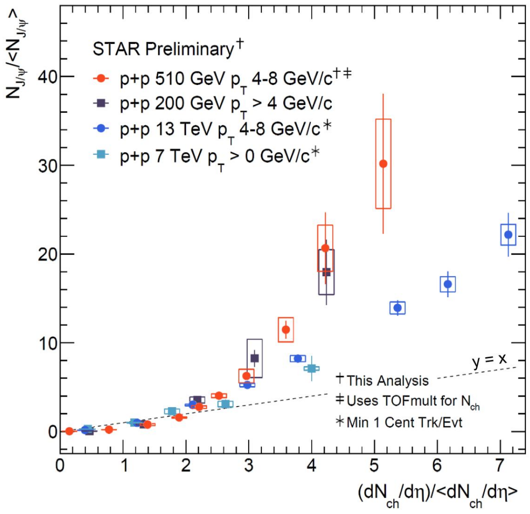
First observation of charmonium sequential suppression in heavy-ion collisions at STAR

Outlook:
The high luminosity *p+p* and Au+Au data at 200 GeV from 2023–2025 will enable more precise measurements of *ψ*(2S) production

STAR

Recent results of *J/ψ* production in *p+p*

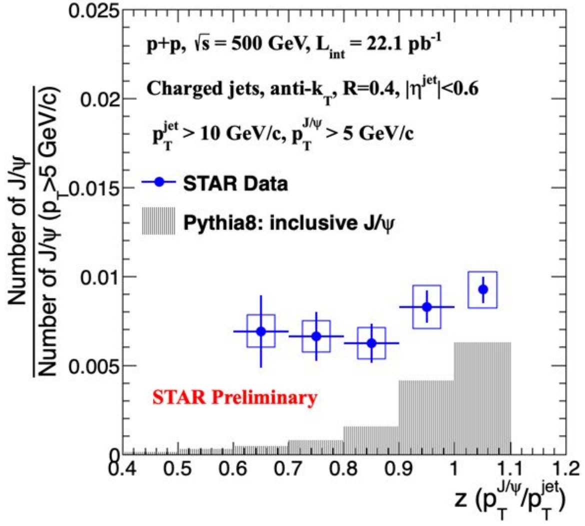
J/ψ Production vs Multiplicity in *p+p*



Sign of splitting between results at RHIC and LHC energies

The results show discrepancy with model predictions

J/ψ Production in Jets in *p+p*



Outlook:
Studies of *J/ψ* polarization in jets in *p+p* collisions are ongoing and shall provide deeper insights into the *J/ψ* production mechanism

Measurements of D^0 and D^* production in p+p collisions at $\sqrt{s}$ = 510 GeV in STAR experiment

Subhadip Pal
(for the STAR Collaboration)

Faculty of Nuclear Sciences and Physical Engineering
Czech Technical University in Prague

CTU
CZECH TECHNICAL UNIVERSITY IN PRAGUE

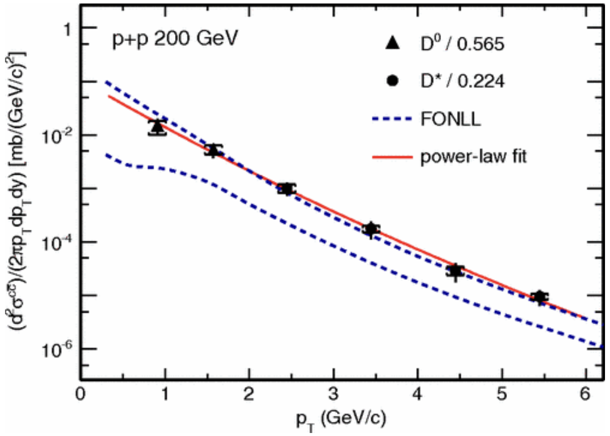
Supported in part by U.S. DEPARTMENT OF ENERGY

24th ZIMÁNYI SCHOOL WINTER WORKSHOP ON HEAVY ION PHYSICS, December 2-6 2024; Budapest

Introduction

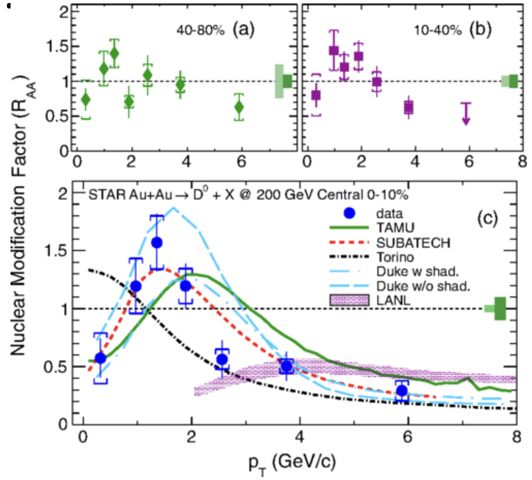
❑ Motivation:

- Studying charm meson production allows for comparisons between experimental results and theoretical models (e.g., perturbative QCD, factorization frameworks).
- Modifications of the charm meson production in heavy-ion collisions with respect to p+p provide insights into QGP.



p_T-differential $c\bar{c}$ production cross-sections compared with FONLL pQCD calculations

[Phys. Rev. D 86, 072013]



D^0 meson nuclear modification factor R_{AA}

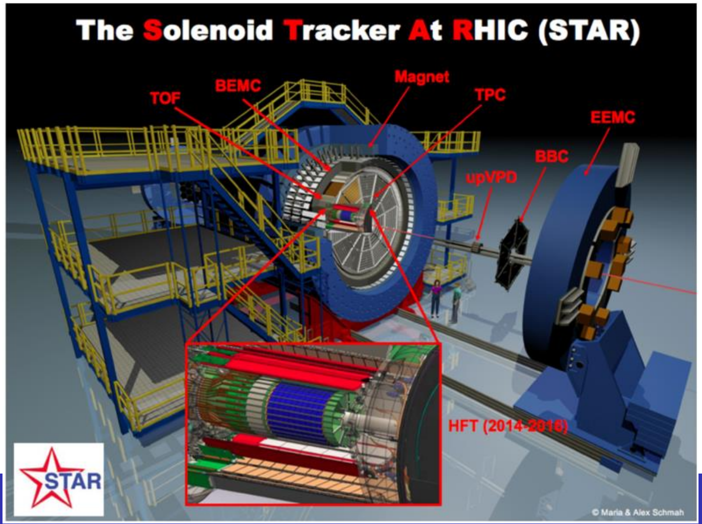
[Phys. Rev. Lett. 113, 142301]

$$D^{*\pm} \xrightarrow{B.R.=67.7\%} D^0(\overline{D^0})\pi_s^\pm \xrightarrow{B.R.=3.89\%} K^\mp\pi^\pm\pi_s^\pm$$

❑ STAR detector:

Time Projection Chamber (TPC): main tracking detector, momentum determination, particle identification via ionization energy loss (dE/dx).

Time Of Flight (TOF): particle identification via velocity (β).



Results

$$D^{*\pm} \xrightarrow{B.R.=67.7\%} D^0(\overline{D^0})\pi_s^{\pm} \xrightarrow{B.R.=3.89\%} K^{\mp}\pi^{\pm}\pi_s^{\pm}$$

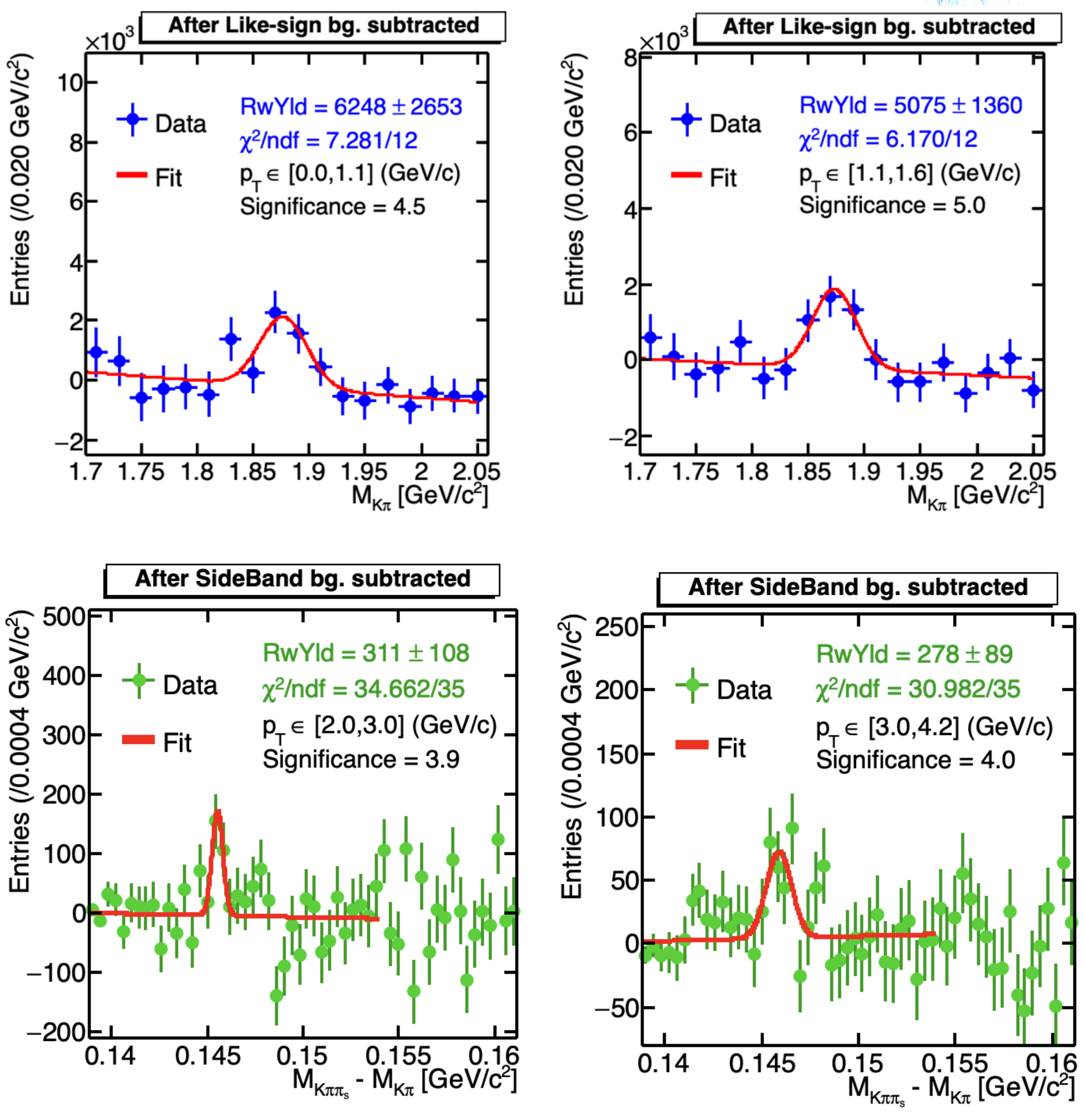
❑ D^0 signal extraction:

- Unlike-sign pions and kaons are paired.

	$p_T \leq 1.6$ GeV/c	$p_T > 1.6$ GeV/c
Kaons	$-2.5 < n\sigma_K^{dE/dx} < 3.0$ p dependent cut on $n\sigma_K^{1/\beta}$	$-2.5 < n\sigma_K^{dE/dx} < 3.0$ p dependent cut on $n\sigma_K^{1/\beta}$
Pions	$-3.0 < n\sigma_\pi^{dE/dx} < 3.0$ p dependent cut on $n\sigma_\pi^{1/\beta}$	$-3.0 < n\sigma_\pi^{dE/dx} < 3.0$ if TOF matched p dependent cut on $n\sigma_\pi^{1/\beta}$ if TOF matched $-2.5 < n\sigma_\pi^{dE/dx} < 2.5$ if no TOF info

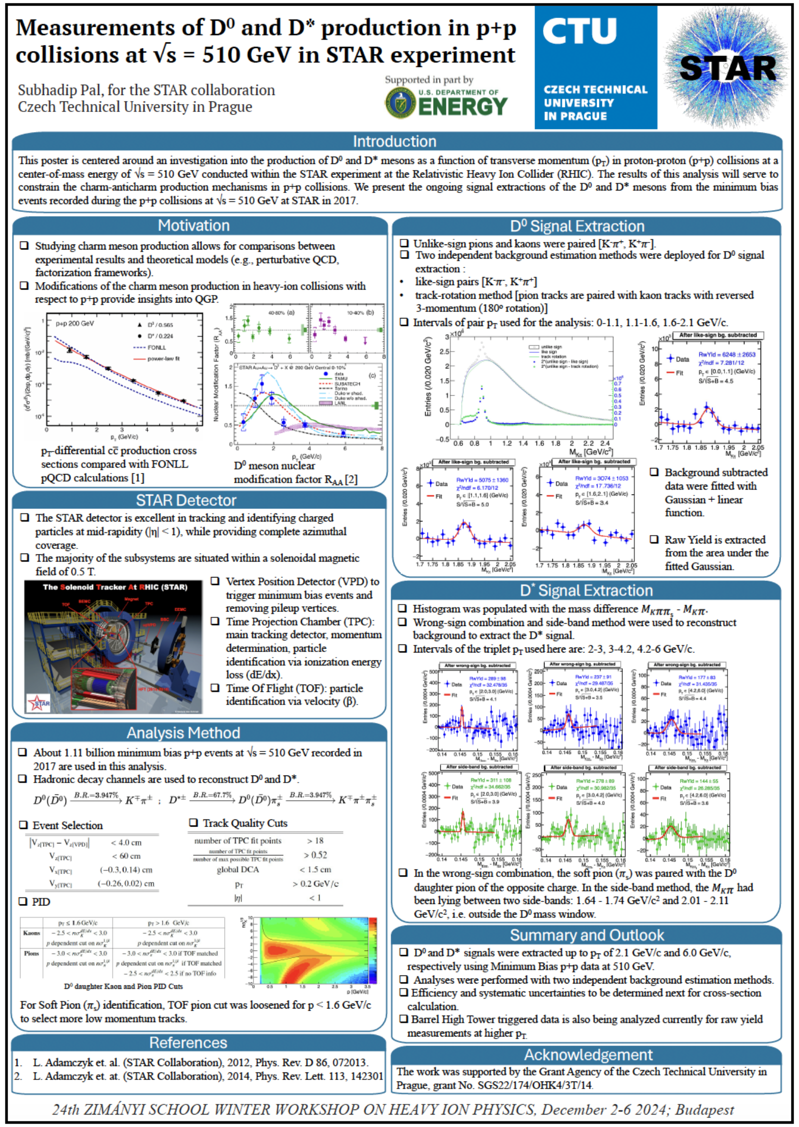
❑ D^* signal extraction:

- Histogram was populated with the mass difference: $M_{K\pi\pi_s} - M_{K\pi}$
- Wrong-Sign Combination and Side-Band Method were used to reconstruct background to extract the D* signal.



