23rd Zimányi School
Budapest

Stability of Non-Relativistic Fluids

Thermodynamic Conditions

Réka Somogyfoki
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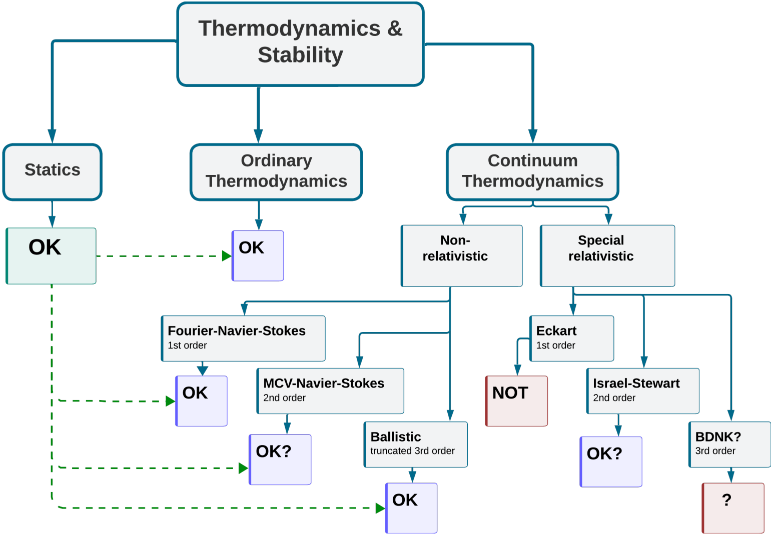
2023. december 5.

Stability of Various Theories

Special and Galilean-relativistic case



Kinematic Self-Similar Solutions with Dynamical Dark Fluid Model

Balázs E. Szigeti [1 2], Imre Ferenc Barna[2], Gergely Gábor Barnaföldi [2]

[1]Eötvös Loránd University

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OTKA: K135515

Motivation

- The properties and existence of dark matter is one of the most fascinating questions in cosmology.
- The scale-free nature of gravitational interaction in both Newtonian gravity and the general theory of relativity gives rise to the concept of self-similarity
- This implies that the governing partial differential equations are invariant under scale transformation if we consider appropriate matter fields.
- Self-similar solutions (SSs) have a wide range of applications in astrophysics
- We studied different kinds of dark fluid models with self-similar solutions.

Self-similarity in General Relativity

- In GR, the concept of SSs is not quite straightforward because GR has general covariance against coordinate transformation.
- Can be seen in two ways: Properties of the space-time, and properties of the matter fields [Cahill and Taub (1971)]
- Self-similarity of the space-time $\Rightarrow$ **Homothetic vector fields (HVF):**

$$\mathcal{L}_\xi g_{\mu\nu} = 2\alpha g_{\mu\nu}$$

The **kinematic self-similar solution** can be defined via a kinematic self-similar vector ξ (KSS). The KSS vector satisfies the following identities:

$$\mathcal{L}_\xi h_{\mu\nu} = 2\delta h_{\mu\nu} \quad (1)$$

$$\mathcal{L}_\xi u_\mu = \alpha u_\mu \quad (2)$$

The definition of the $h_{\mu\nu} = g_{\mu\nu} + u_\mu u_\nu$ projection tensor.

General Spherically Symmetric Space-time

The line element of the general symmetric spacetimes is given by:

$$ds^2 = -e^{2\Phi(t,r)}dt^2 + e^{2\Psi(t,r)}dr^2 + R(t,r)^2[d\theta^2 + \Sigma(k,\theta)^2 d\phi^2] \quad (3)$$

where,

$$\Sigma(k,\theta) = \begin{cases} \sin(\theta), & k = 1 \\ \theta, & k = 0 \\ \sinh(\theta), & k = -1 \end{cases}$$

We adopt comoving frames:

$$u_\mu = (e^{-\Phi}, 0, 0, 0)$$

Equation of State

We are interested in finding kinematic self-similar solutions for different dark energy models. We are interested to find solution when the following linear equation of state (EOS1) are used:

$$p = w(\xi)\rho, \tag{4}$$

where the w parameter is explicitly depend on the ξ similarity variable. Linear equation of state are widely used in cosmological astrophysics to describe dark matter, dark energy as well as ordinary matter. The other equation of state we used is more restricted (EOS2):

$$p = w(\mathcal{R}(r,t))\rho, \tag{5}$$

Solutions and Summary

From this analysis, we showed that for the first EoS $p = w(\xi)\rho$, the **relevant solutions** yet we find are the following:

Second kind, tilted	Homothetic Static
Second kind, parallel	Flat FRWL
Second kind, orthogonal	Homothetic Static
Zeroth kind, tilted	No solution
Zeroth kind, parallel	No solution
Zeroth kind, orthogonal	All static solution

We are currently working on the solutions, where the EOS2 is used, and we are also interested in those solutions, where bulk viscosity is added to the $T_{\mu\nu}$.

Thermodynamically compatible family of non-relativistic self-gravitating weakly nonlocal fluids

Mátyás Szücs, Péter Ván

HUN REN WIGNER

MŰEGYETEM 1782

montavid

23rd Zimányi School Winter Workshop on Heavy Ion Physics
Budapest, December 4–8, 2023

- How universal is thermodynamics?
  - Gravity?

$$\Delta\varphi = 4\pi G\left[\varrho + \nabla\cdot\left(C\frac{\nabla\varrho}{\varrho}\right)\right]$$

  - Quantum mechanics? $\Longrightarrow$ Korteweg fluids $\Longrightarrow$ Bohmian (hydrodynamical) formulation of QM
- How universal is holographic property?

$$\varrho\dot{\mathbf{v}} = -\nabla\cdot\mathbf{P}_{\text{perfect}} \qquad \overset{?}{\Longleftrightarrow} \qquad \varrho\dot{\mathbf{v}} = -\varrho\nabla\Phi$$

- Does a thermodynamically consistent family of fluids exist? $\Longrightarrow$ YES

Thank you for your attention!

Silicon Tracking System of CBM Experiment

S. Mehta[1,2] for the CBM collaboration

[1] Eberhard Karls Universität Tübingen (DE)

[2] GSI Helmholtzzentrum für Schwerionenforschung GmbH (DE)

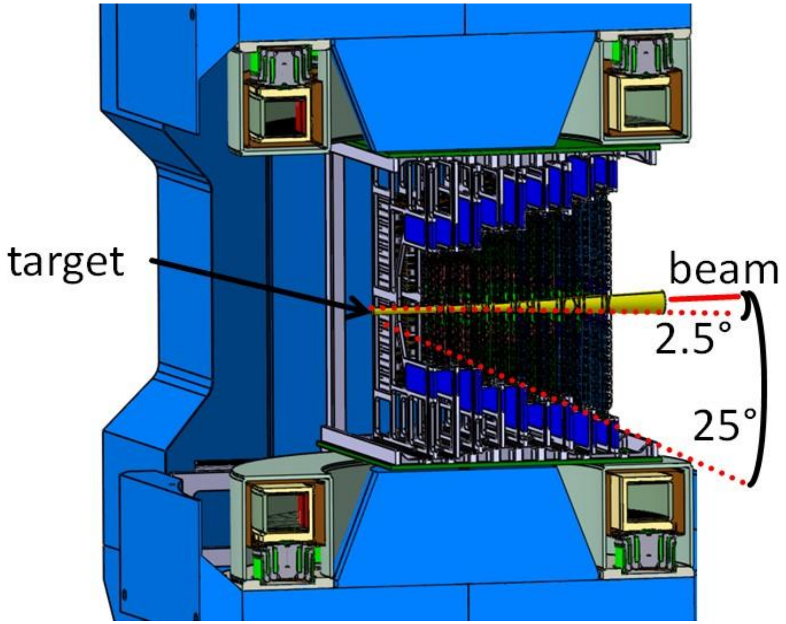
Zimanyi Winter School 2023

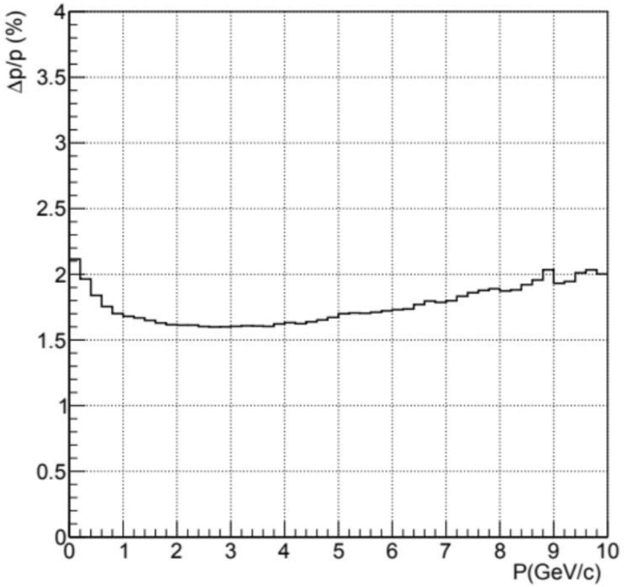
EBERHARD KARLS UNIVERSITÄT TÜBINGEN

MATHEMATISCH-NATURWISSENSCHAFTLICHE FAKULTÄT
Physikalisches Institut

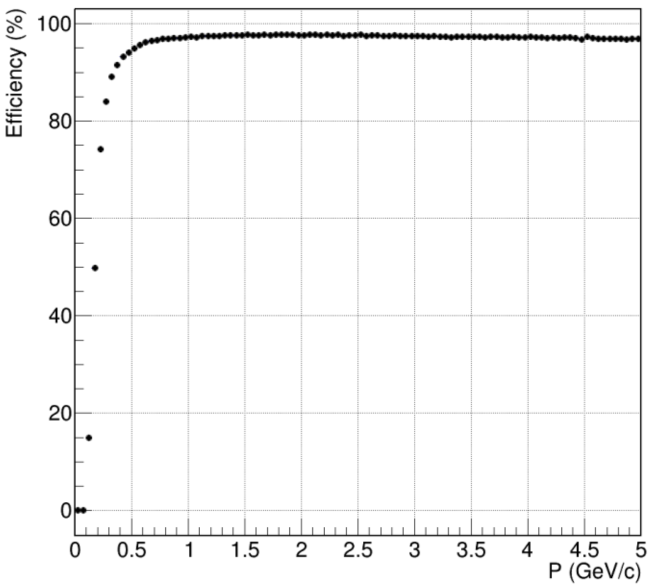
Silicon Tracking System of CBM experiment

Silicon Tracking System is designed to provide good momentum resolution (< 1.5 %) with tracking efficiency (< 97 %) -> Low material budget (exp challenge)





Momentum resolution



Au target with 12 GeV/c Au beam

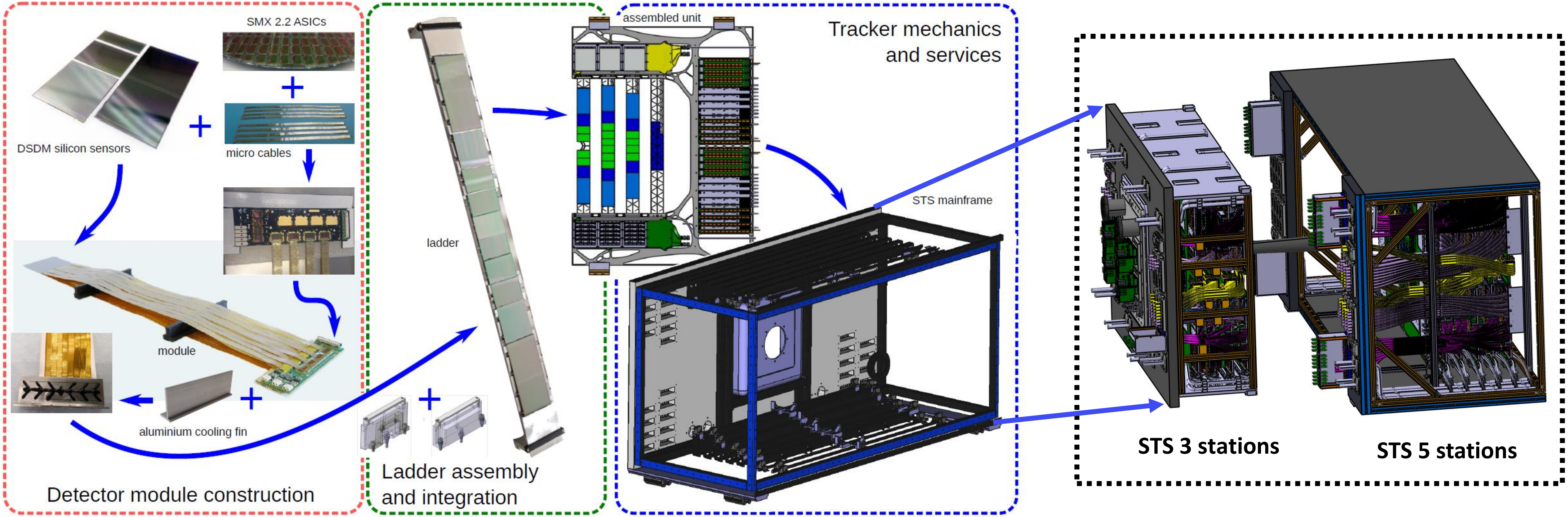
Tracking efficiency

- **S**ilicon **T**racking **S**ystem is the key **tracking detector** of CBM experiment
- 8 Tracking Stations inside 1 T.m superconducting dipole magnet
- Material budget per station: 0.3 % - 2 % X_0
- Power dissipation ~ 40 kW in ~ 3 m^3