Thank you for your attention

See you at my poster



Study of Upsilon-pion Azimuthal Correlation

Kristýna Šedová

Czech Technical University in Prague - Faculty of Nuclear Sciences and Physical Engineering

Predictions and Simulations

- The aim is to study production mechanism of Upsilon
- The bound state is formed through color-singlet or color-octet channel

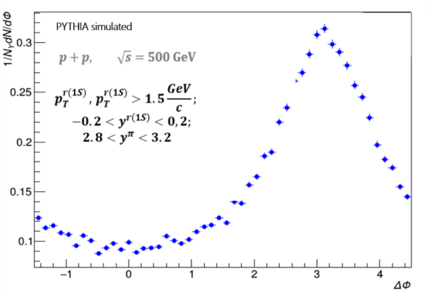


Figure 1: Upsilon-Pion azimuthal correlation using PYTHIA Generator.

Taken from: O. Mezhenska, SQM 2024.

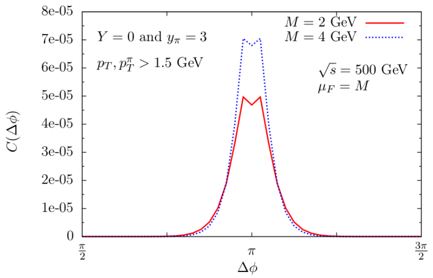


Figure 2: The correlation function $C(\Delta\varphi)$ in p+p collision at $\sqrt{s}$ = 500 GeV.

Taken from: E. Basso et al., PoS, EPS-HEP2015, 191 (2016).

Real Data

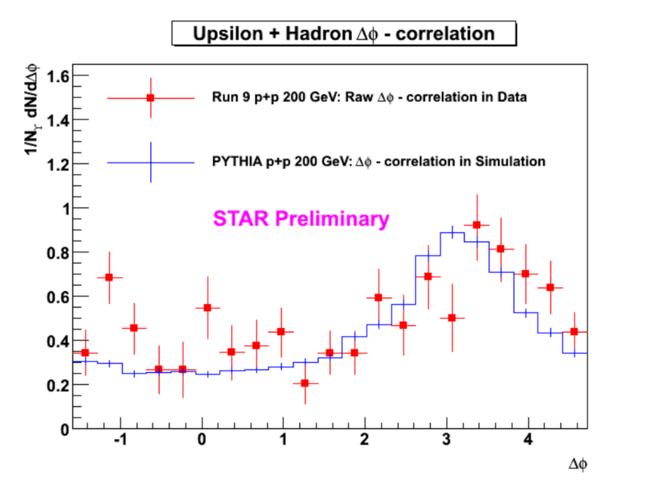


Figure 3: Upsilon-Hadron azimuthal correlation measured by STAR.

Taken from: M. C. Cervantes, J. Phys.: Conf. Ser. 316 012023 (2011).

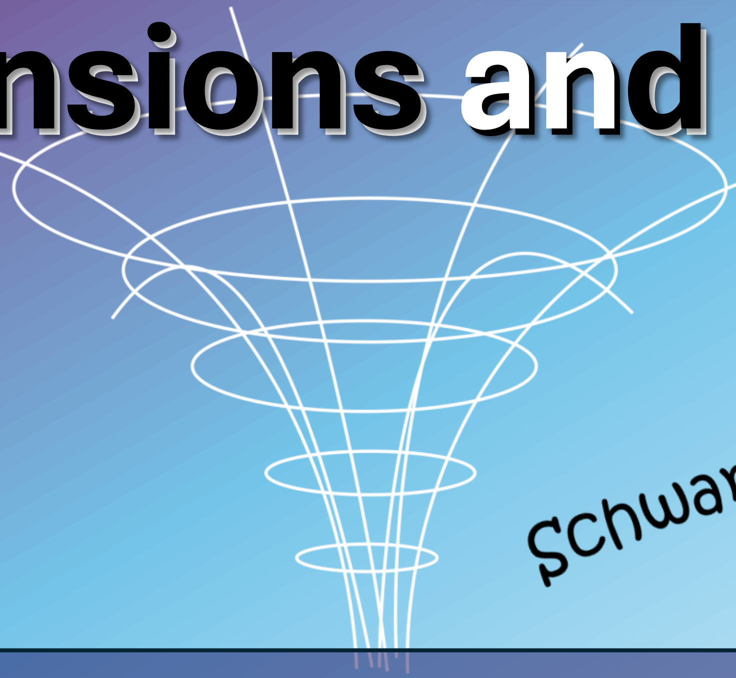
Anna Horváth, Aneta Wojnar, Gergely Gábor Barnaföldi

Kaluza – Klein theory with $1{+}3{+}1_C$ spacetime dimensions

Generalized Uncertainty Principle

$$\Delta x \Delta p \geq \frac{\hbar}{2} + \beta \Delta p^2$$

Extra dimensions and gravity



Thermodynamics and neutron stars

Black holes and a Schwarzschild-like solution

EÖTVÖS LORÁND UNIVERSITY | BUDAPEST

HUN REN | WIGNER

Acknowledgements
This work was supported by Hungarian National Research, Development and Innovation Office (NKFIH) under Contracts No. OTKA K135515, No. NKFIH NEMZ_KI-2022-00031, 2024-1.2.5-TÉT-2024-00022 and Wigner Scientific Computing Laboratory (WSCLAB, the former Wigner GPU Laboratory). Author A.H. is supported by NKFIH through the DKÖP program of the Doctoral School of Physics of Eötvös Loránd University and HUN-REN's Mobility fellowship with indentifiers KMP-2023/101 and KMP-2024/31.

Galactic rotation curves with thermodynamic gravity

Máté Pszota

in collaboration with

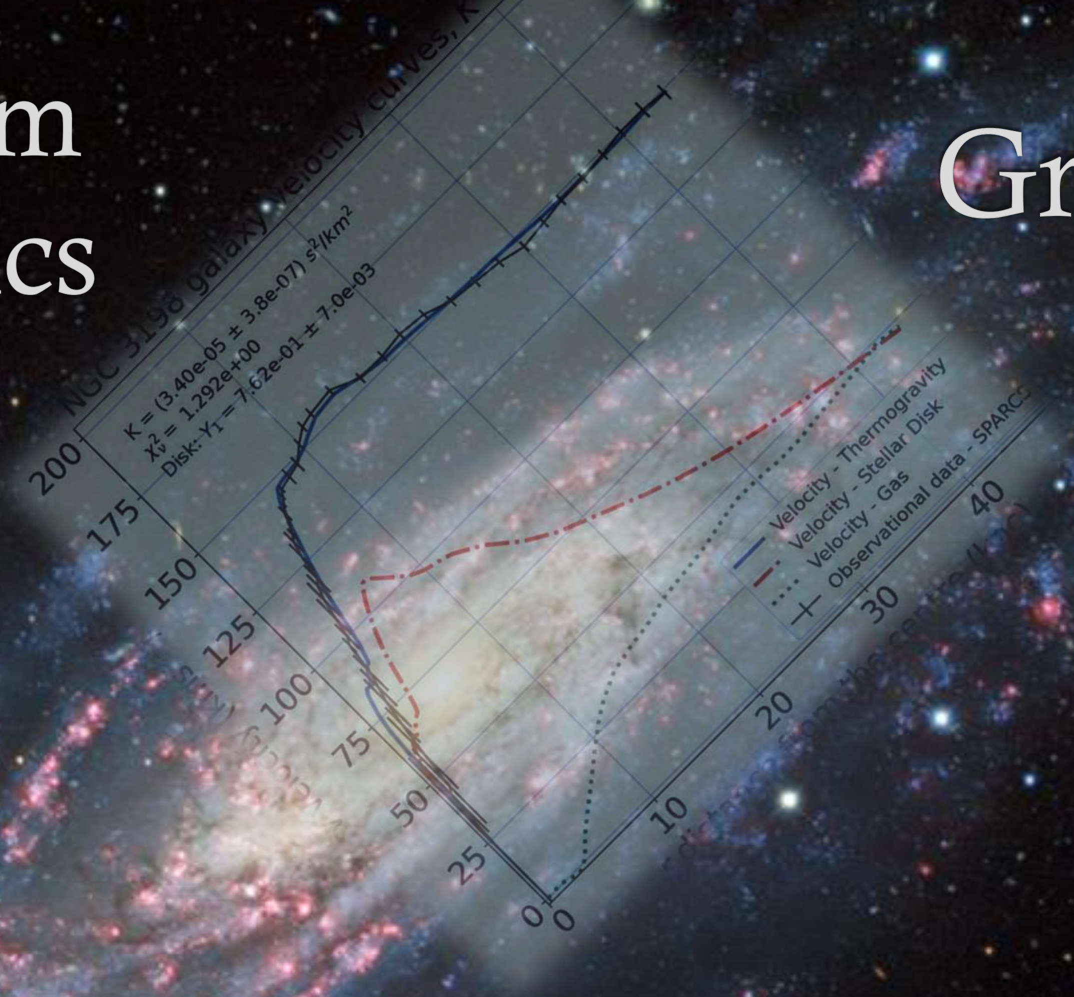
Péter Ván

HUN REN | Wigner

ELTE EÖTVÖS LORÁND UNIVERSITY

Nonequilibrium thermodynamics

Gravity



$$u = e - \varphi - \frac{\nabla\varphi \cdot \nabla\varphi}{8\pi G\rho}$$

$$\Delta\varphi = 4\pi G\rho + K(\nabla\varphi)^2$$

Image credit: KPNO/NOIRLab/NSF/AURA.

ZIMÁNYI SCHOOL 2024

L. Kassák: Image architecture

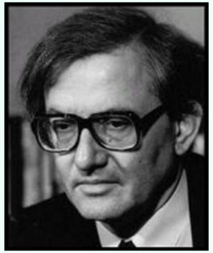
24th ZIMÁNYI SCHOOL

WINTER WORKSHOP

ON HEAVY ION PHYSICS

December 2-6, 2024

Budapest, Hungary



József Zimányi (1931 - 2006)

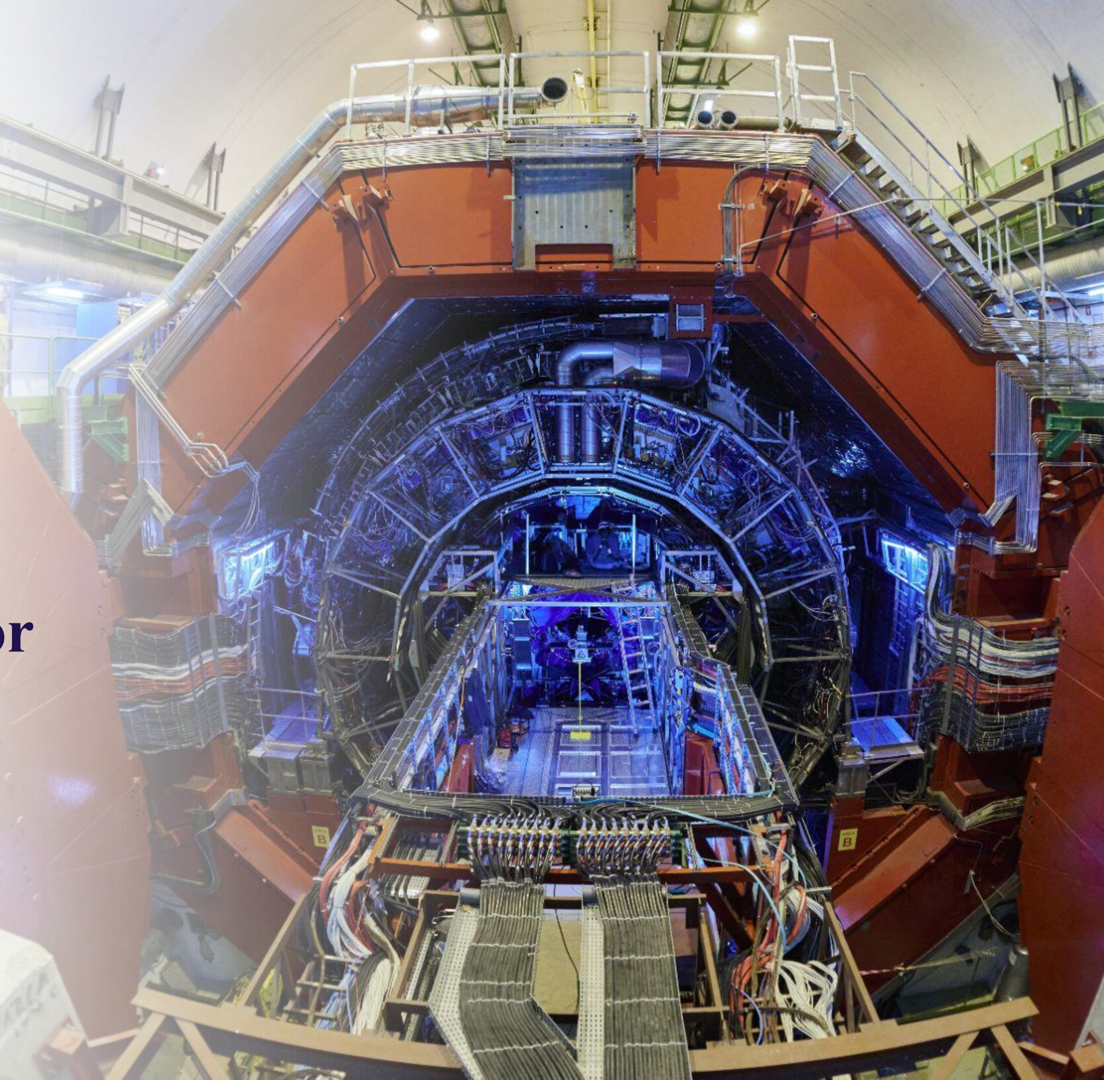
Drell-Yan measurements at low invariant masses with the upgraded ALICE detector