- Radiation tolerance: ≤ 10^{14} n_{eq} cm^{-2}
  - Sensor temperature 10 °C at EOL
- Self-triggering Front End Electronics outside the physics aperture
  - cooled at -20 °C using 3M NOVEC 649

STS expands reconstruction horizons from 3D to 5D with spatial, timing and amplitude in free streaming mode essential for CBM goals

Experimental challenge for STS: Optimize material of the components under acceptance region

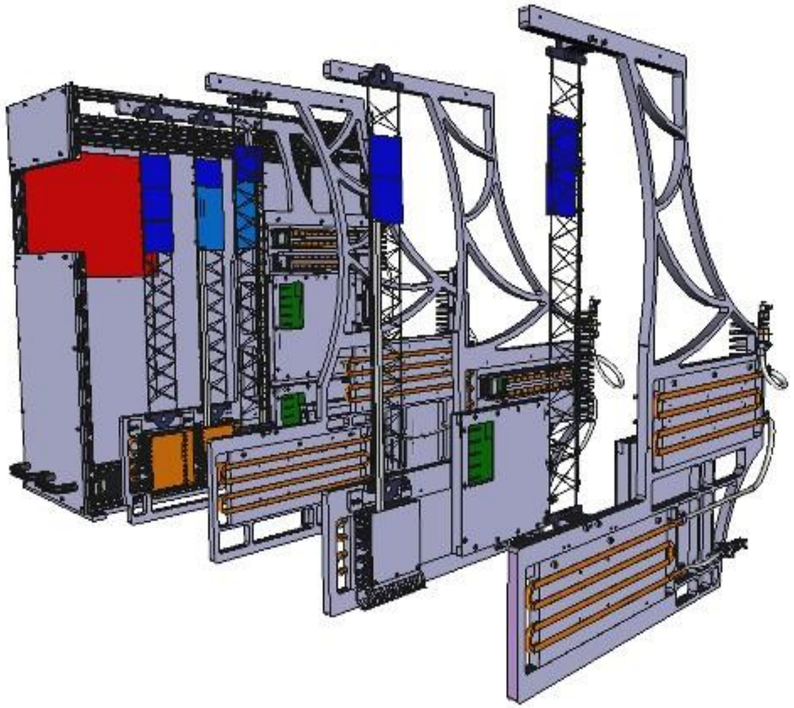


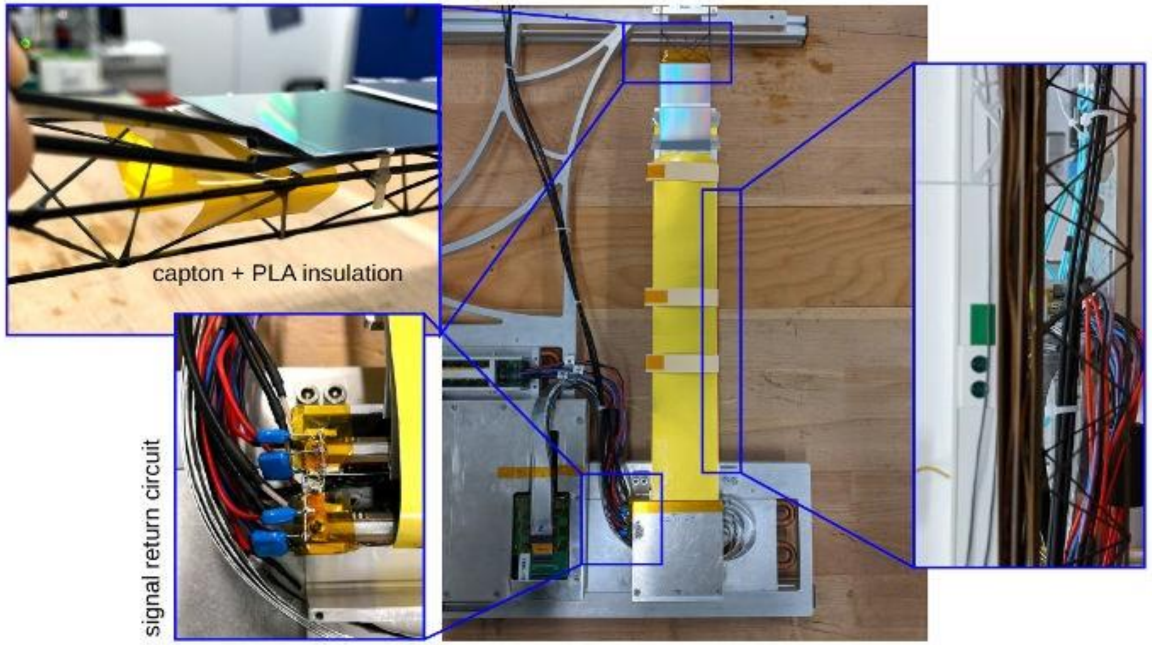
- **Module assembly** procedure has been developed and tested in the lab as well as with beam
- **Ladder Assembly** has been optimized with achievable mounting precision of ± 100 µm
- **Detector integration** aspects has been understood using mechanical and thermal demonstrators

Modular STS design has been prepared for enhanced flexibility: allowing first 3 stations to be detachable during the maintenance

Assembly and testing procedure is well established and module series production has started

mSTS: functional prototype at SIS 18





- mini-CBM is the small precursor of full scale CBM detector
- mini-STS operation involves using STS modules in real data taking scenario
- 2 tracking stations (sensor layers) $12 \times 12\ cm^2$ and $18 \times 18\ cm^2$ arranged on 2 stations without magnetic field
  - 11 modules (<1 % of STS modules) mounted on 4 ladders
- Testing of hit reconstruction performance, timing resolution, vertex reconstruction

Pre-liminary results: Hit reconstruction efficiency of 97 % is reached using tracks from station (6 modules) and an external detector (TOF) as reference

University of Debrecen,
Faculty of Informatics

sPHENIX TPC monitoring system

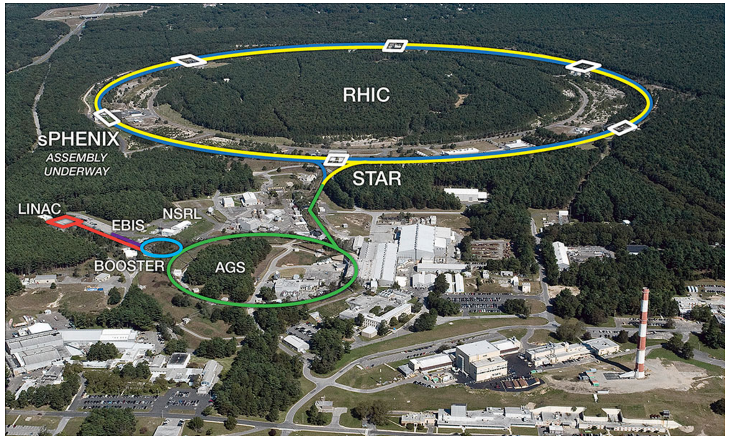
ZIMANYI SCHOOL 2023

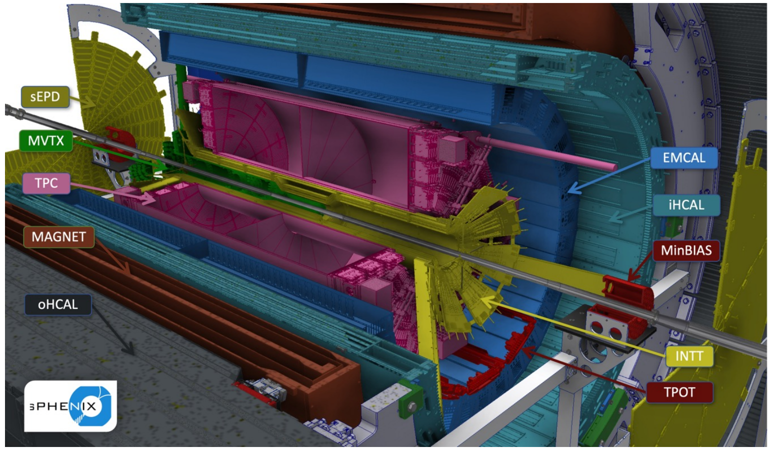
Tamas Majoros

07 December 2023

sPHENIX

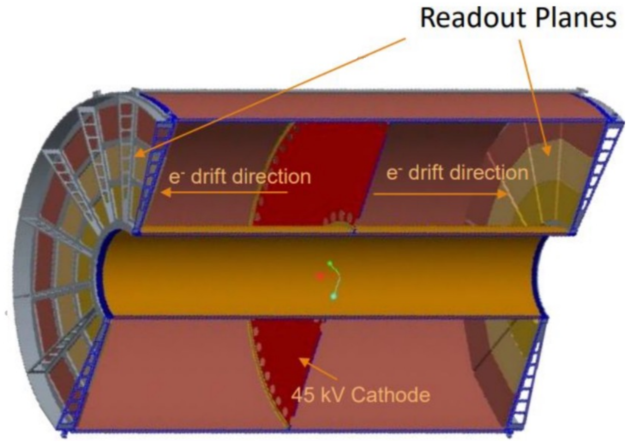
- sPHENIX is located at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL)
- It will study properties of Quark Gluon Plasma by various probes
- The commission of the detector began in May 2023
- Strength of the magnetic field is 1.4 T
- One of its subdetectors is the Time Projection Chamber (TPC)





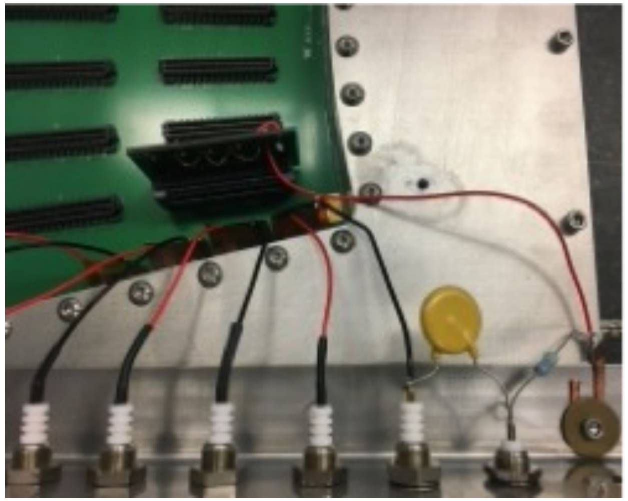
TPC

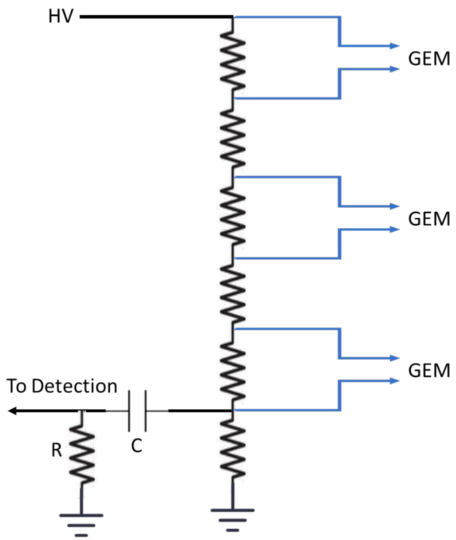
- It is the central tracking detector of the experiment
- The working gas of the TPC is Ar/CF_4 60:40
- Amplification of the electron is carried out using a stack of four Gas Electron Multipliers (GEMs) (quad-GEM), inspired by ALICE
  - 36 modules are placed per side
  - Each stack contains two standard and two large pitch planes



System characterization

- A voltage divider is used to supply operational voltages for GEMs.
- When powering GEMs with a resistor chain only one high voltage (HV) channel powers a whole module.
- If small resistor values are used in the chain, in the case of a spark, a large amount of current (compared to the nominal) will be driven through the system. A large amount of energy will be dissipated.
- Large resistor values limit the energy of sparks, but it is harder to detect sparks through the power supply current.
- A capacitor connected to the bottom of the bottom GEM is used as a pickoff capacitor for triggering and event counting.

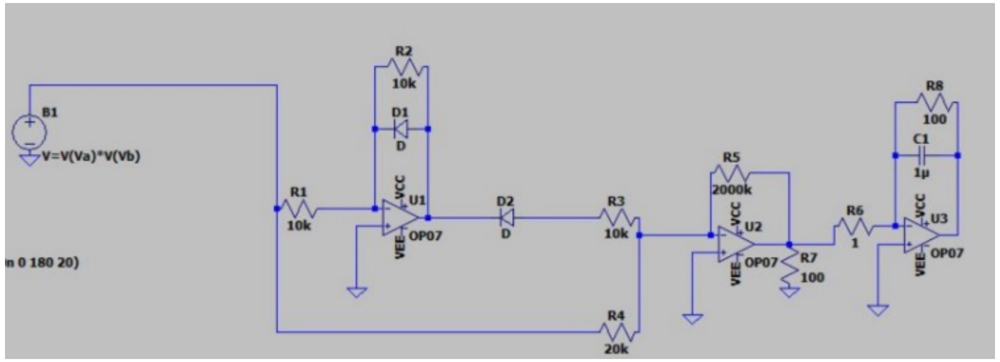




- Normal "signal" pickoff
  - SMALL signal
  - R ~ 1 MΩ
  - Preamp-Shaper
  - MIPS seen
- Spark sensor
  - BIG signal
  - R=0.2 Ω
  - Directly visible on scope

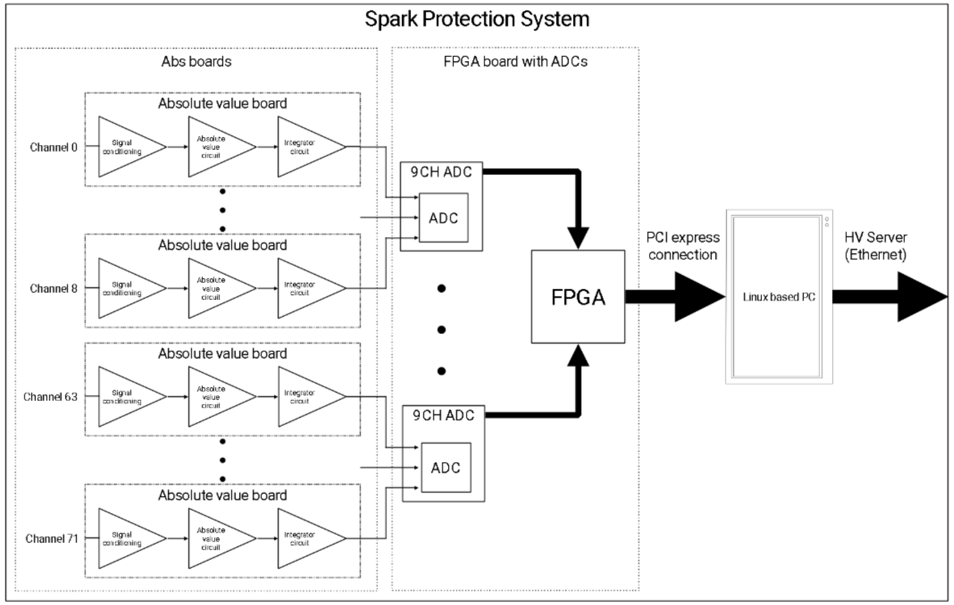
Digitizing spark signals

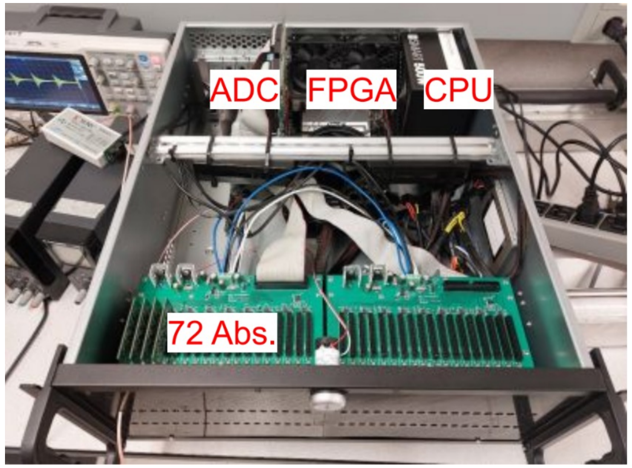
- Main requirement of the spark signal digitizer system was being able to continuously monitor 72 channels simultaneously with fast and reliable signal detection
- The original signal is bipolar and has high frequency, requires high-speed and expensive ADCs
- The idea is to convert this signal to a unipolar, pulse-like signal that can be digitized with a slower ADC
- For this, we designed an absolute value-integrator board. It takes the absolute value of the input signal and then integrates that



Digitizing spark signals

- The outputs of the absolute value boards are connected to a digitizer board
- This board has eight 9-channel ADCs connected to an FPGA
- The digitizer board is connected to a PC using PCI-Express communication
- This PC is able to communicate with the high voltage power supplies and intervene in their operation using a TCP/IP connection in case of a spark is detected





Thank you for your attention!