SAHIL UPADHYAYA

THE HENRYK NIEWODNICZAŃSKI
INSTITUTE OF NUCLEAR PHYSICS
POLISH ACADEMY OF SCIENCES
KRAKÓW, POLAND

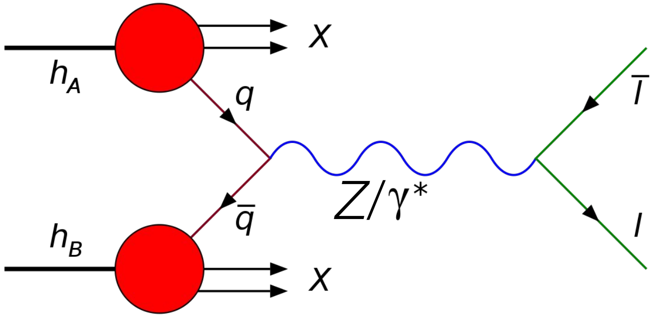
ALICE

CERN



Drell-Yan process

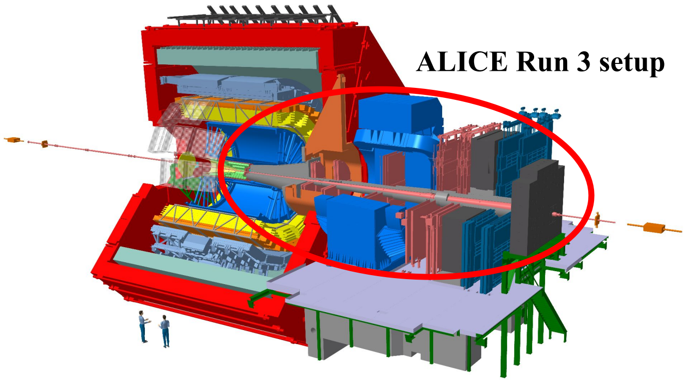
→ The Drell-Yan (DY) process is the production of a **lepton pair** from an **electroweak interaction** of a **quark-antiquark pair** :

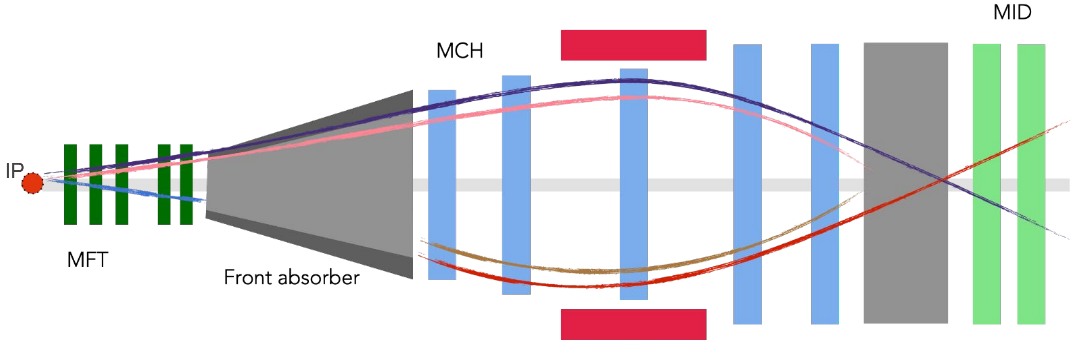


→ Measuring the DY process at LHC energies is particularly important to characterize thermodynamic and transport properties of the hot and dense medium created in ultra-relativistic heavy-ion collisions

→ Measurements provide stringent **tests for the theory of perturbative Quantum Chromodynamics** (pQCD) as well as **significant constraints on** the evaluation of **parton distribution functions** (PDFs)

Drell-Yan measurements with upgraded ALICE





→ Drell-Yan with **ALICE Run 3 setup** → ***μ+μ–*** detection and tracking in **forward direction** (–3.6 < *η* < –2.5) using the **ALICE muon spectrometer**

→ **Goal:** To measure **low-mass DY lepton pairs** (M_{DY} down to 4 GeV/c^2) to constrain nuclear PDFs at small Q^2 and *x* (**down to 10^{-5}**) where there is lack of data

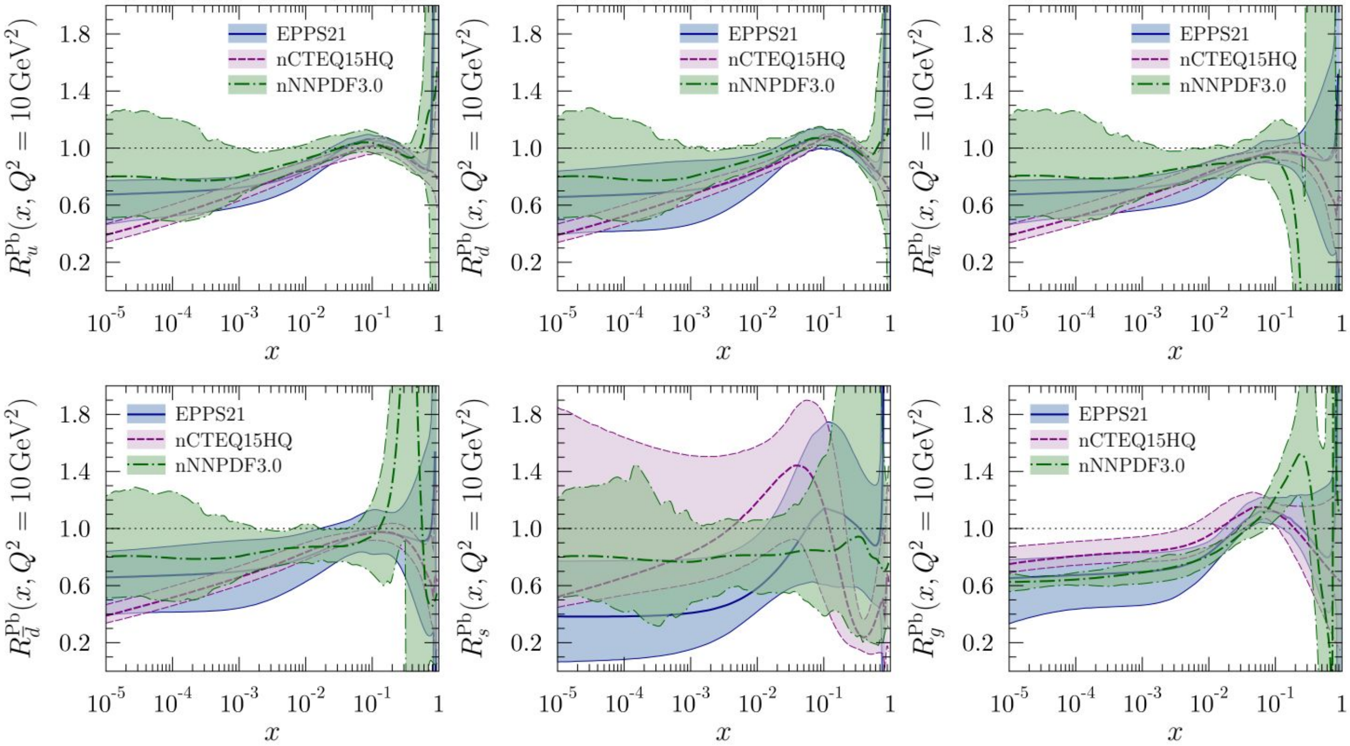
→ **~10^4 – expected Drell-Yan statistics** at forward rapidity in pp with the proposed luminosity (*L*) ~ 200/pb (Pythia and NLO calculations for lepton p_T ~ 3 GeV/c)

Prospect

→ At small-x, the ratio of the **nuclear modification factors** of DY and J/ψ in **p-Pb collisions** (R_{pPb}) can provide important **constraints on gluon densities**

→ Comparison of the ^{208}Pb nuclear modifications from the EPPS21, nCTEQ15HQ and nNNPDF3.0 global analyses of nuclear PDFs show **large uncertainties for x<10^{-3}**

→ **Certainly a need to improve the precision of the low-x calculations**

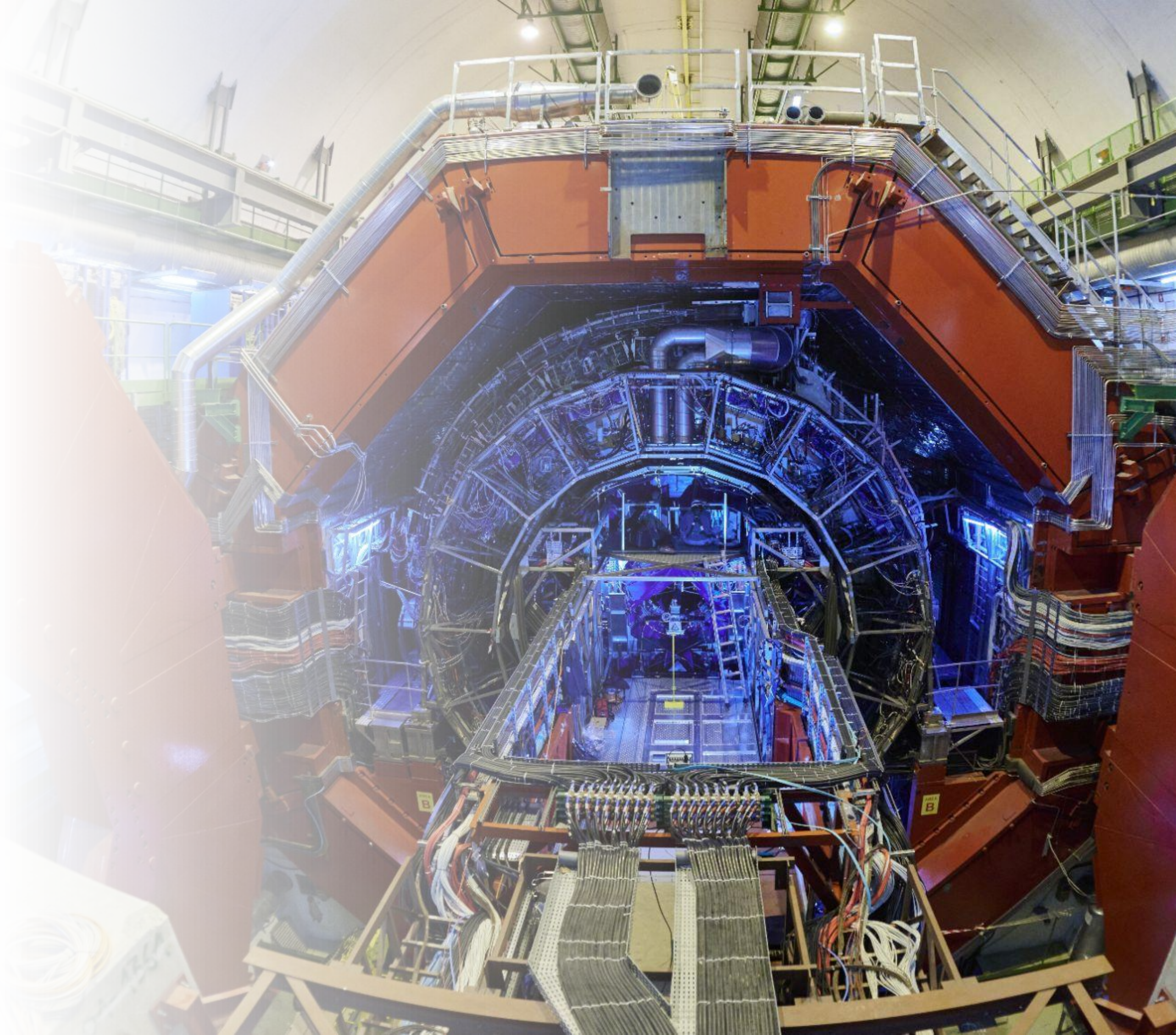


Thank You
Köszönöm

Contribution supported by the Polish Ministry of Education and Science Grant - DIR-WSIB.92.11.2023

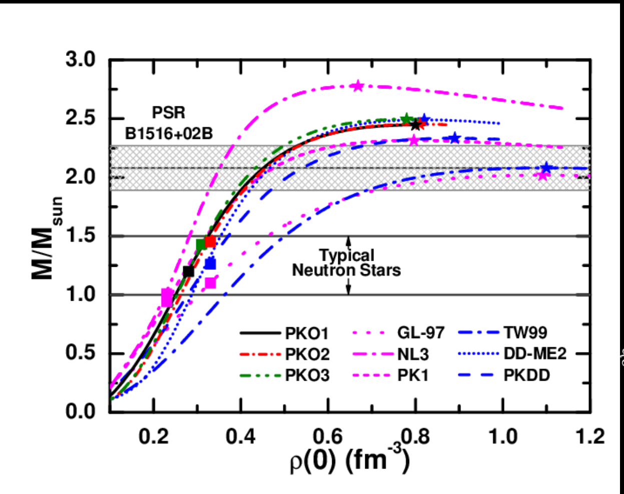
References:

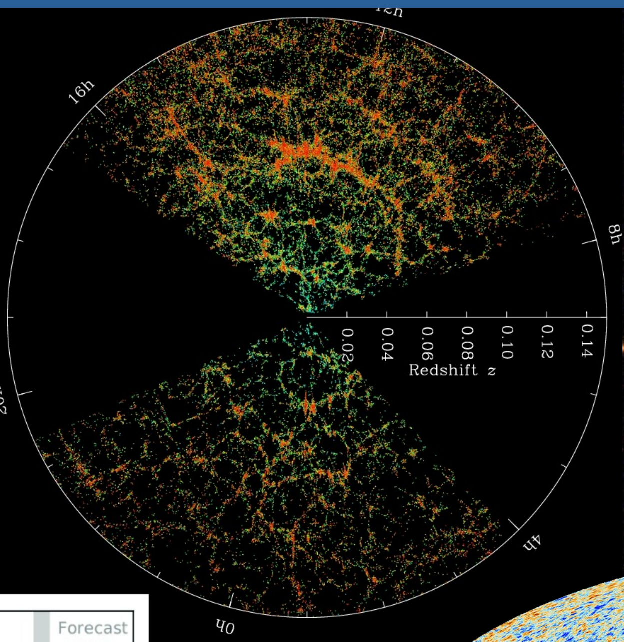
[1] Phys. Rev. Lett. **25** 316 (1970)
[2] ALICE–MFT, CERN-LHCC-2015-001, ALICE-TDR-018, May 2015
[3] POWHEG box - powhegbox.mib.infn.it
[4] CERN-THESIS-2022-319
[5] Ann. Rev. Nucl. Part. Sci. **60** (2010) 463
[6] Phys. Rev. D **58** (1998) 074012
[7] Phys. Rev. D **96** (2017) 094014
[8] arXiv:2311.00450v2

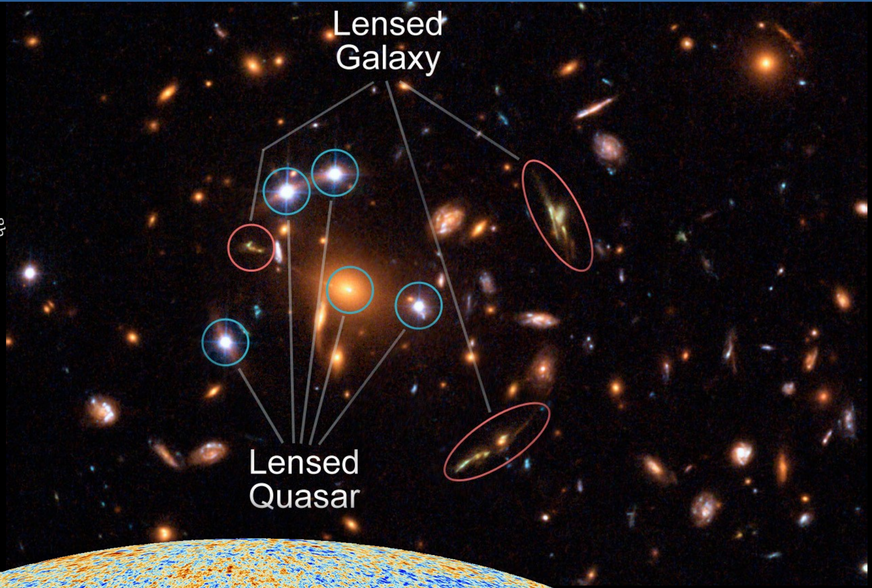


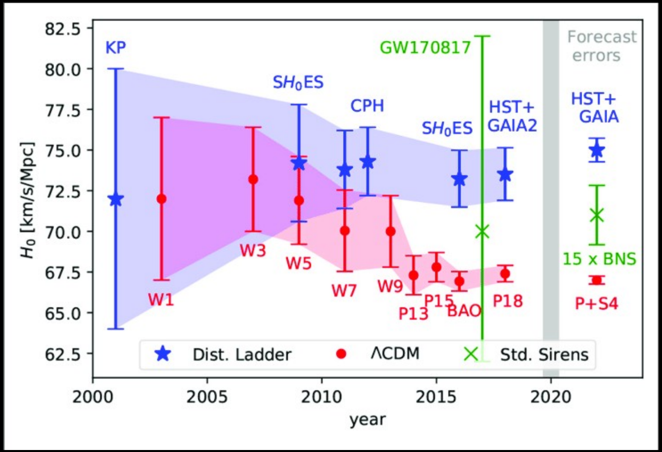
Modern Cosmology

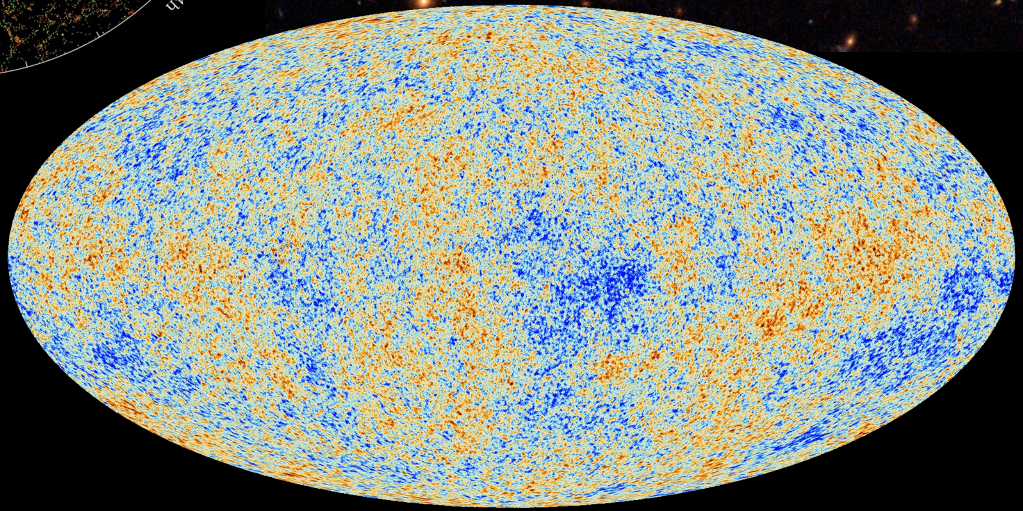
Pál Balázs
@ ELTE/Wigner
Zimányi 2024







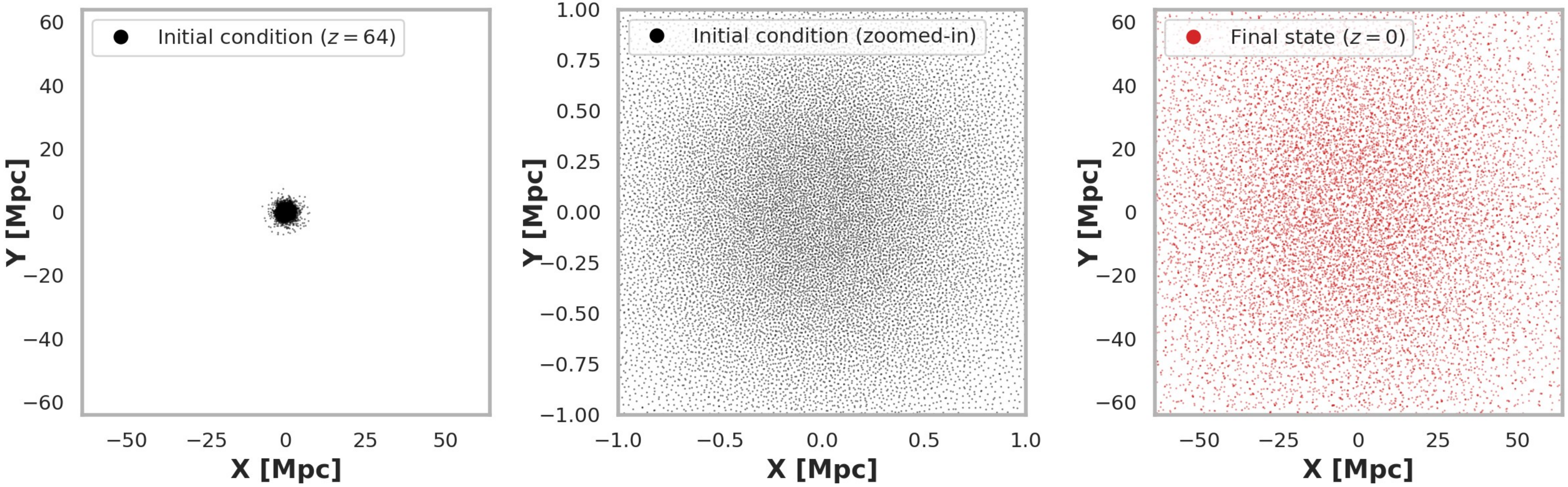




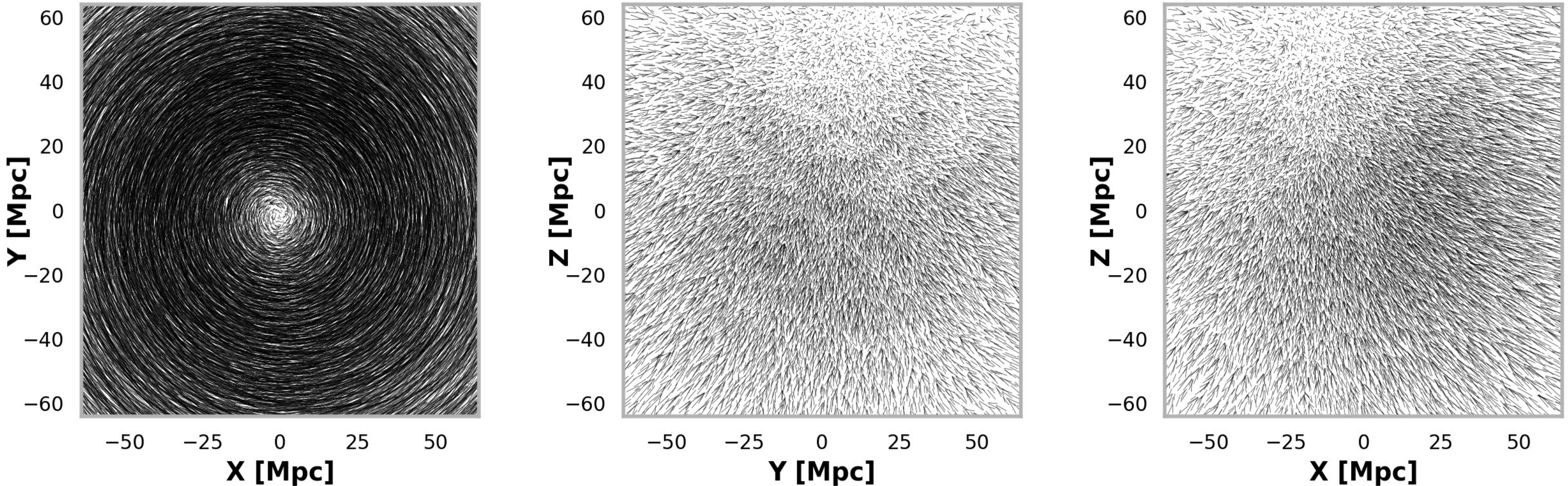
StePS rotating simulation

Pál Balázs
@ ELTE/Wigner
Zimányi 2024

Evolution



Displacement field



Measuring the expansion of the Universe

Pál Balázs
@ ELTE/Wigner
Zimányi 2024

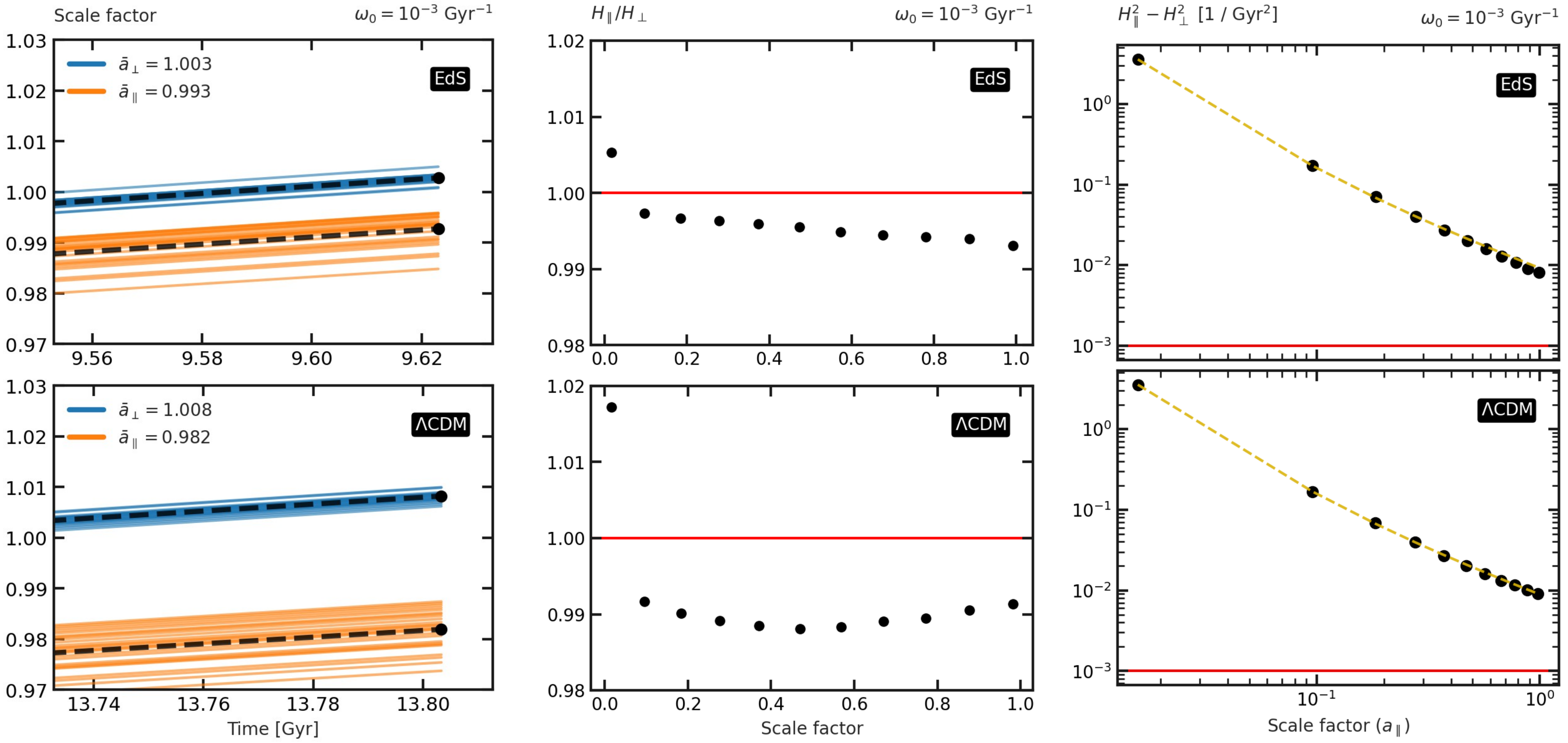


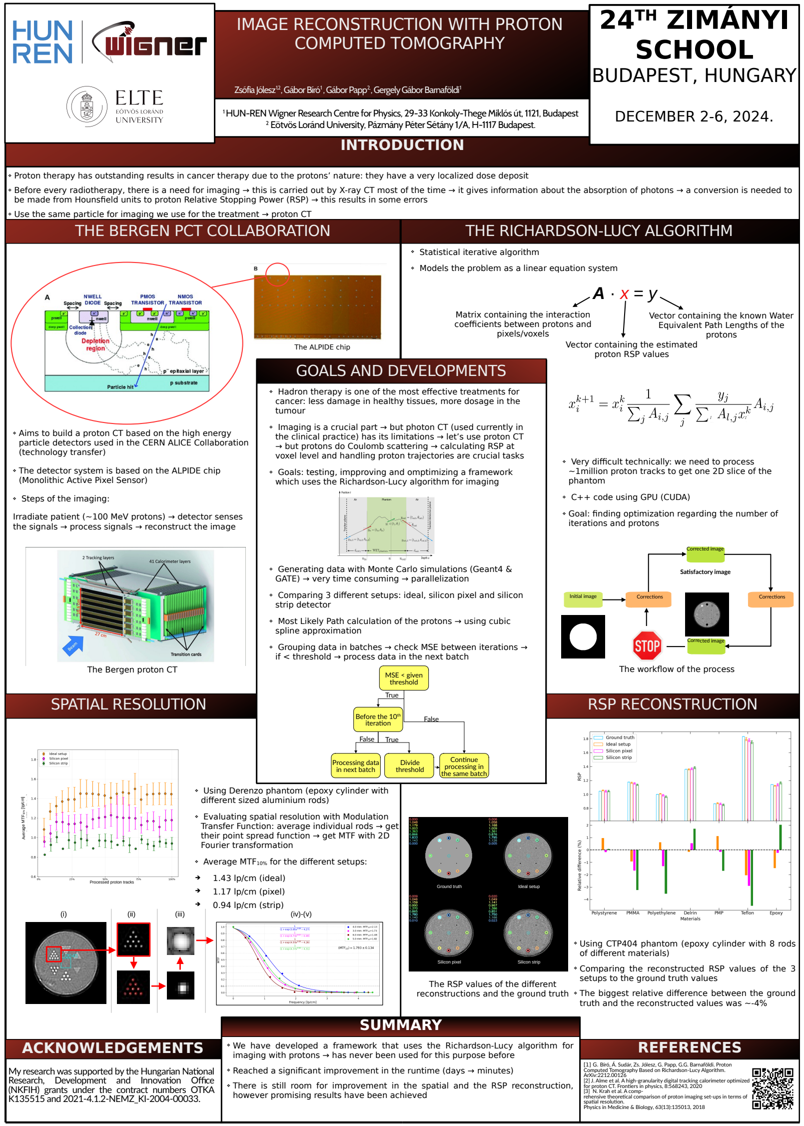
Image reconstruction
in
proton computed tomography

Zimányi Winter Workshop on Heavy Ion Physics
Budapest
2-6/12/24

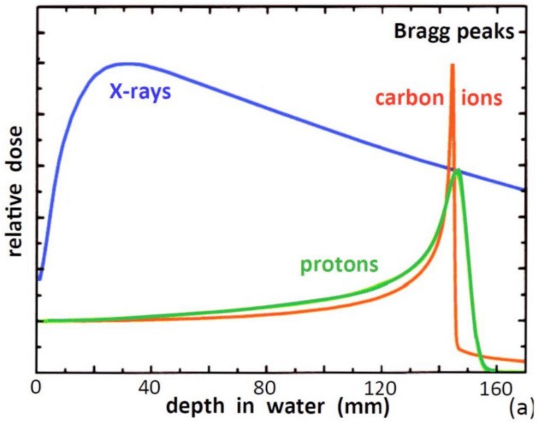
ZSÓFIA JÓLESZ
jolesz.zsofia@wigner.hun-ren.hu

Gábor Bíró
Gábor Papp

ArXiv:2212.00126

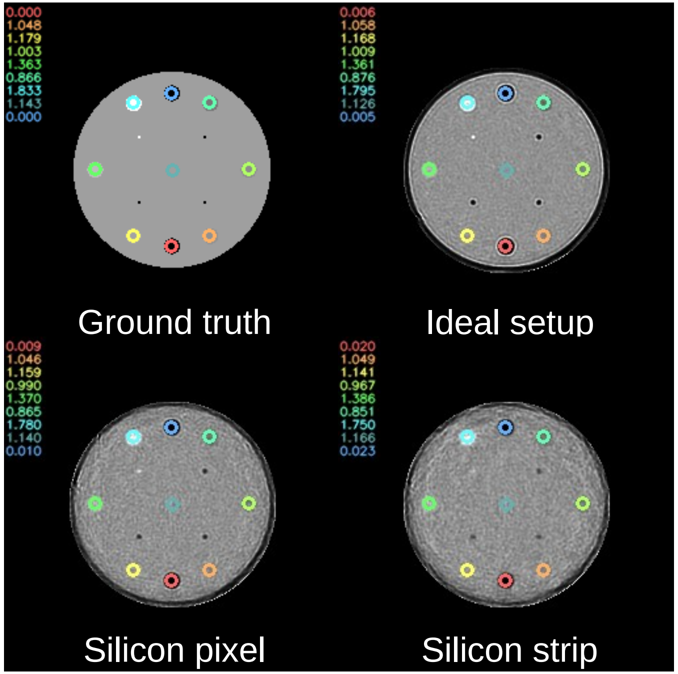


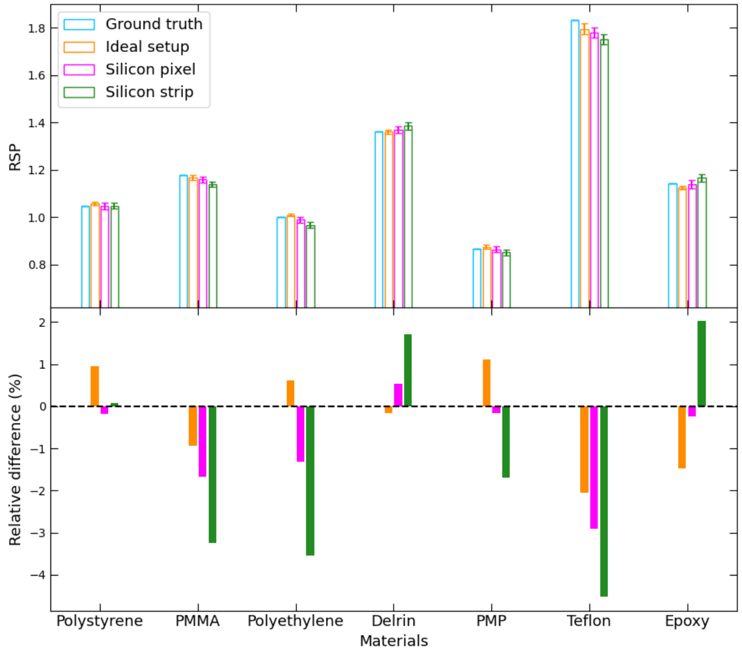
Richardson-Lucy algorithm for imaging



- Protons & heavy ions: Coulomb scattering → Bragg peak → localized dose deposit

- Hadron therapy: outstanding cancer treatment – but there are challenges with the imaging





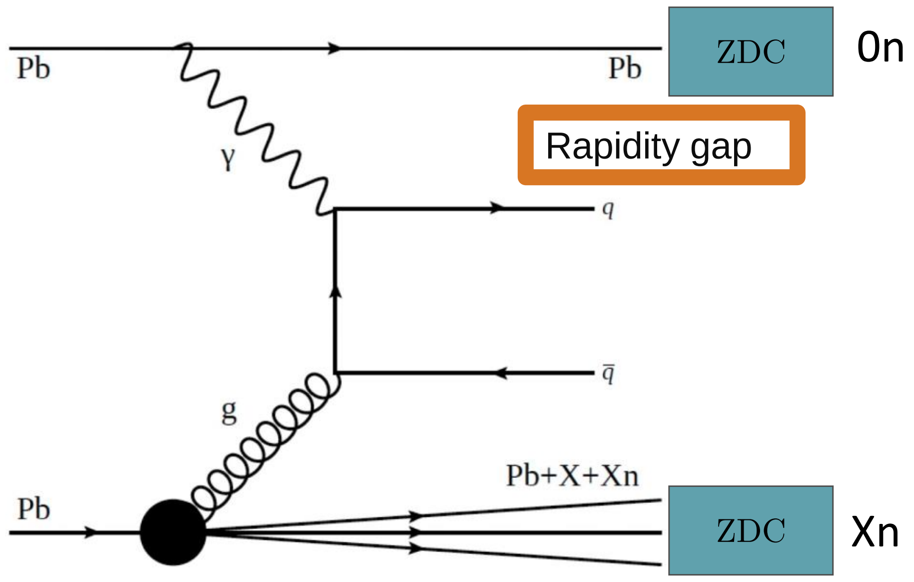
- First time using Richardson-Lucy algorithm for medical imaging
- Optimizing the framework: speed & accuracy
- Testing the algorithm on 2 phantoms: spatial resolution & RSP reconstruction
- Promising results (using ~10^6 protons), comparable with other used algorithms

First $d^2\sigma/dp_Tdy$ measurement of D^0 photoproduction in PbPb UPCs

BALÁZS CSABA KOVÁCS (ELTE) ON BEHALF OF THE CMS COLLABORATION
POSTER SESSION, 24. ZIMÁNYI SCHOOL,
2-6 DEC. 2024, BUDAPEST

D^0 photoproduction in UPCs

- D^0 mesons produced in scatterings of **quasi-real photons** emitted by one nucleus with **partons** from the other colliding nucleus
- Decay channel: $D^0 \to K^- \pi^+$ (and charge conj.)

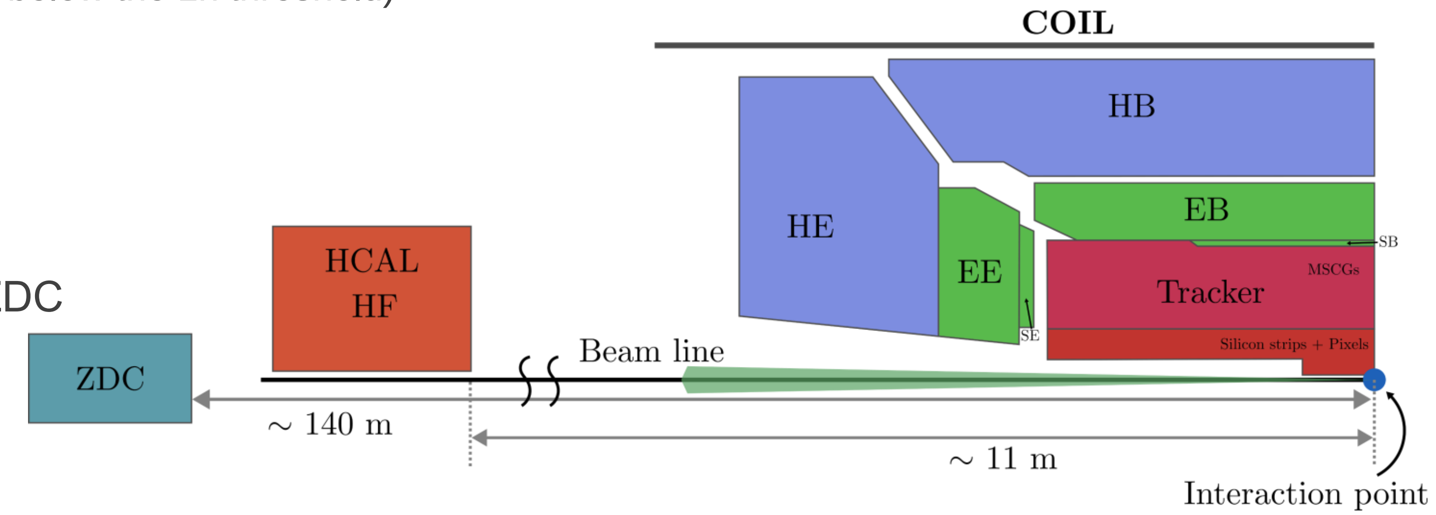


New trigger strategy for photoproduction

- New Level-1 triggers that use **both ZDC and HCAL/ECAL** information to maximize the statistics of D^0 photonuclear events
- D^0 p_T dependent trigger use:
  - **High p_T D^0 → ZDC XOR** (exactly one ZDC above the 1n threshold) **+ Jet trigger**
  - **Low p_T D^0 → ZDC OR trigger** (at least one ZDC below the 1n threshold)