Tamas Majoros

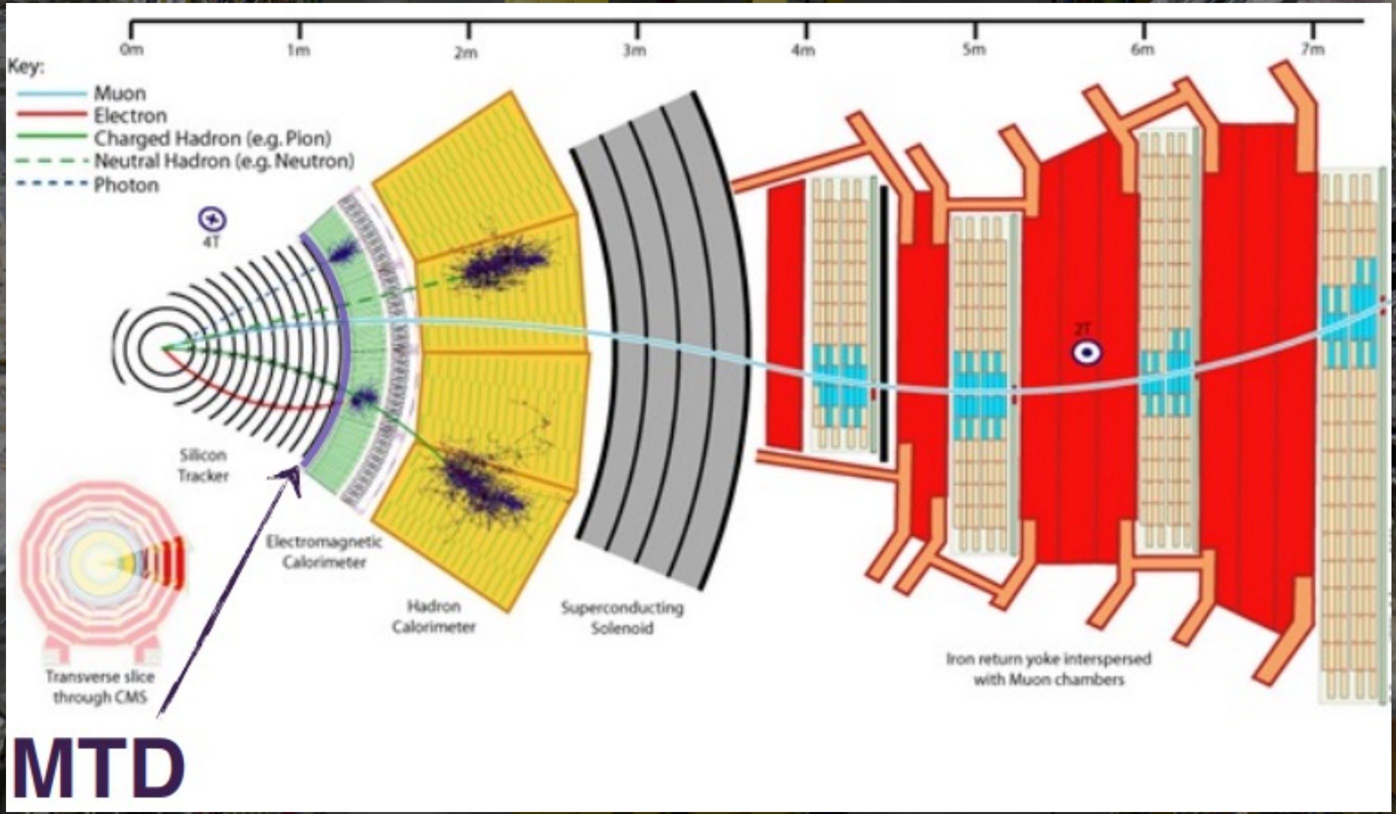
SiPM Module Tester for CMS BTL

David Baranyai

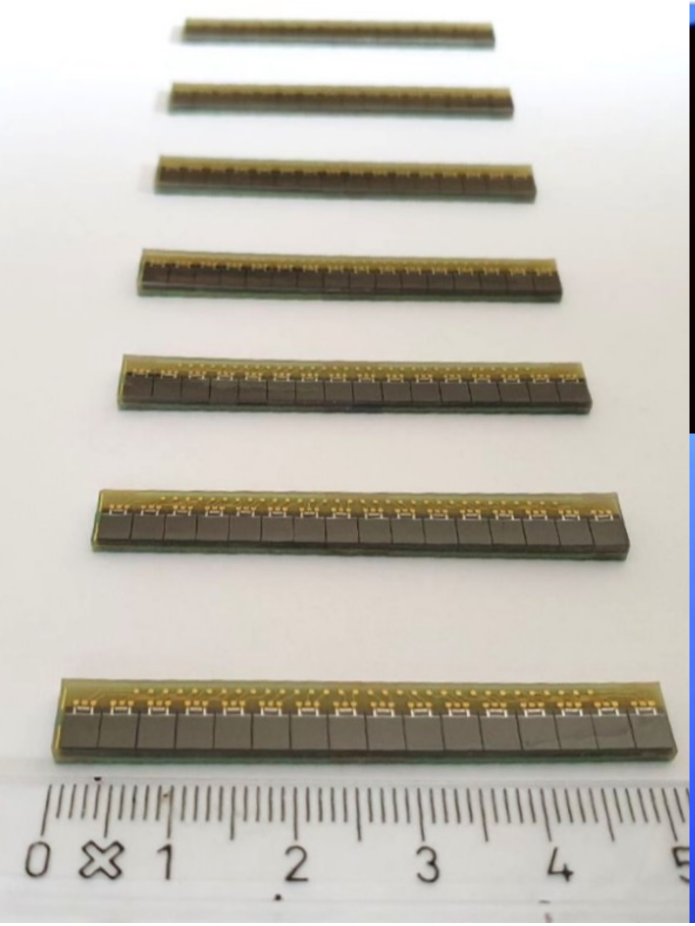
ZIMANYI SCHOOL 2023

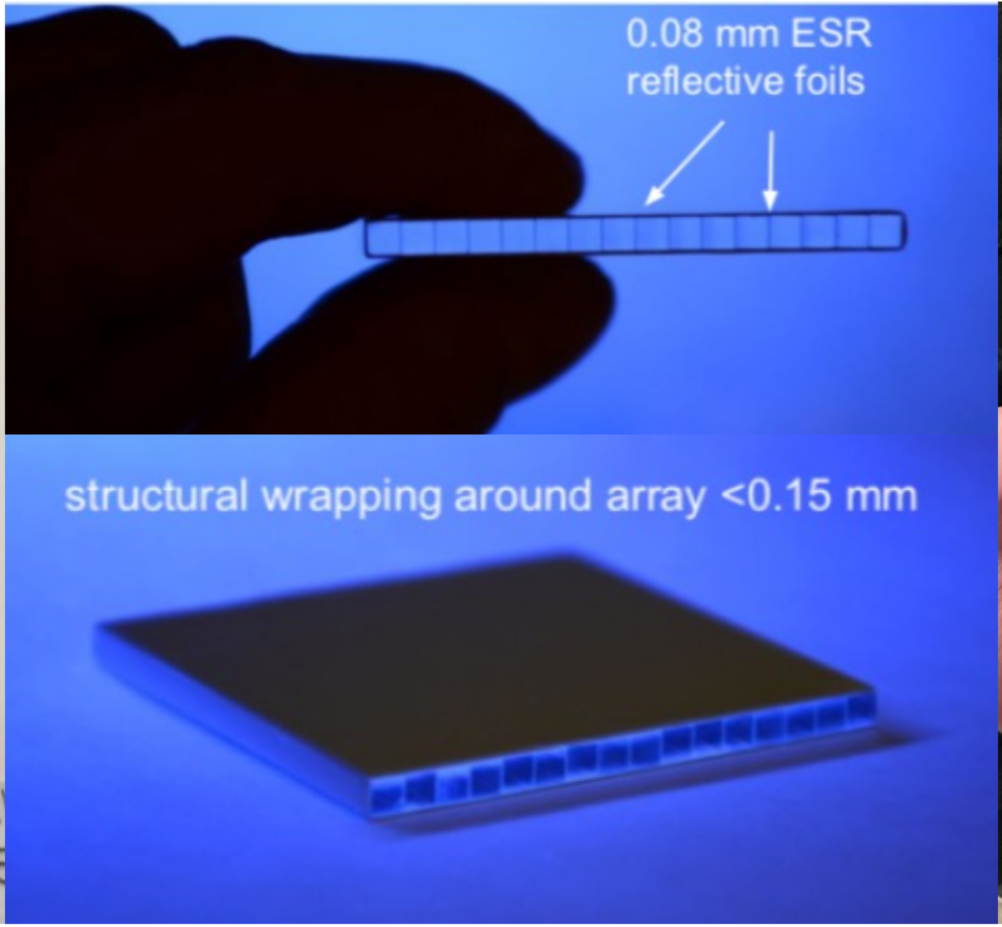
2023.12.07

LHC – CMS - BTL

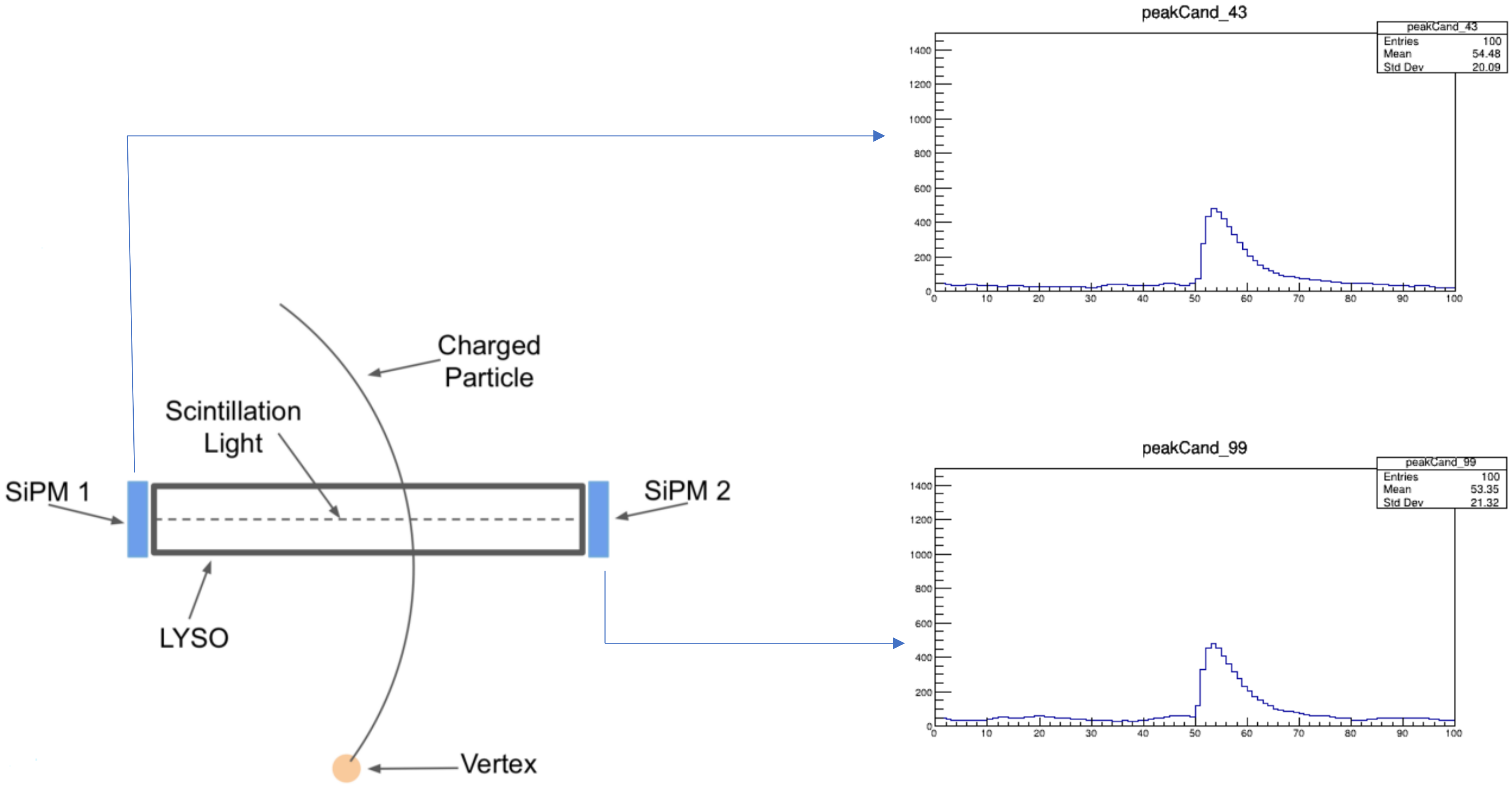

0m
1m
2m
3m
4m
5m
6m
7m
Key:
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon
4T
2T
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed with Muon chambers
Transverse slice through CMS
MTD

BTL Module

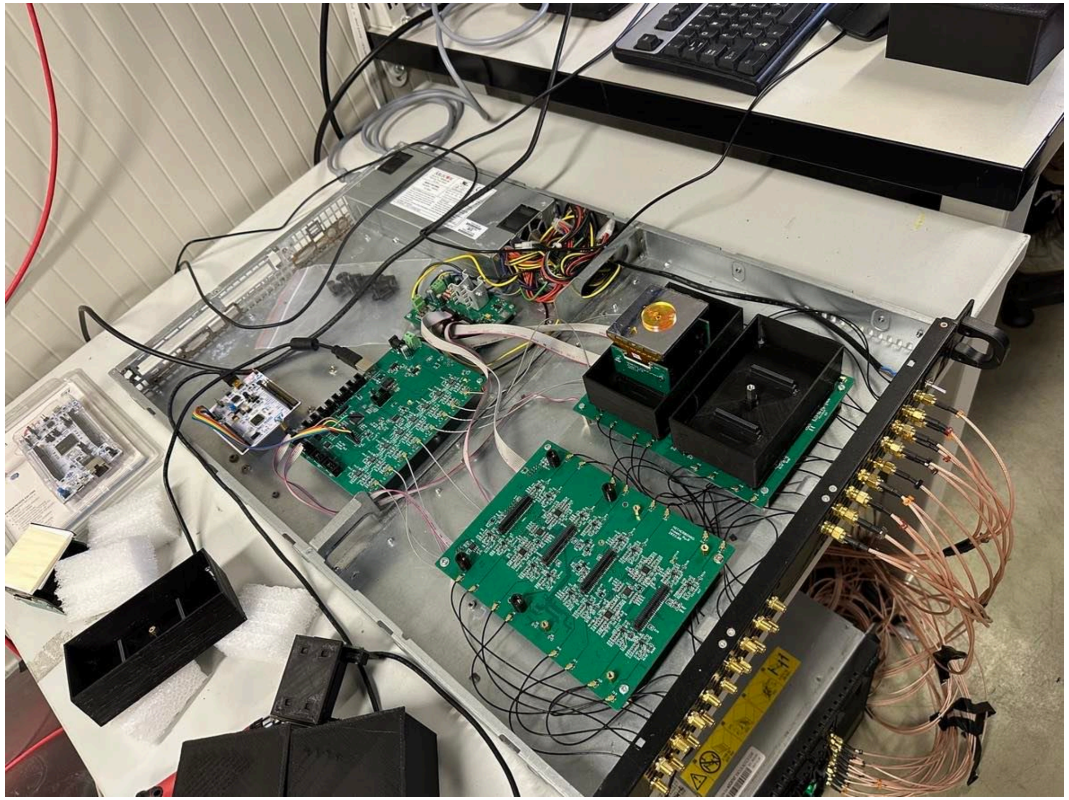


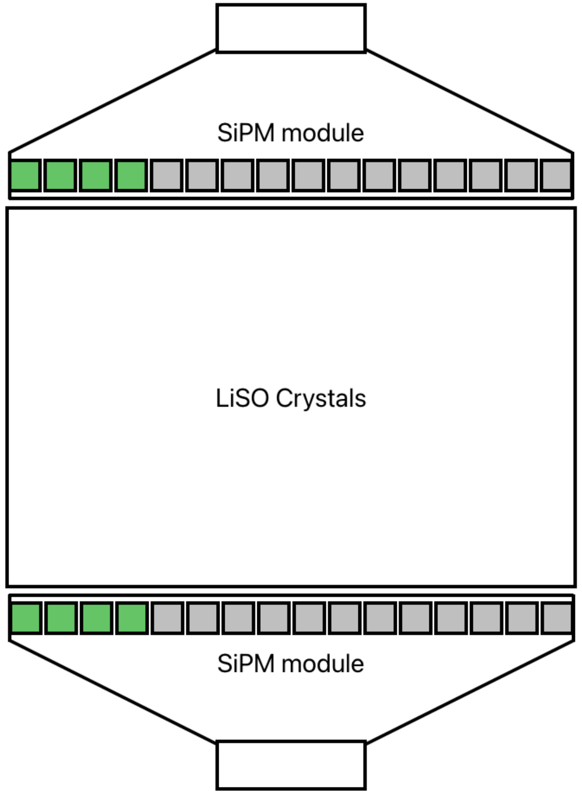

0.08 mm ESR
reflective foils
structural wrapping around array <0.15 mm

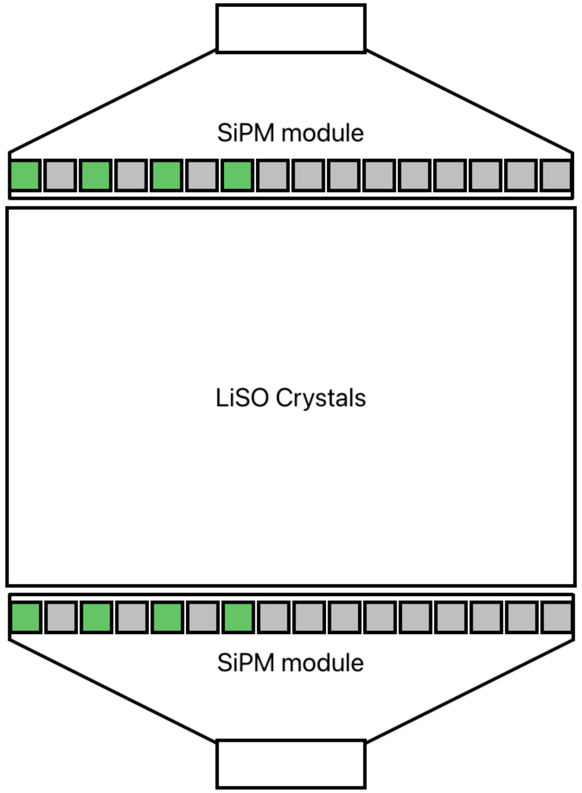
SiPM Detector



The module tester







Thank you for your attention!

David Baranyai

ZIMÁNYI SCHOOL 2023

A. Gáspár: Calculate the Entropy XIV

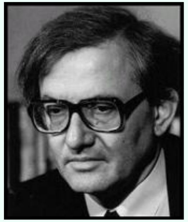
23rd ZIMÁNYI SCHOOL

WINTER WORKSHOP

ON HEAVY ION PHYSICS

December 4-8, 2023

Budapest, Hungary



József Zimányi (1931 - 2006)