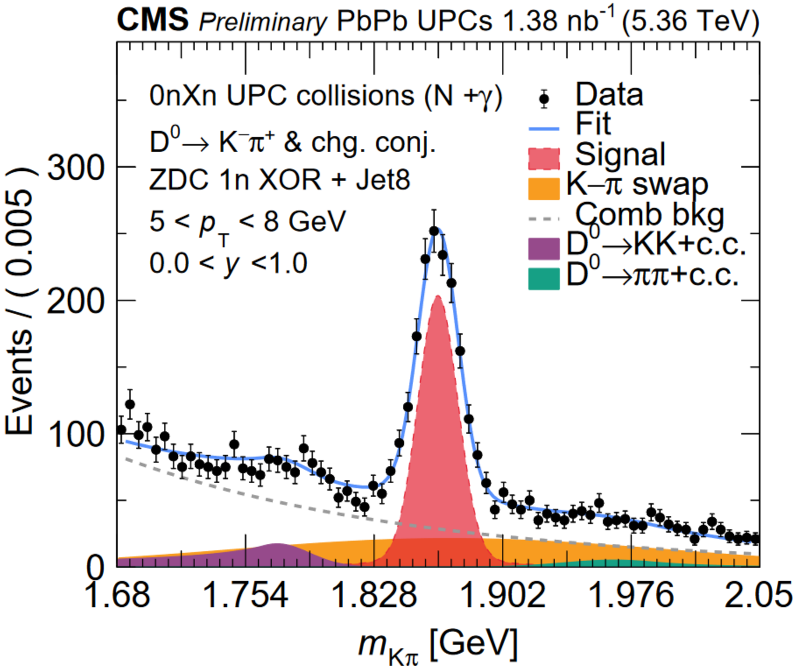
Main offline event selections

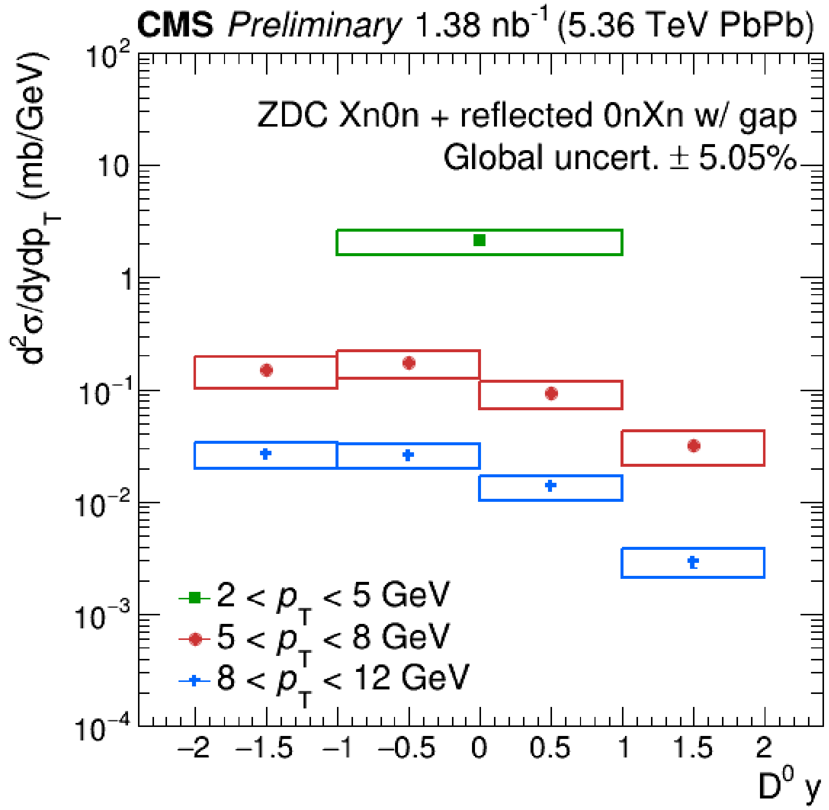
- **ZDC selection:** Xn0n or 0nXn
- **Rapidity gap** ($3 < |\eta| < 5.2$) on the side of „empty" ZDC



Final cross sections

$$\frac{d^2\sigma}{dp_T dy}(\mathrm{D}^0 p_T, \mathrm{D}^0 y) = \frac{1}{2}\frac{1}{\mathcal{L}\mathcal{B}}\frac{N^{\mathrm{raw}}_{\mathrm{D}0}}{\Delta p_T \Delta y}\frac{1}{\epsilon_{\mathrm{evt}}\ \epsilon_{\mathrm{trigger}}\ P_{\mathrm{prescale}}\ (\alpha\ \epsilon_{\mathrm{D}0})\ \epsilon_{\mathrm{EM,pileup}}}$$





- **Conclusions:**
  - New constraints on nuclear matter with open charmed hadrons in UPCs in a large region of x and Q^2
  - Future: improved (x,Q^2) reach with lower p_T measurements, heavy-flavour jets, correlations

Triggers for exclusive processes with photons and electrons in ultra-peripheral lead-lead collisions in the ATLAS experiment in Run 3

Karolina Domijan

AGH University + UNIBO

Zimanyi Winter School

05.12.2024

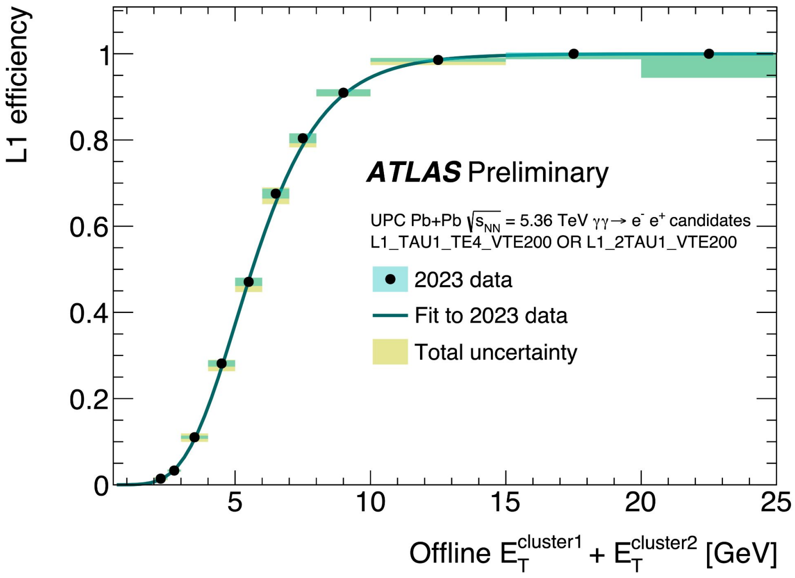
L1 trigger efficiency studies

- 2023 UPC Pb+Pb data

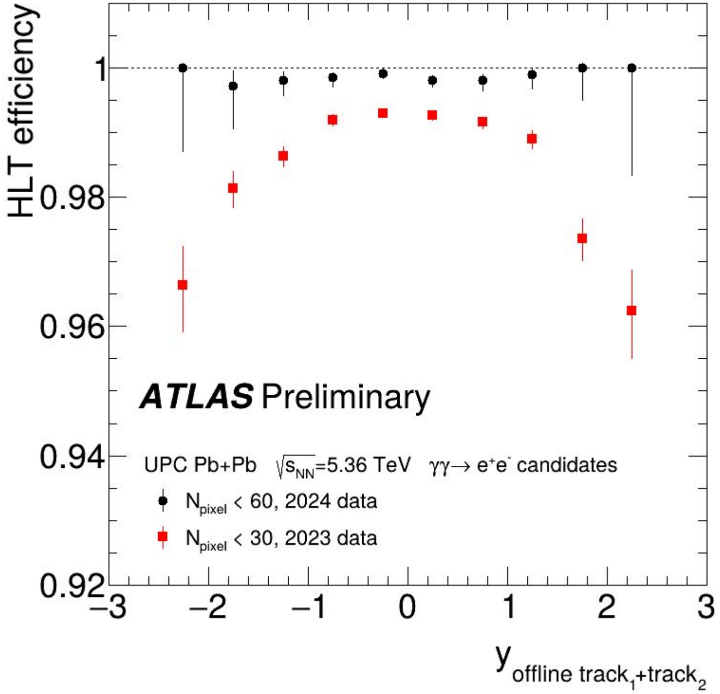
- UPC can induce a wide variety of exclusive final states in lead–lead (Pb+Pb) collisions – dileptons, dijets, and diphotons, e.g. **light-by-light scattering**

- The performance is calculated for the log OR of two triggers, L1_TAU1_TE4_VTE200 and L1_2TAU1_VTE200, and is compared with 2018 reference data.

- The poster discusses the full performance analysis of the L1 trigger with a systematic uncertainty study



HLT trigger efficiency studies



- A comparison between **2023** and **2024** vpix trigger efficiency
- This trigger is essential for measuring photons, i.e. **light-by-light scattering**
- Veto for events with more than 30 pixel hits was introduced in Run 3 after vpix15 was deemed inefficient during the Run 2
- Veto for events with more than 60 pixel hits was introduced in 2024 in order to increase performance and reduce dependence on rapidity

CMS luminosity measurement for nucleus-nucleus collisions at 5.02 TeV

Krisztián Farkas
CMS-ELTE Lendület group
Eötvös University, Budapest

Luminosity introduction

- Determines the rate of particle collisions
- Relates the cross section of process to the observed rate

$$R(t) = \frac{dN}{dt} = L(t) \cdot \sigma_{process}$$

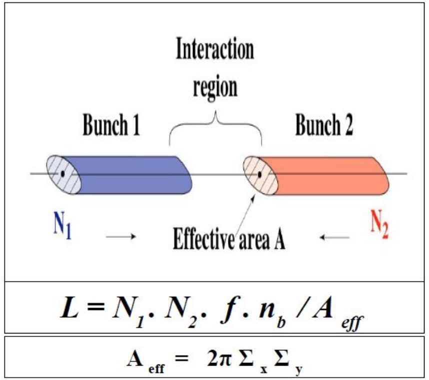
$$\sigma_{vis} = \frac{2\pi \cdot \Sigma_x \cdot \Sigma_y}{N_1 \cdot N_2 \cdot f \cdot n_b} \cdot R_{peak}$$

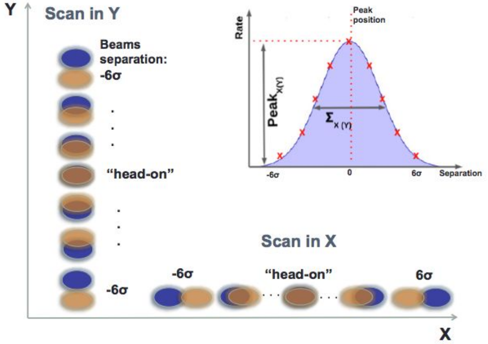
Why precise luminosity measurement is important?

➔ Real-time feedback on accelerator performance

Luminosity measurement

- Using well-known physics process
- Using machine parameters ➔ Beam overlap widths are obtained from vdM scan



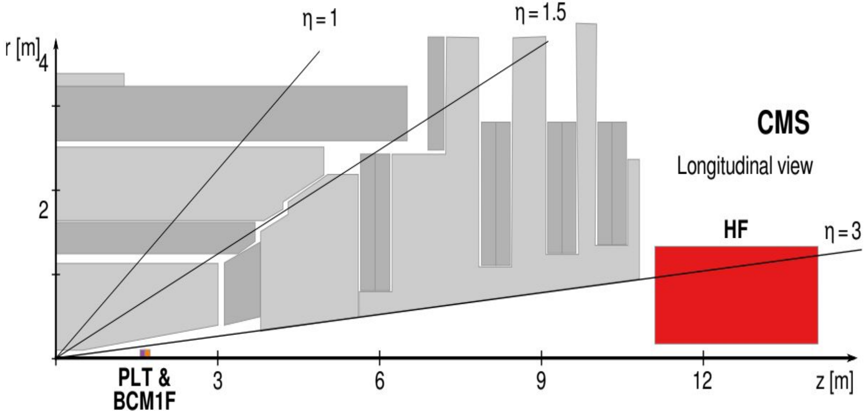


- Beams are separated in X, Y in discrete steps and measure the rate
- Various corrections applied
- Detector dependent calibration constant σ_{vis} measured then used during physics fills

CMS luminometers

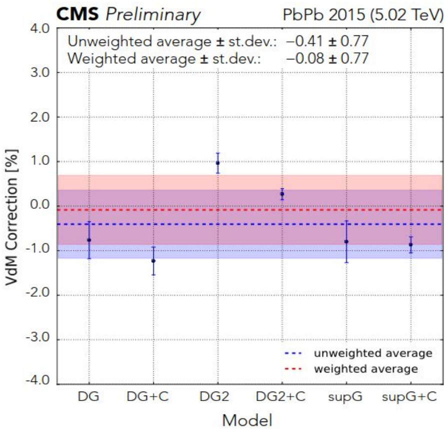
Requirement: linear measured rate-luminosity response or at least correctability