The ALICE Fast Interaction Trigger performance and upgrade

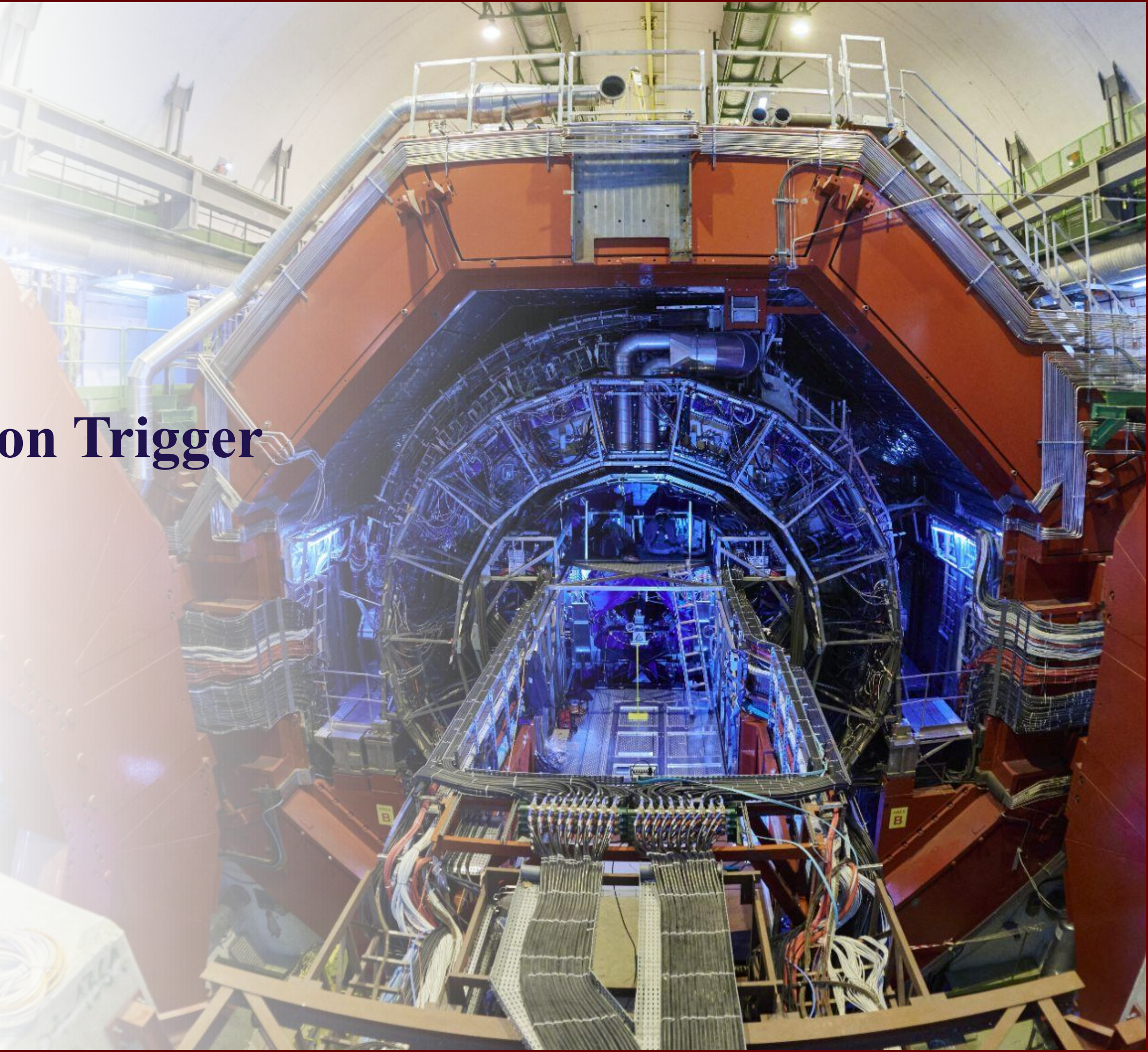
Sahil Upadhyaya

on behalf of the ALICE *collaboration*

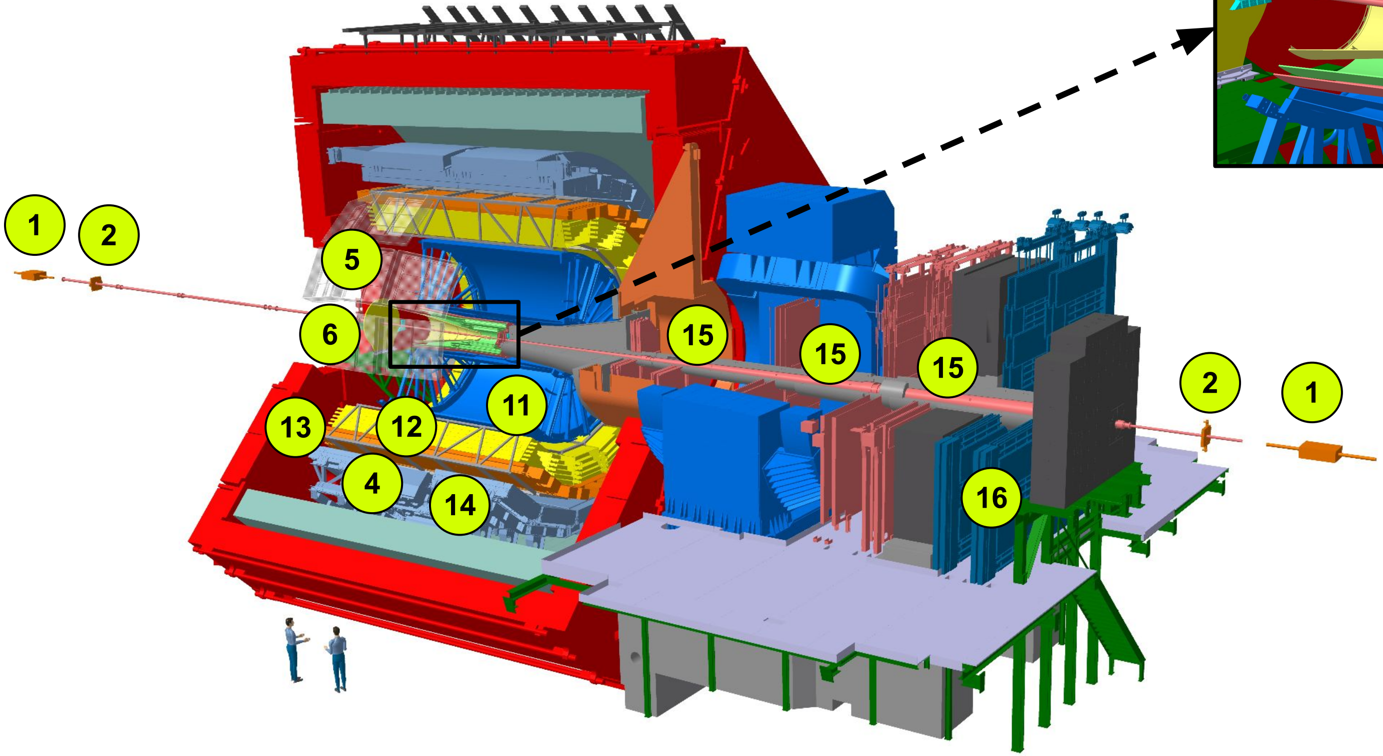
THE HENRYK NIEWODNICZAŃSKI INSTITUTE OF NUCLEAR PHYSICS POLISH ACADEMY OF SCIENCES

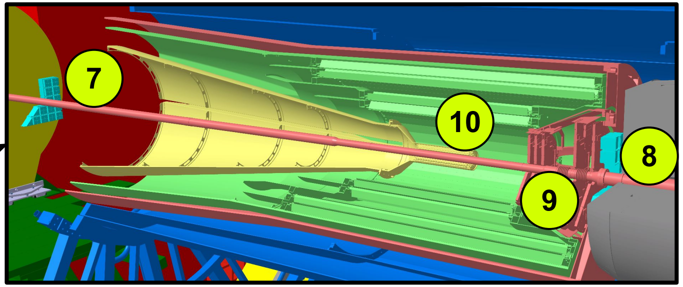
ALICE

CERN



ALICE Upgrade

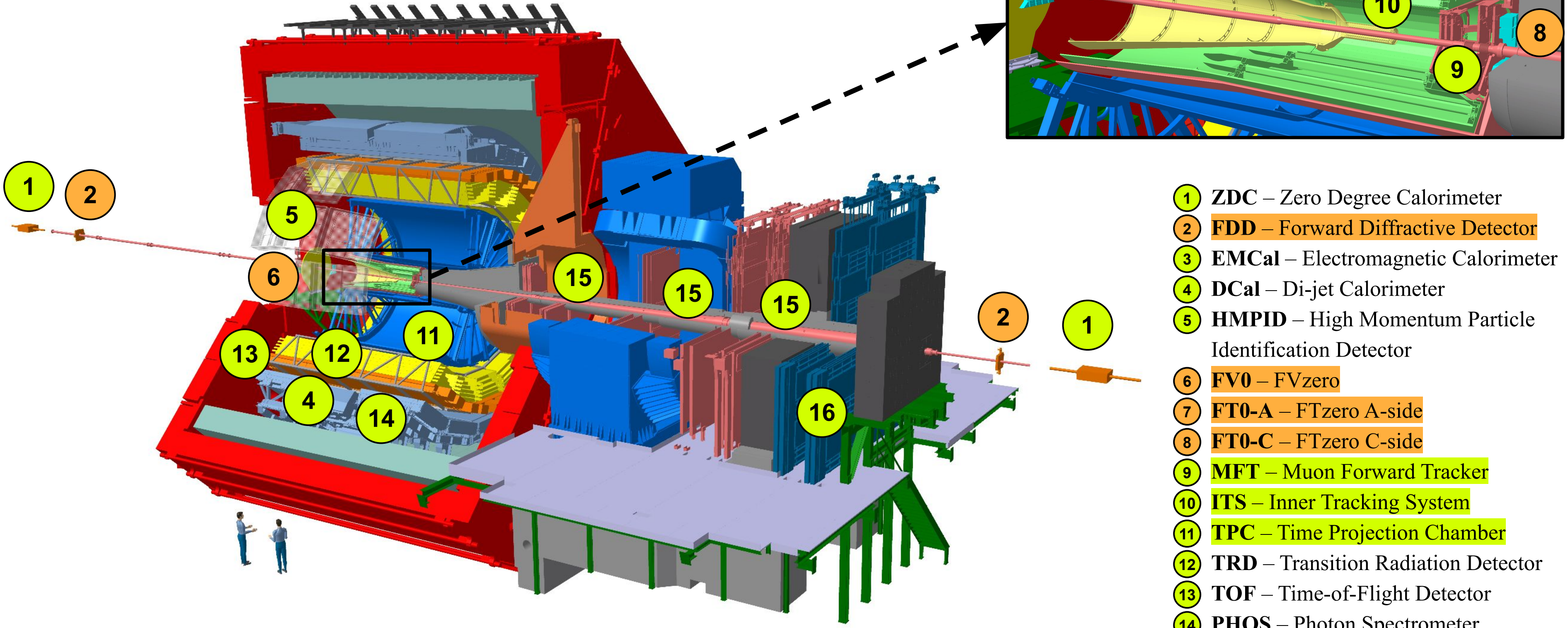




ALICE Run 3 setup

1. **ZDC** – Zero Degree Calorimeter
2. **FDD** – Forward Diffractive Detector
3. **EMCal** – Electromagnetic Calorimeter
4. **DCal** – Di-jet Calorimeter
5. **HMPID** – High Momentum Particle Identification Detector
6. **FV0** – FVzero
7. **FT0-A** – FTzero A-side
8. **FT0-C** – FTzero C-side
9. **MFT** – Muon Forward Tracker
10. **ITS** – Inner Tracking System
11. **TPC** – Time Projection Chamber
12. **TRD** – Transition Radiation Detector
13. **TOF** – Time-of-Flight Detector
14. **PHOS** – Photon Spectrometer
15. **MCH** – Muon Tracking Chambers
16. **MID** – Muon Identifier

ALICE Upgrade



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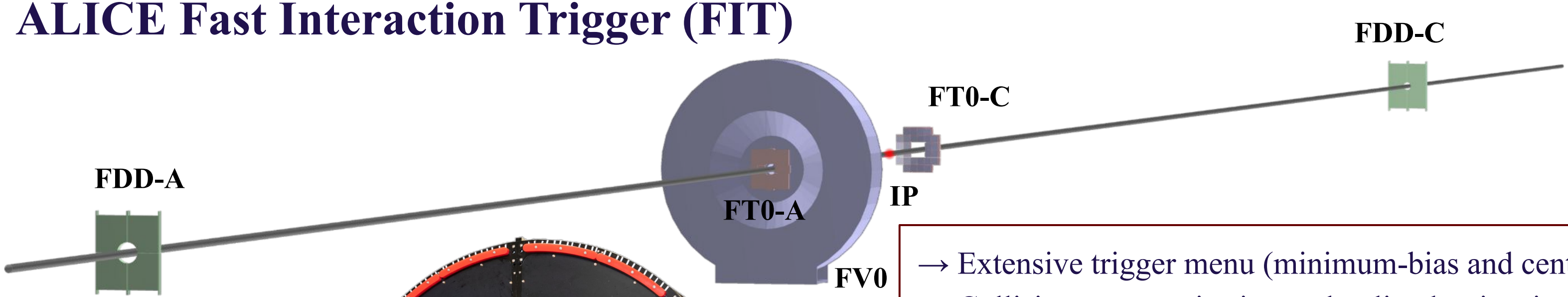
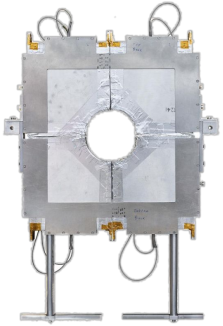
ALICE Fast Interaction Trigger (FIT)

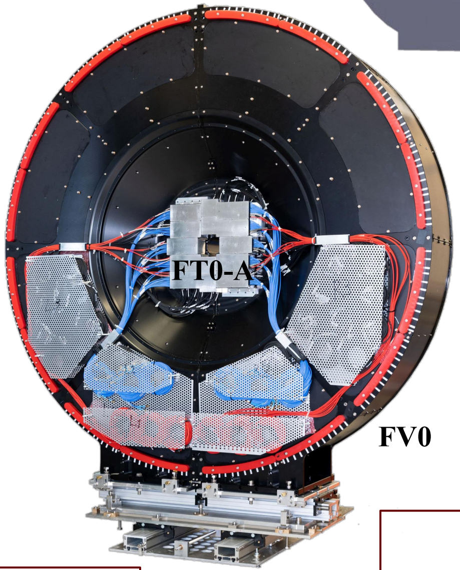


Detector	η_{min}	η_{max}
FDD-A	4.8	6.3
FT0-A	3.5	4.9
FV0	2.2	5.0
FT0-C	-3.3	-2.1
FDD-C	-7.0	-4.9

→ Extensive trigger menu (minimum-bias and centrality-based triggers)
→ Collision rate monitoring and online luminosity feedback to the LHC
→ LHC beam induced background monitoring

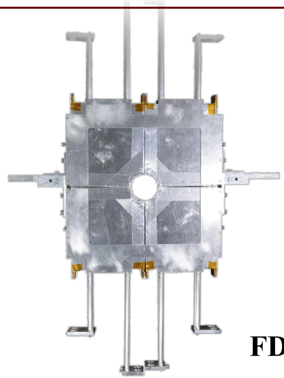


FDD-A



FV0

FT0-C



FDD-C

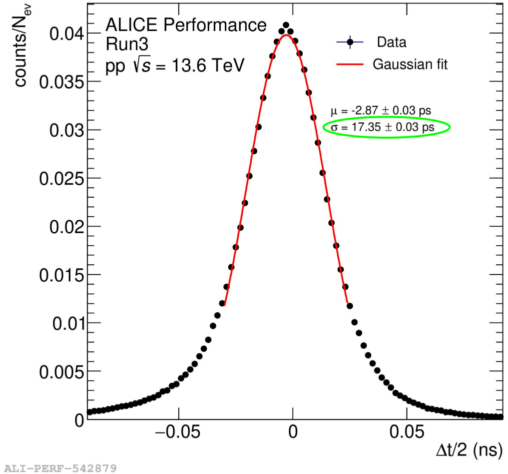
FV0
– **48 plastic scintillator** cells
– **Large acceptance –** 144 cm diameter
– Event centrality determination

FT0
– **Cherenkov** arrays (total **208** pixels)
– Minimum-bias and centrality **trigger generation**
– **Collision time** and **vertex position** calculations.
– **Excellent time resolution**.

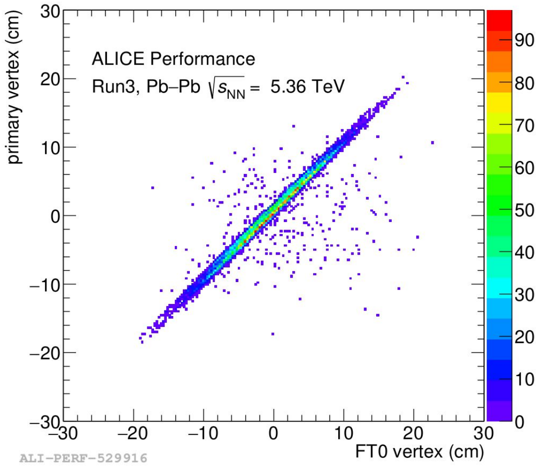
FDD
– Forward **D**iffractive **D**etector
– **Plastic scintillator** arrays (total **16** pixels)
– **Diffractive** and **ultra-peripheral** events tagging

FIT Performance

FT0 time resolution in pp 13.6 TeV

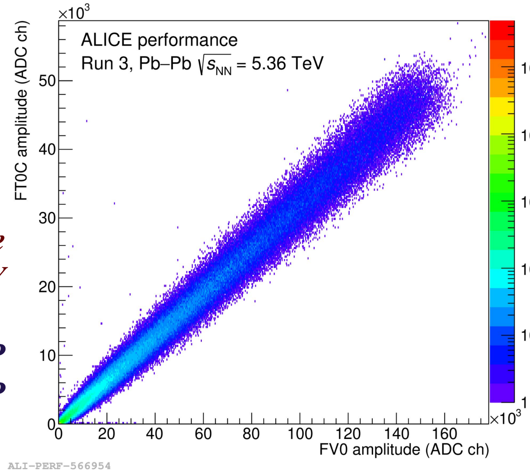


Primary vertex vs. FT0 vertex in Pb-Pb 5.36 TeV

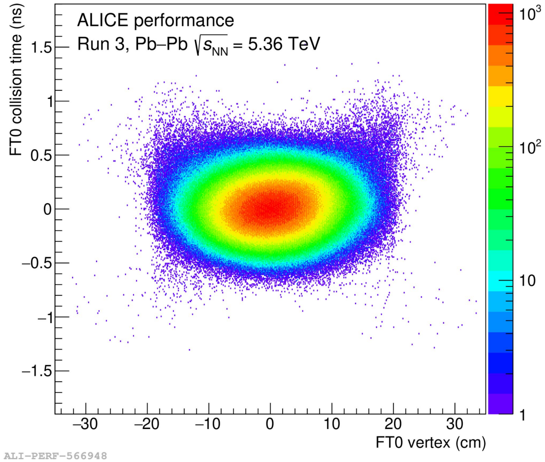


FV0 charge vs FT0C charge in Pb-Pb collisions at 5.36 TeV

FV0 - 4 ADC channels/MIP
FT0 - 14 ADC channels/MIP

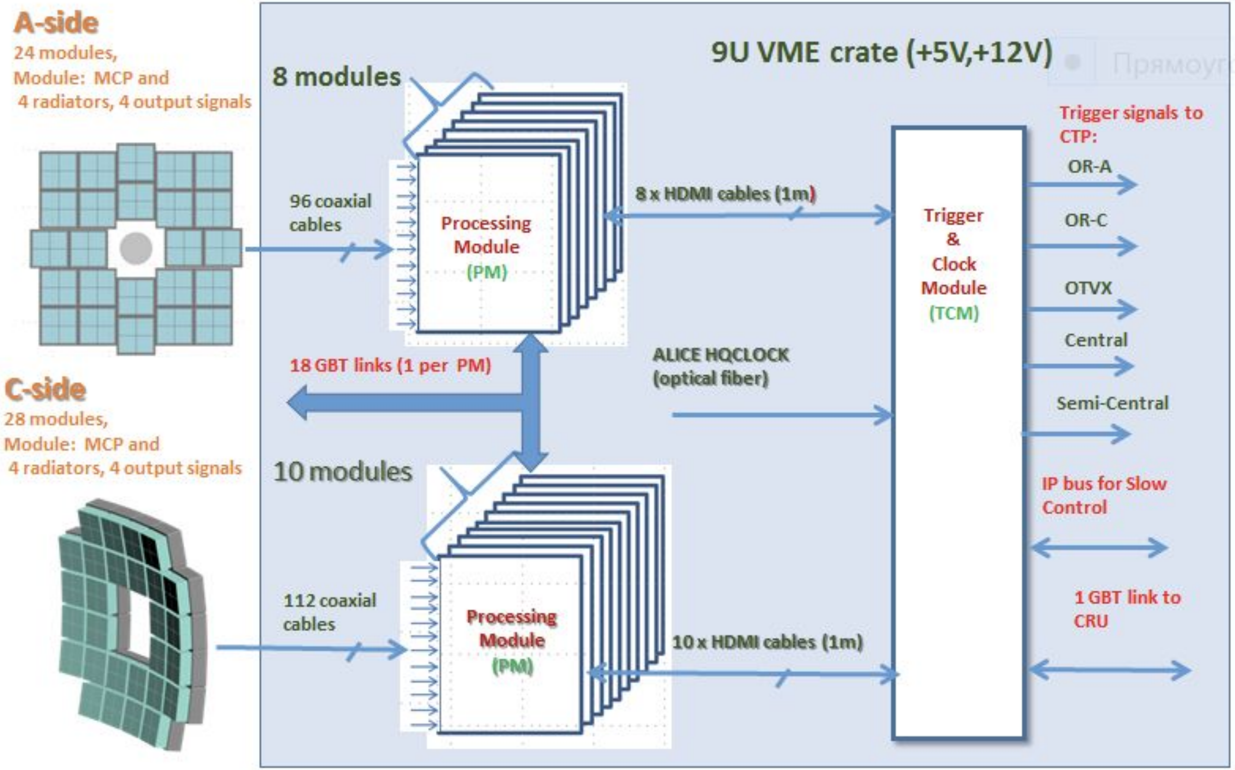


FT0 collision time Vs FT0 vertex in Pb-Pb 5.36 TeV



FIT Upgrade

Current FIT FEE (based on FT0)



Upgrade plans for Run 4

– Replacement of analog with digital electronics based on FPGA and RFSoC
– Increase ADC dynamic range for charge measurements.
– Online tagging of pileup events

Thank You !
Köszönöm !

References

[1] M. Slupecki, NIMA 1039 (2022) 167021
[2] W. H. Trzaska, NIMA 958 (2020) 162116
[3] M. Slupecki, PoS (ICHEP2020) 779
[4] S. Bysiak, PoS (LHCP2020) 251
[5] D. Finogeev et al, 2020 JINST 15 C09005

Acknowledgement

Supported by Polish Ministry of Education and Science Grant - **DIR-WSIB.92.11.2023**

YouTube FIT Videos

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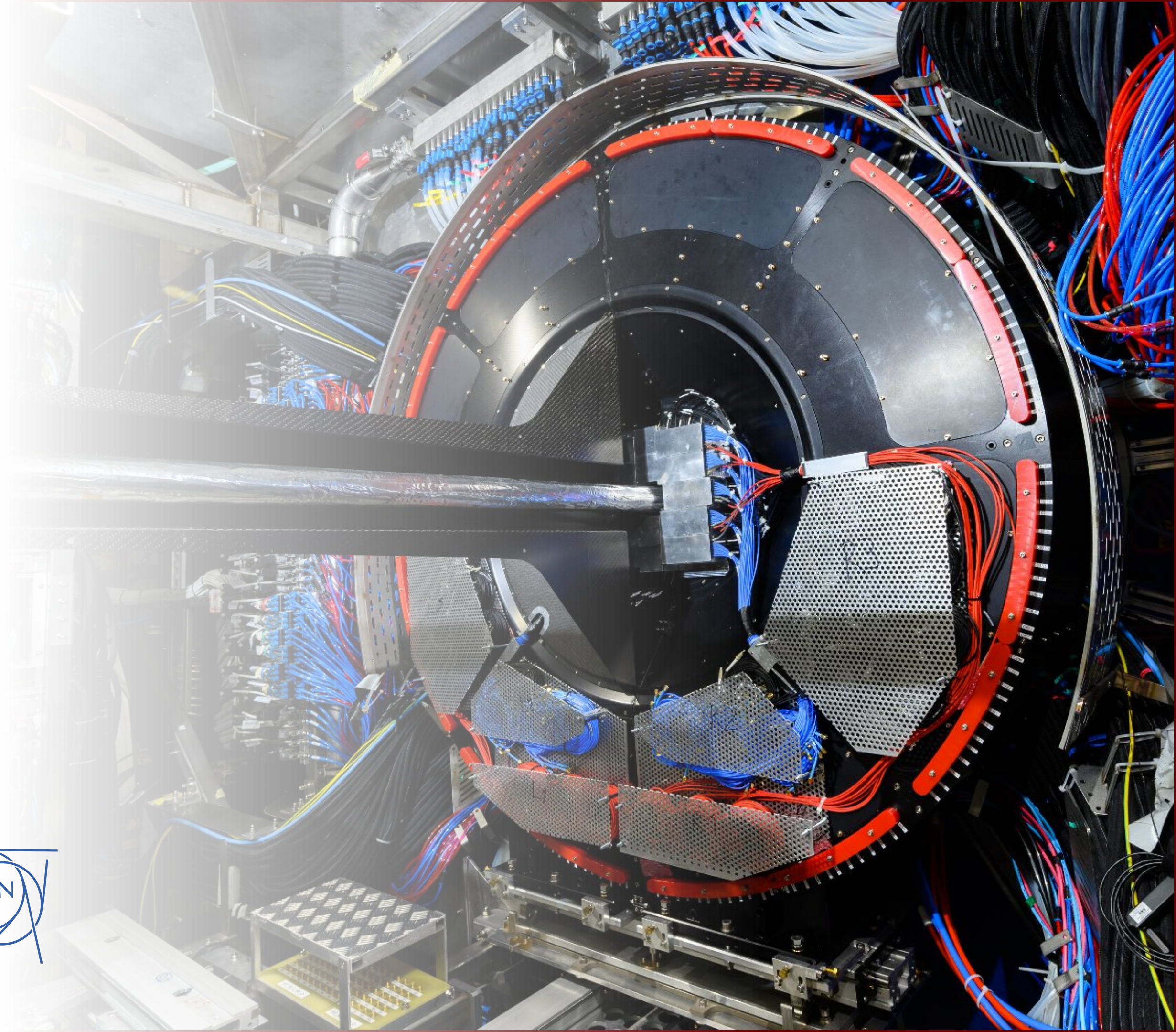

UPSILON - HADRON AZIMUTHAL CORRELATIONS IN PYTHIA-SIMULATED PROTON-PROTON COLLISIONS AT 500 GeV

O. Mezhenska [1], J. Bielčík [1], L. Kosarzewski [2]

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[2] Ohio State University, Columbus, OH 43210, USA.