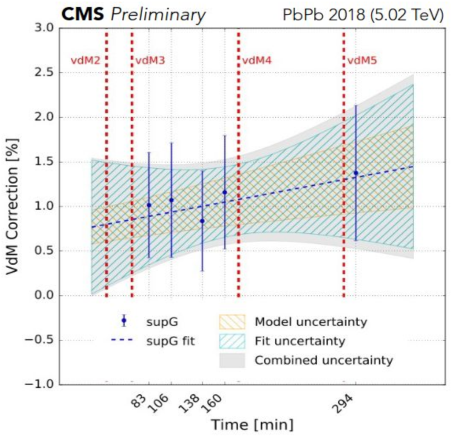
- Pixel Luminosity Telescope
- Hadron Forward calorimeters
- Fast Beam Condition Monitor
- Beam Position Monitors



Corrections to absolute luminosity

- Bunch current normalization
- Non-collision rate
- Orbit drift
- Length scale calibration
- Beam-beam effects
- Transverse factorizability



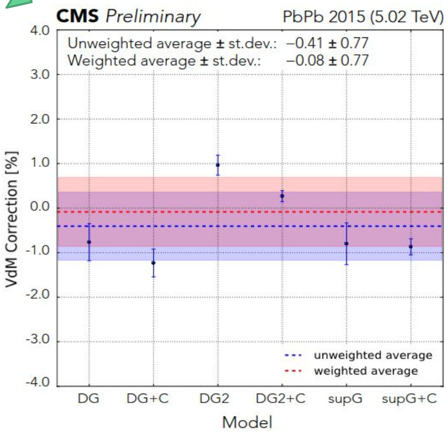


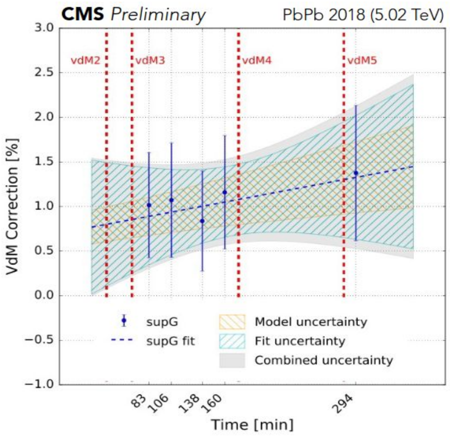
Corrections to absolute luminosity

- Bunch current normalization
- Non-collision rate
- Orbit drift
- Length scale calibration
- Beam-beam effects
- Transverse factorizability

Source	2015 [%]	2018 [%]	Corr
Normalization uncertainty			
Bunch population			
Ghost and satellite charge	0.3	0.5	Yes
Beam current calibration	0.2	0.2	Yes
Noncolliding bunches			
Noncollision rate	0.5	0.2	No
Beam position monitoring			
Random orbit drift	0.5	0.1	No
Systematic orbit drift	0.2	0.2	Yes
Beam overlap description			
Length scale calibration	0.5	0.5	Yes
Beam-beam effects	0.2	0.3	Yes
Transverse factorizability	1.1	1.1	No
Result consistency			
Cross-detector consistency	2.5	0.4	No
Scan-to-scan variation	—	0.5	No
Statistical uncertainty	0.2	0.1	No
Integration uncertainty			
Detector performance			
Cross-detector stability	0.7	0.8	No
Noncolliding bunches			
Noncollision rate	0.1	0.1	Yes
Total normalization uncertainty	2.9	1.5	—
Total integration uncertainty	0.7	0.8	—
Total uncertainty	3.0	1.7	—

Combined 2015+2018: 1.6% precision





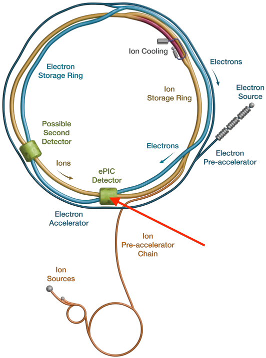
Performance of the nHCal for ePIC experiment based on Simulations

Alexander Godál

Faculty of Nuclear Sciences and Physical Engineering,
Czech Technical University in Prague

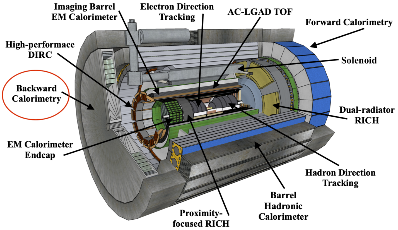
Thursday, 5 December 2024

Electron-Ion Collider and ePIC detector



- approved accelerator for BNL
- repurposing a lot of infrastructure from RHIC
- both colliding beams polarised
- center-of-mass energies in the range from 20 GeV up to 140 GeV

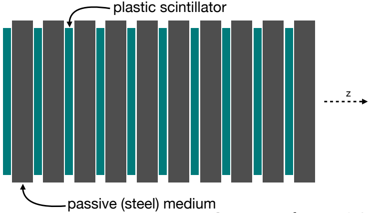
- 9.5 m long cylindrical barrel detector
- located at Interaction Point 6
- tracking and vertexing, PID, EM and hadronic calorimetry
- asymmetrical design to accommodate the difference in energies of opposing colliding beams
- large coverage in pseudorapidity



Negative Hadronic Calorimeter (nHCal) and Simulations

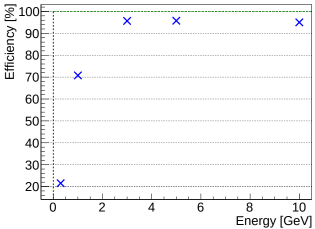
- sampling calorimeter in e^- direction
- tail catcher for ECal in e^- PID
- critical for ePIC $\rightarrow$ enables precise studies at low-x

$\downarrow$ 4 mm plastic scintillators $\times$ 10



$\uparrow$ 4 cm non-magnetic steel $\times$ 10

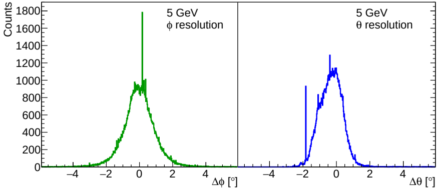
RECONSTRUCTION EFFICIENCY



- improves with higher energies
- efficiency $> 95\%$ for $E \geq 5$ GeV

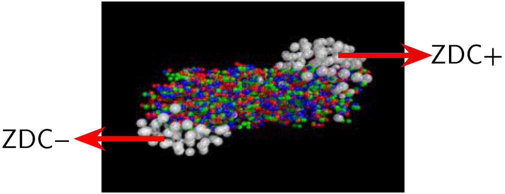
ANGULAR RESOLUTION $\longrightarrow$

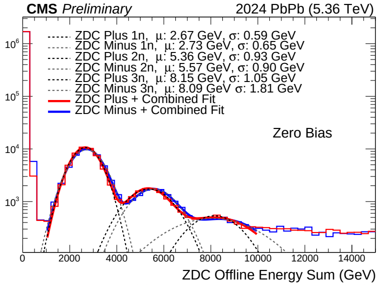
$\hookrightarrow$ difference of reconstructed and Monte Carlo angles



Motivation and physics behind the ZDC

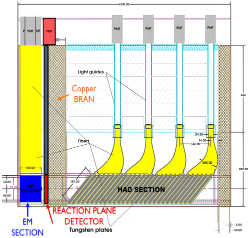
- heavy-ion collisions: centrality connected to spectator neutrons
- ZDC classifies events based on neutron emission
- different neutron emission = different classes of ultra-peripheral events
- UPC: large impact parameter, no hadronic interactions
- photon-ion and photon-photon collisions

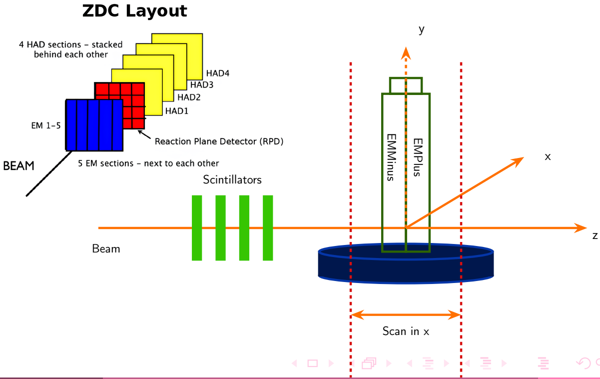




The CMS ZDC detector

- measures spectator neutrons and photons
- sampling calorimeters 140 m from CMS
- tungsten plates and quartz fibers
- EM and HAD sections: photons and neutral hadrons
- RPD: event plane for flow measurements





Eötvös Loránd University

Wigner research center for physics

ZIMÁNYI SCHOOL 2024

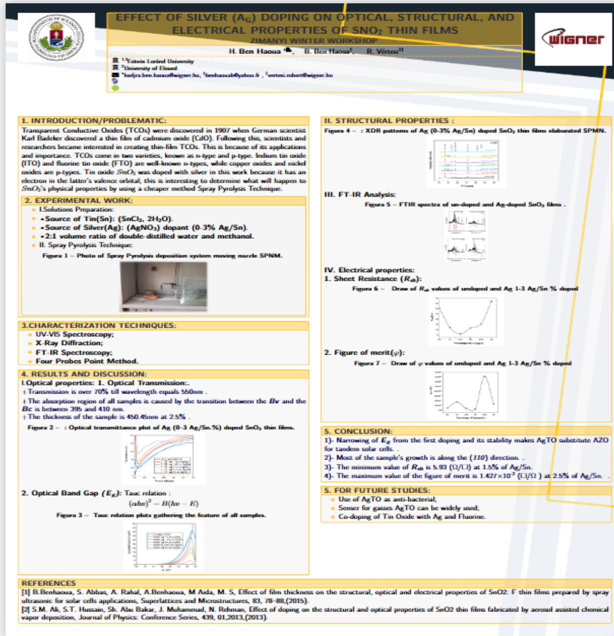
Poster about:

Effect of silver (Ag) doping on optical, structural, and electrical properties of SnO_2 thin films.

Prepared by a student:

Hadjra BEN HAOUA

December 5, 2024



Motivation:

- Transparent Conductive Oxides (TCOs) combine two properties: conductivity, and high transparency.
- In this work, tin oxide SnO2 was doped with silver.
- Using a cheaper method Spray Pyrolysis Technique.

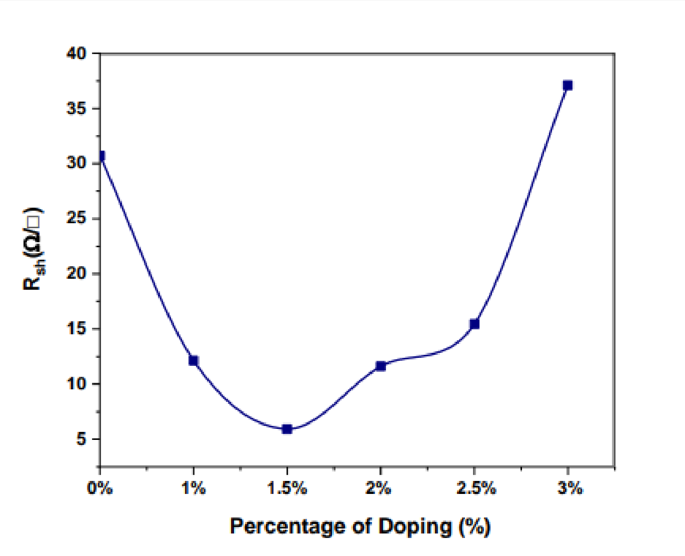


Fig.1: Draw of R_{sh} values of undoped and Ag 1-3 Ag/Sn % doped

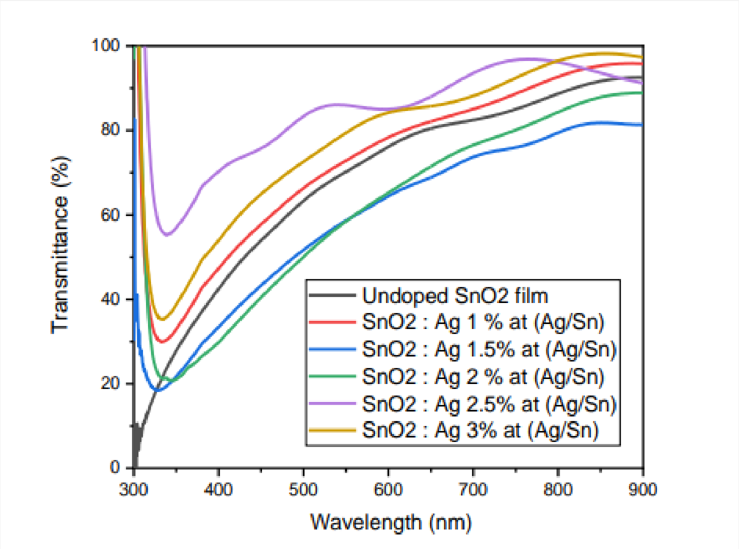


Fig. 2: Optical transmittance plot of Ag (0–3 Ag/Sn.%) doped SnO_2 thin films.

The Most Important Results:

1. Redshift of E_g from 3.76 eV to 3.07 eV.
2. The maximum value of the figure of merit is 1.427×10^{-2} (□/Ω) at 2.5% of Ag/Sn doping.
3. Future studies will make AgTO substitute AZO for tandem solar cells.

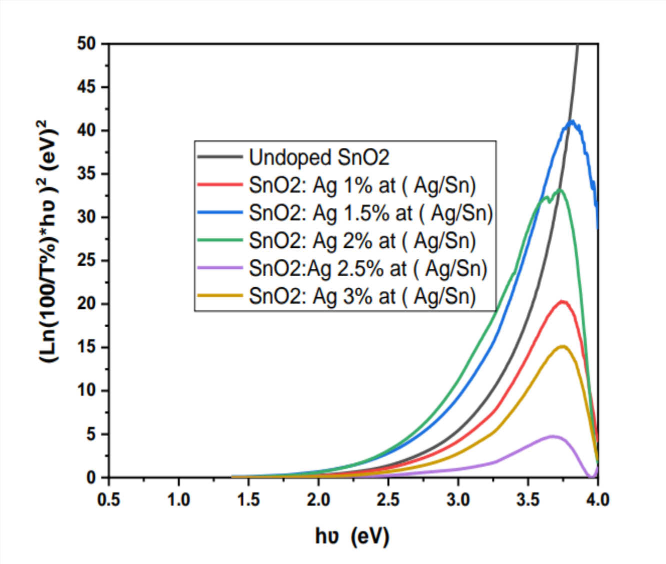


Fig. 3: Tauc relation plots gathering the features of all samples.