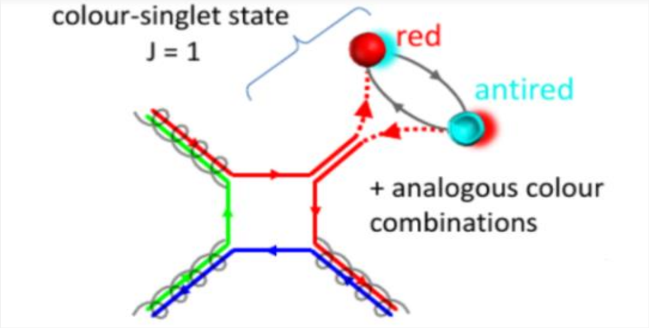
23rd ZIMÁNYI SCHOOL
WINTER WORKSHOP ON HEAVY ION PHYSICS
December 4-8, 2023
Budapest, Hungary

Flash talk, 7.12

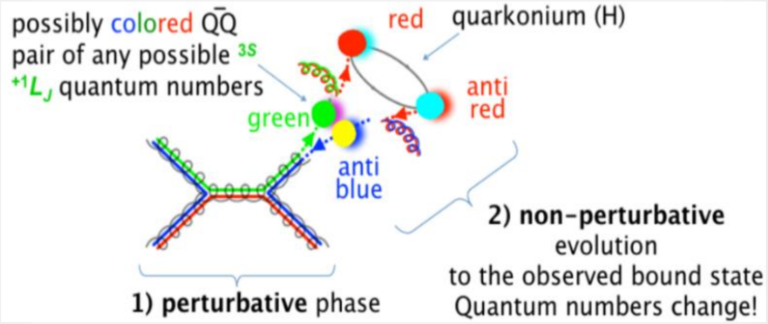
Introduction

- In heavy ion collisions, quarkonium can be used as a probe of quark-gluon plasma(QGP) properties.
- The production mechanism of heavy quarkonium is not fully understood by current models, e.g;
- *Physics Goal:* Investigate CS and CO Upsilon production mechanism by looking at Upsilon-hadron azimuthal correlations
- We employ the **PYTHIA event** generator to simulate *pp* collisions at 500 GeV to study **azimuthal angular correlation.**
- This study will be used as a reference for STAR measurements.

Color singlet (CS): $Q\bar{Q}$ produced directly in a color-neutral state in association with a gluon

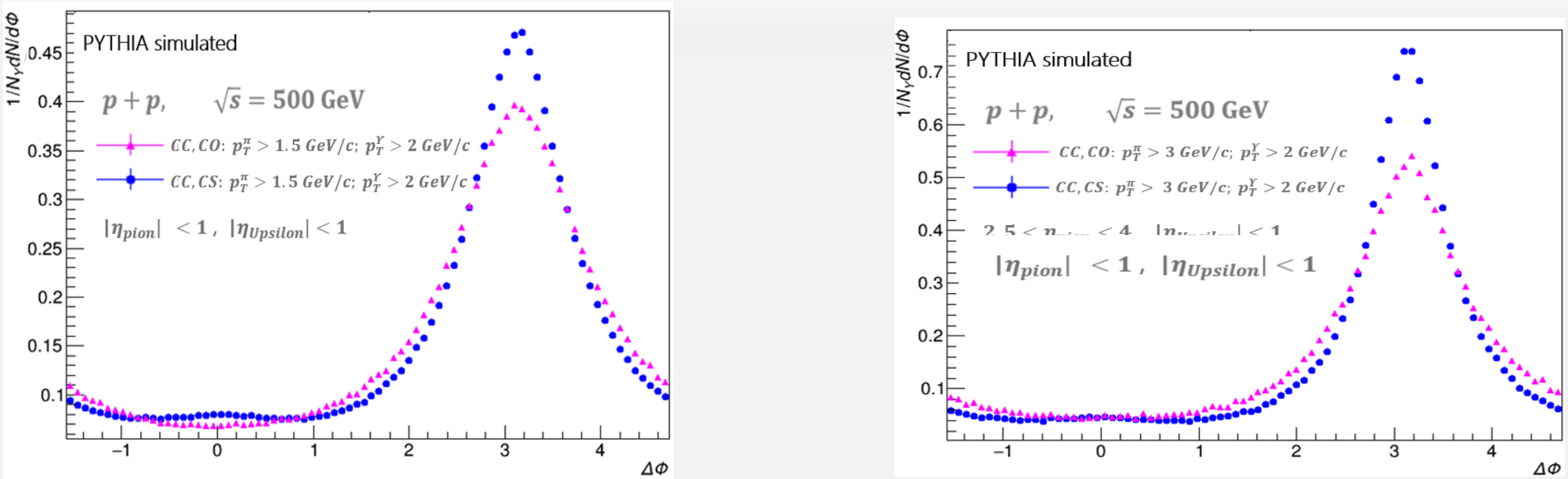


Color Octet (CO): $Q\bar{Q}$ can be produced in any colored or color-neutral state, with any quantum numbers $^{+1}L_J$

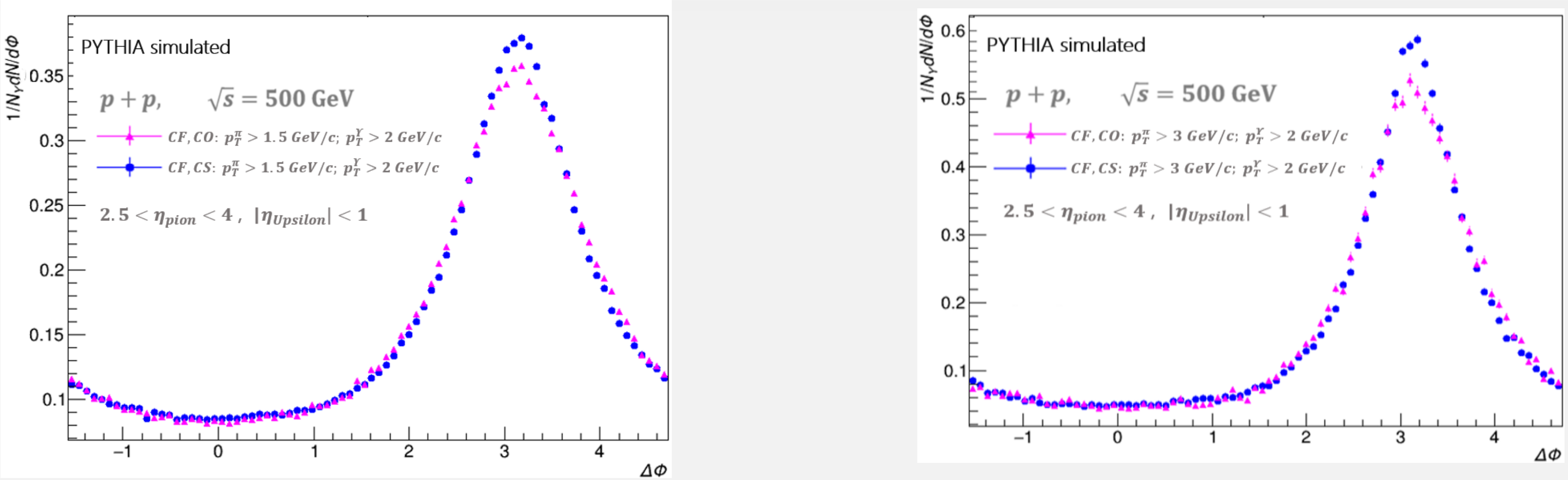


- Pion selection:
  - $p_T > 0.2$ GeV/c;
  - $|\eta| < 1$ (Central pseudorapidity range) or
    $2.4 < \eta < 4$ (Forward rapidity range) -> the double peak is expected [*E. Basso et al., PoS, EPS-HEP2015, 191 (2016)*].
- Upsilon selection:
  - directly produced Upsilon(1S) - no feed-down contribution;
  - dielectron decay (Υ (1S) $\rightarrow e^-e^+$) only.

Results



Υ + hadron azimuthal correlations for CS and CO production mechanism for central – central pseudorapidities



Υ + hadron azimuthal correlations for CS and CO production mechanism for central – forward pseudorapidities.

Conclusions

- The Υ + hadron correlation is characterized by an away-side peak at $\Delta\Phi = \pi$.
- Upsilon – hadron azimuthal correlations were obtained for the Υ particles generated for both the CS and CO production mechanisms.
- Stronger correlation in CS case compared to the CO.
- Correlation with a double-peak structure hasn`t been observed in the production of Υ particles via a color singlet state for pions located with forward pseudorapidities.
- The results of the simulation will serve as a basis for comparison with the experimental data gathered from the STAR experiment conducted at the RHIC in BNL

Thank you for attention!

Study of the J/ψ photoproduction with tagged forward proton in $p+p$ collisions at $\sqrt{s} = 510$ GeV

Michaela Sverakova (for the STAR collaboration)
Faculty of Nuclear Sciences and Physical Engineering
Czech Technical University in Prague

STAR

FACULTY OF NUCLEAR SCIENCES AND PHYSICAL ENGINEERING CTU IN PRAGUE

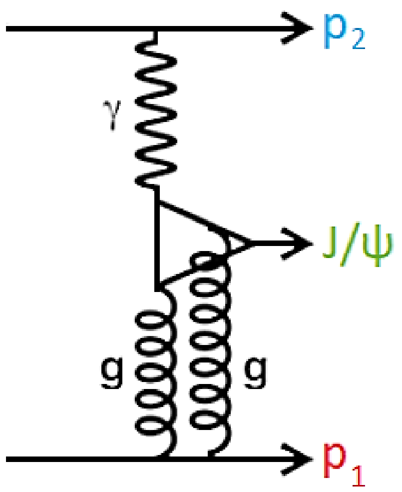
23rd ZIMANYI SCHOOL WINTER WORKSHOP ON HEAVY ION PHYSICS

December 4-8 2023, Budapest, Hungary

The work was supported by the Grant Agency of the Czech Technical University in Prague, grant No. SGS22/174/OHK4/3T/14 and by the Ministry of Education, Youth and Sports of the Czech Republic through the project LM2023034 Brookhaven National Laboratory - the participation of the Czech Republic.
The STAR Collaboration https://drupal.star.bnl.gov/ STAR/presentations

Supported in part by U.S. DEPARTMENT OF ENERGY

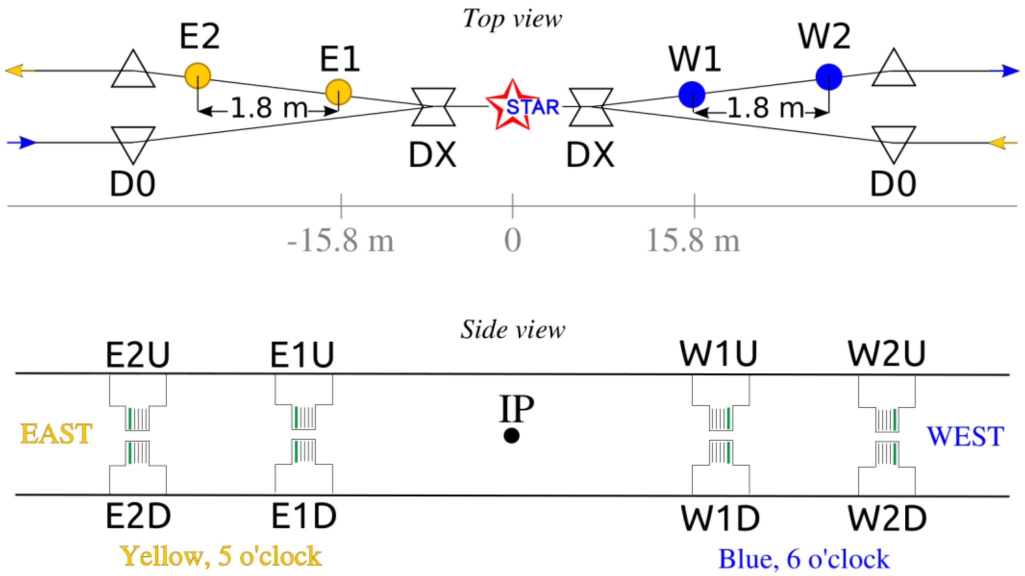
Exclusive measurement of J/ψ photoproduction



- p + p → p_1 + J/ψ + p_2
- J/ψ → $e^+ + e^-$ decay channel
- Interactions of proton's (p_1) electromagnetic fields, which are taken as fluxes of photons, with the other proton (p_2)
- Photons can fluctuate to a virtual hadronic state ($q\bar{q}$) which scatters of other proton and turns into a real vector meson (J/ψ)
- Interaction of $q\bar{q}$ pair with target proton through Pomeron exchange