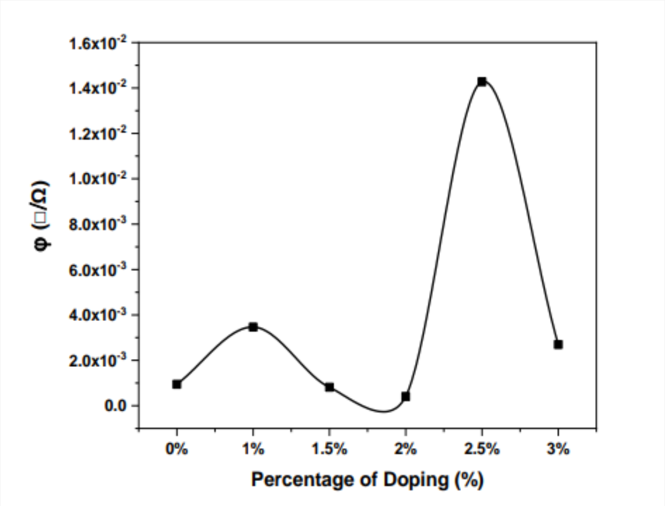
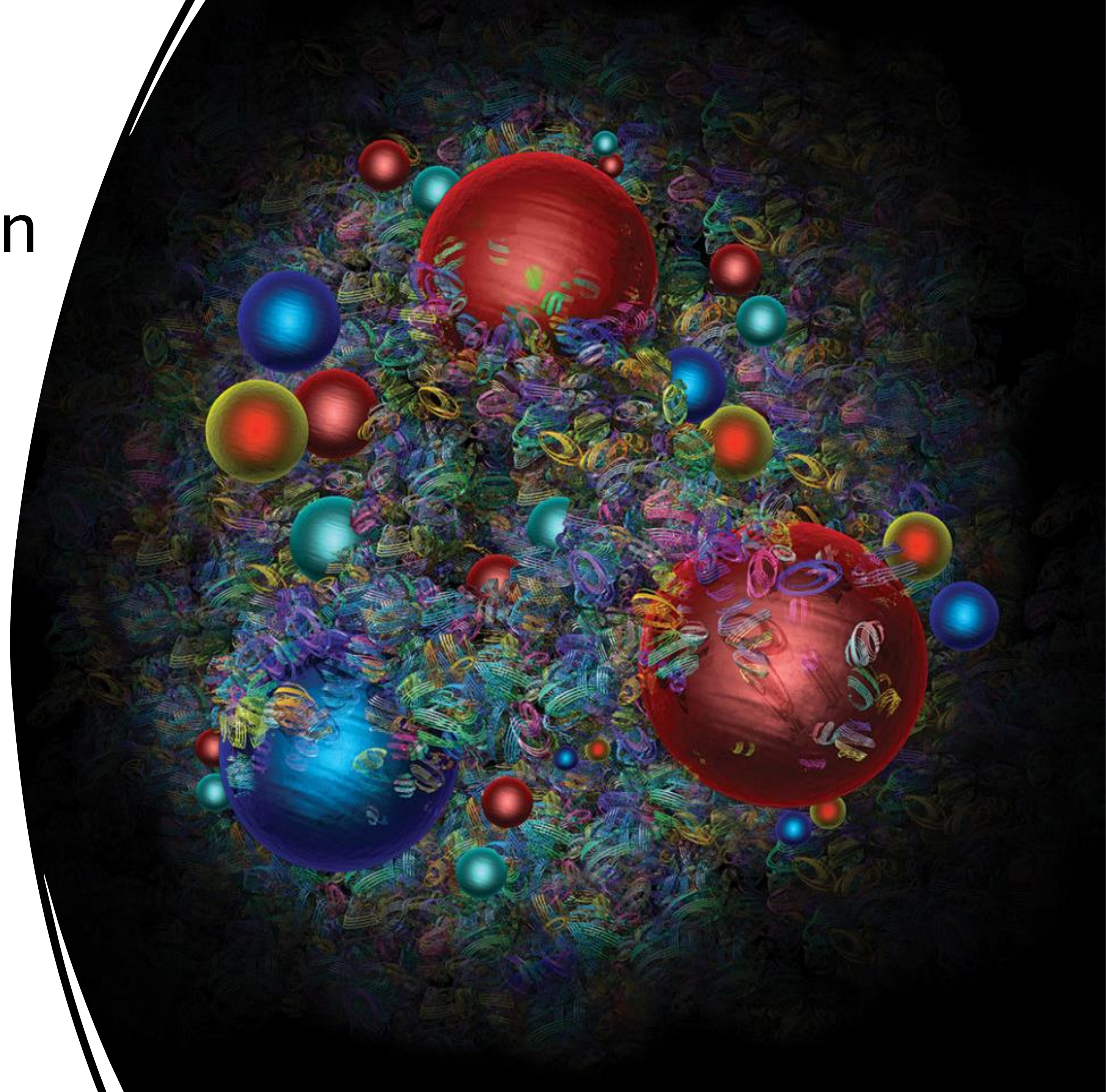


Fig. 4: Draw of R_{sh} values of undoped and Ag 1-3 Ag/Sn % doped

Quantum entanglement in high energy collisions (?)

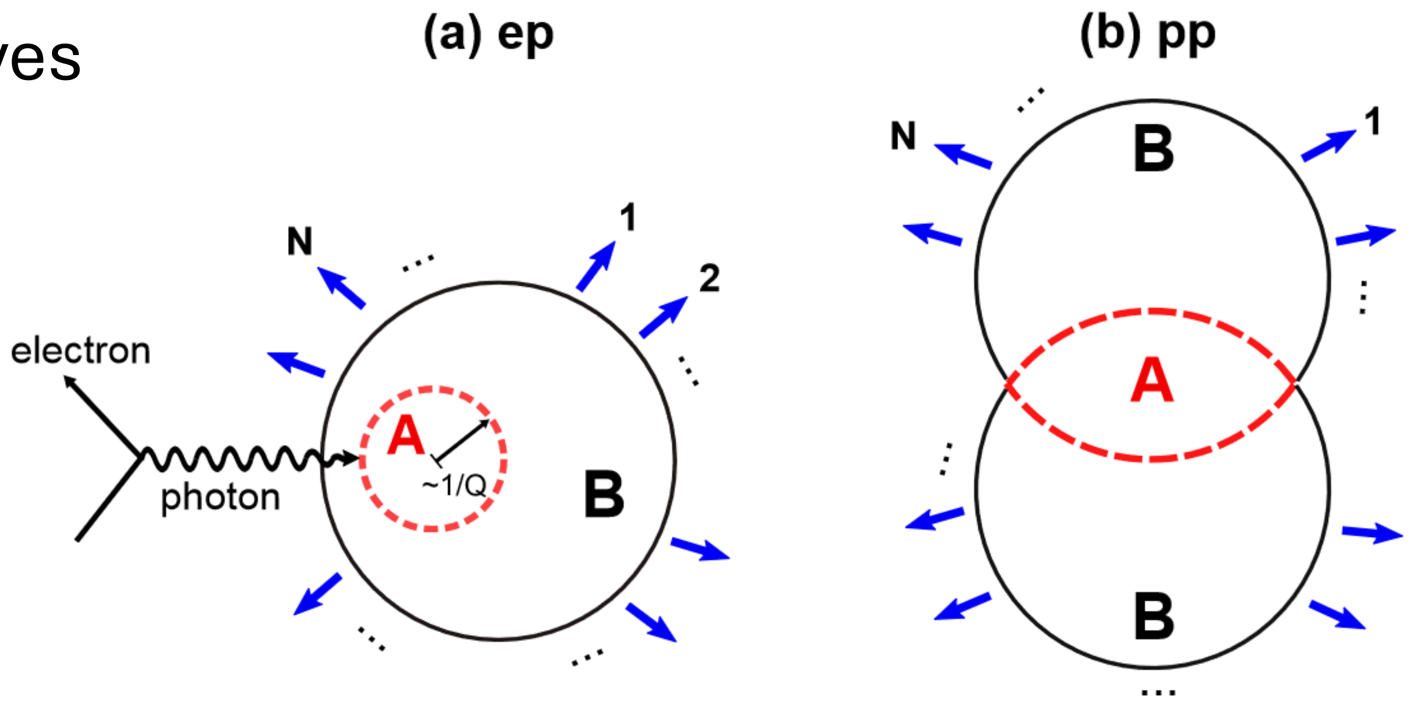
- “The confinement of coloured quarks inside a hadrons provides perhaps the most dramatic example of quantum entanglement that exists in nature.” (Tu, Phys. Rev. Lett.,124,6)

- Can we capture the “entanglementness” of the initial partonic system?



- Parton – hadron duality : yes

- Collision: sampling
- Observation: distribution of partons
- If maximally entangled, all partonic microstates have equal probability
- What is the distribution?



$$S_A = -tr[\hat{\rho}_A \ln \hat{\rho}_A] = S_B = -tr[\hat{\rho}_B \ln \hat{\rho}_B] \overset{?}{=} S_{\text{hadron}} = -\sum P(N) \ln P(N)$$

Maximal entanglement ⇒ maximal von Neumann entropy

Principle of maximal entropy ⇒ exponential distribution in the initial state

Parton – hadron duality ⇒ final state distribution: exponential distribution

Is it so? Visit my poster and find out!

Gauge field digitization in the Hamiltonian limit

Dávid Pesznyák

in collaboration with

Attila Pásztor

Eötvös Loránd University

Zimányi School 2024
5 December 2024

HUN-REN Wigner Research Centre for Physics

Motivation: Complex Action Problem

partition function as a path integral

$$\mathcal{Z} = \int \mathcal{D}\phi \, e^{-S[\phi]} = \int \mathcal{D}\phi \, w[\phi]$$

if weights $w[\phi] \notin \mathbb{R}^+$ usual MCMC methods relying on importance sampling not applicable:

complex action problem

in principle, can be bypassed with the help of quantum computers

`[quant-ph/1811.03629]`

Digitizing gauge groups – U(1)

in the NISQ era the main bottlenecks are the limited

- circuit depths
- **number of qubits**

the Hilbert space for a gauge theory based on a continuous gauge group is infinite dimensional

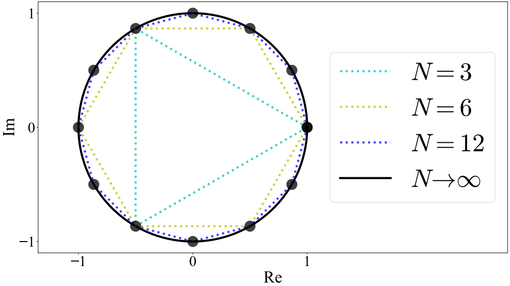
$\Downarrow$

shall be made discrete and finite via **digitization scheme**

[hep-lat/1906.11213], [hep-lat/2201.09625]

e.g. U(1) discretized to Z(N)

$$g_\infty(\varphi \in \mathbb{R}) = e^{i\varphi} \quad \mapsto \quad g_N(n \in \mathbb{Z}^+) = e^{2\pi i n/N}$$



Dirac fermions under imaginary rotation

Tudor Pătuleanu, Dariana Fodor, Victor Ambruș, Cosmin Crucean

West University of Timișoara

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4 décembre 2024

Outline of the setup

- Growing interest in studying strongly-interacting systems under rotation, usually by lattice simulations $\implies$ Sign problem
- Sign problem can be solved by using imaginary rotation $\Omega \mapsto i\Omega_I$.
- Present work : Free massless fermions with chemical potential μ.
- Density operator given by :

$$\hat{\rho} = \exp\left\{-\beta\left(: \hat{H} : -\mu : \hat{Q} : -\Omega : \hat{J}_z :\right)\right\}.$$

- Thermal expectation values $\langle \hat{A} \rangle = Z^{-1}\,\mathrm{Tr}(\hat{\rho}\hat{A})$ with $Z = \mathrm{Tr}(\hat{\rho})$.

Results

- Studied t.e.v. $A_\beta^{i\Omega_I} \equiv \langle : \hat{A} : \rangle_\beta^{i\Omega_I}$ for the femionic condensate $\bar{\Psi}\Psi$, the currents J_V, J_A, J_H and the energy-momentum tensor T.
- Interesting behavior in systems undergoing imaginary rotation : FRACTALIZATION far away from the rotation axis. This is defined as a $1/q^n$ dependence for rational values and 0 for irrational values.
- The chemical potential term breaks fractalization (it is q-independent).
- Consequence : there is no analytic continuation to real rotation, outside of the rotation axis.

Anomalous $U(1)_A$ couplings and the Columbia plot

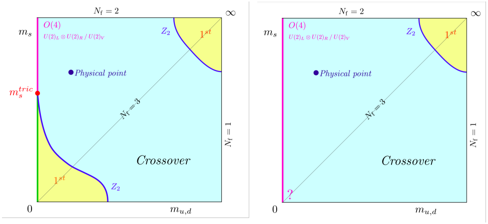
Péter Kovács, Győző Kovács

HUN-REN Wigner RCP

Zimányi 2024 Falsh Talk session
2 - 6 Dec 2024

Collaborators: Francesco Giacosa, Győző Kovács, Robert D. Pisarski, Fabian Rennecke

Columbia plot scenarios



F. Cuteri, O. Philipsen, A. Sciarra, JHEP 11 (2021) 141

We tested whether these different behaviors could be caused by different $U(1)_A$ terms.