Diffractive process

- Presence of one or both incoming particles that remain intact after a collision detected by special forward detectors - Roman Pots
- Produced central system of particles X separated by large rapidity gaps (LRG) from the forward protons



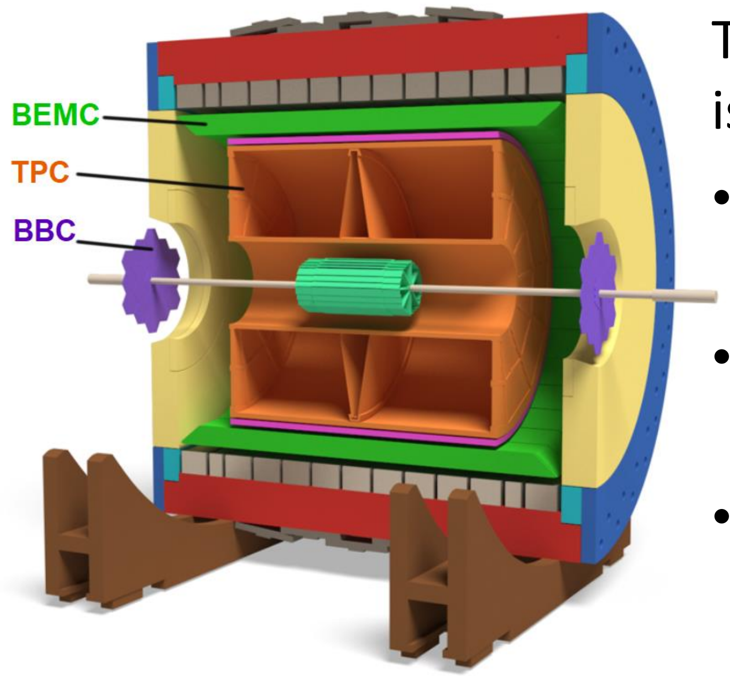
Goals of the analysis

J/ψ photoproduction in *p*+*p* collisions at √*s* = 510 GeV

Data from 2017 collected at the STAR experiment

A) Cross-section of J/ψ photoproduction as a function of transferred momentum $|-t|$

B) Possibility to have a precise measurement of the p_T of the virtual photon thanks to the measurement of forward proton in Roman Pot detectors: $-\mathbf{p}_{2,T} = (\mathbf{p}_{J/\psi} + \mathbf{p}_1)_T$

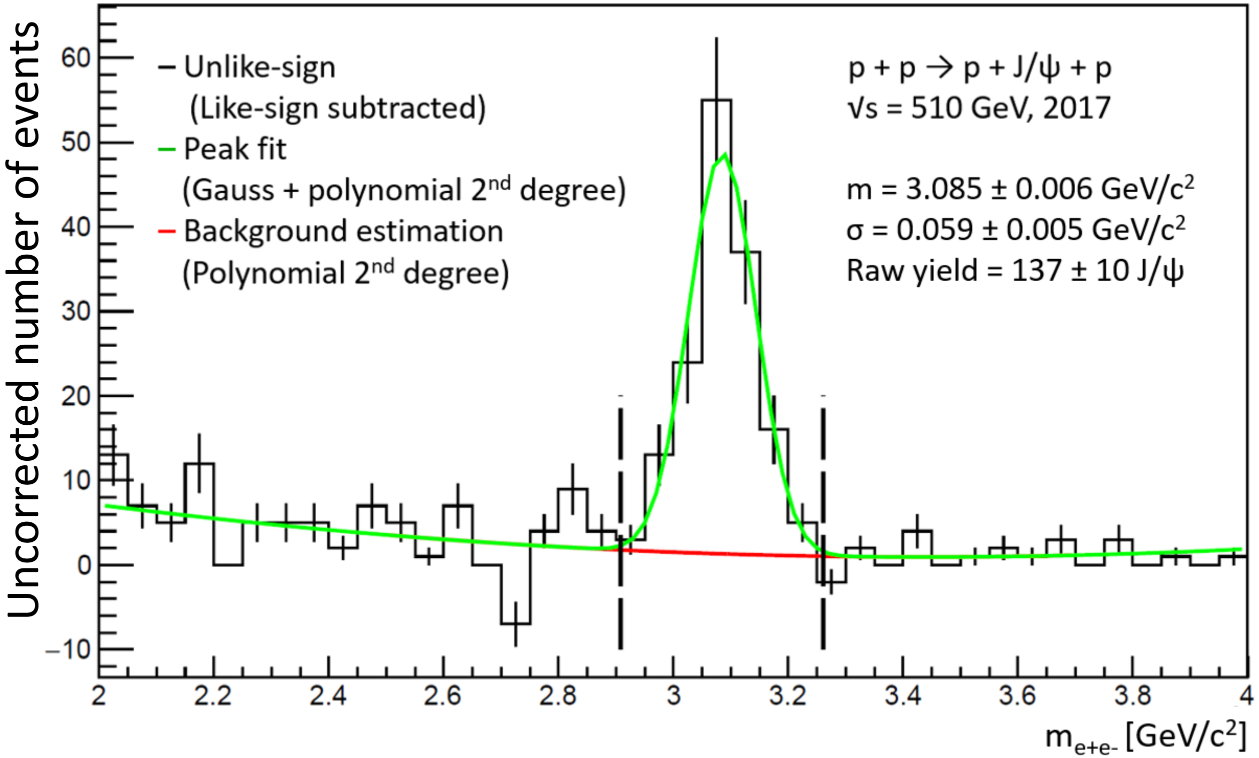


This analysis utilizes the unique ability of the STAR experiment, which is the detection of forward-going protons using Roman Pot detectors

- Proton p_1 from Pomeron vertex (high p_T) detected in Roman Pot detectors
- Proton p_2 from photon vertex (low p_T) scatters at a small angle, not measured in Roman Pots
- The electron and positron tracks (J/ψ → $e^+ + e^-$) are detected in the Time Projection Chamber and Barrel Electromagnetic Calorimeter

Results

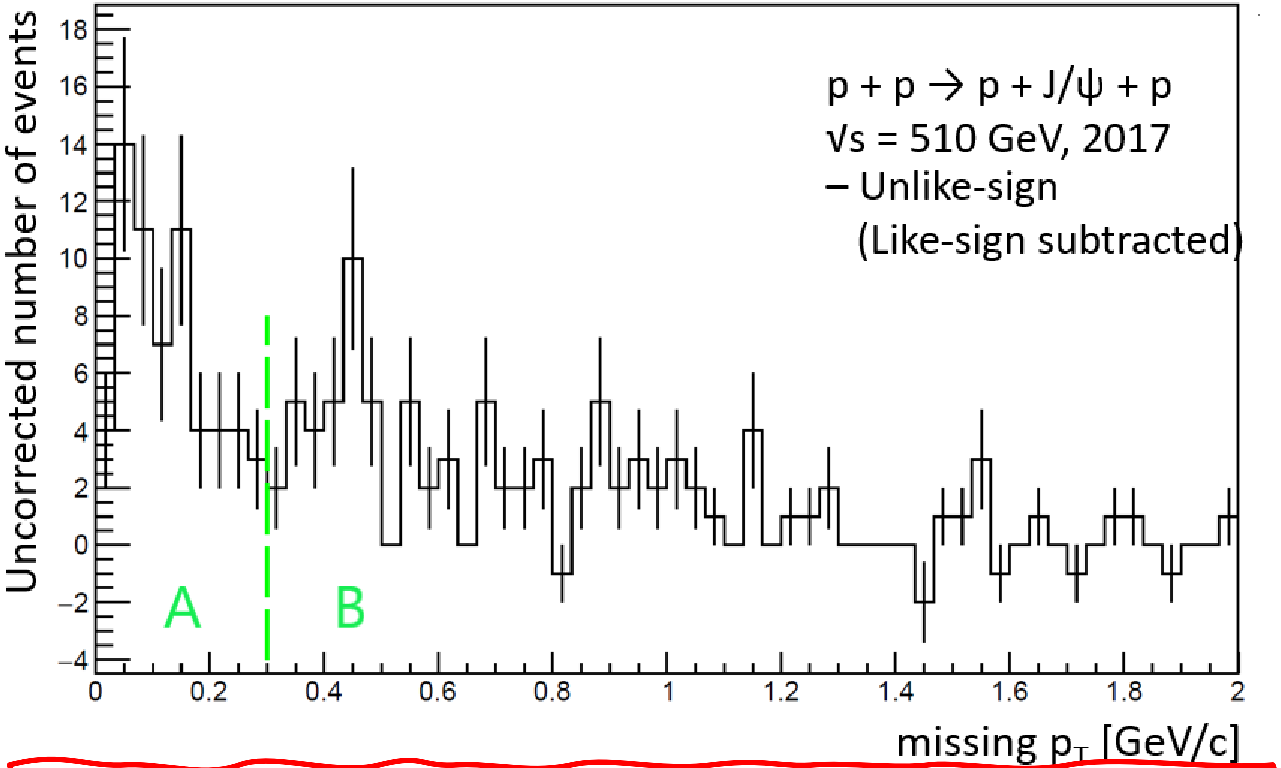
UNCORRECTED INVARIANT MASS AND RAW YIELD



- Prominent peak visible in the uncorrected invariant mass distribution
- Raw yield of $J/\psi \rightarrow e^{+} + e^{-}$ in *p+p* collisions with RP proton tagging extracted for the first time

MISSING p_T

- Momentum conserved in a collision $(\mathbf{p}_1 + \mathbf{p}_2 + \mathbf{p}_{J/\psi})_T = 0$
- J/ψ and proton measured
- p_T of virtual photon is the missing p_T : $-\mathbf{p}_{2,T} = (\mathbf{p}_1 + \mathbf{p}_{J/\psi})_T$



A: Peak at zero consistent with the exclusive process
B: Broad structure from 0.3 GeV/c is consistent with non-exclusive processes

Zimányi School 2023

Event-activity dependence of the beauty production in the enhanced color reconnection model at LHC energies

Zoltán Varga[1,2], Róbert Vértesi[1]

1. Wigner Research Centre for Physics

2. Budapest University of Technology and Economics

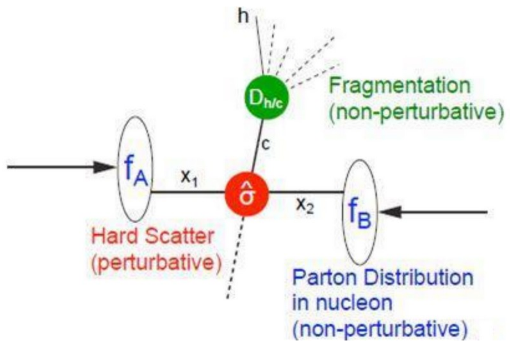
This work was supported by the Hungarian NKFIH OTKA FK 131979 and OTKA FK 135515 grants, as well as by the 2019-2.1.11-TÉT-2019-00078 and 2019-2.1.6-NEMZ_KI-2019-00011 projects.

Motivation

- **Heavy-flavor** production can be described with the factorization approach, in which the **incoming hadron PDFs**, **the parton-parton scattering cross-section** and the **fragmentation function** are independent:

$$d\sigma^{hard}_{AB\to C} = \sum_{a,b} f_{a/A}(x_a, Q^2) \otimes f_{b/B}(x_b, Q^2) \otimes d\sigma^{hard}_{ab\to c}(x_a, x_b, Q^2) \otimes D_{c\to C}(z, Q^2)$$

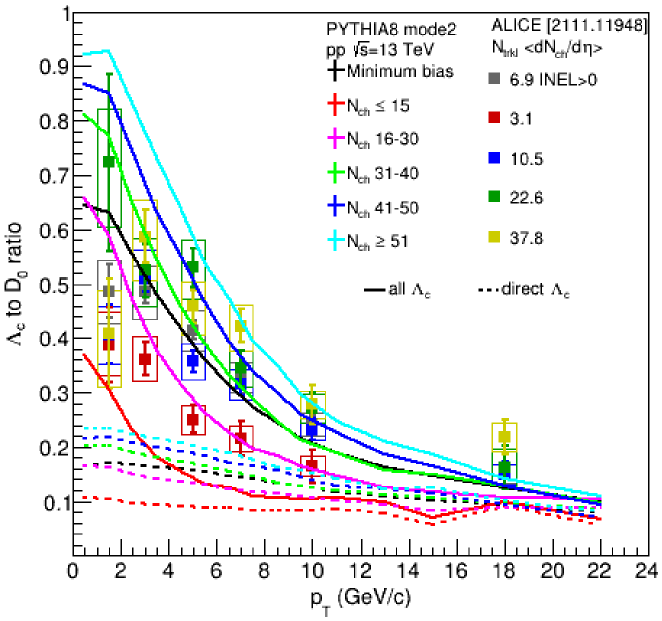
Parton Distribution Function (PDF) | Partonic hard scattering cross-section | Fragmentation Function (FF)

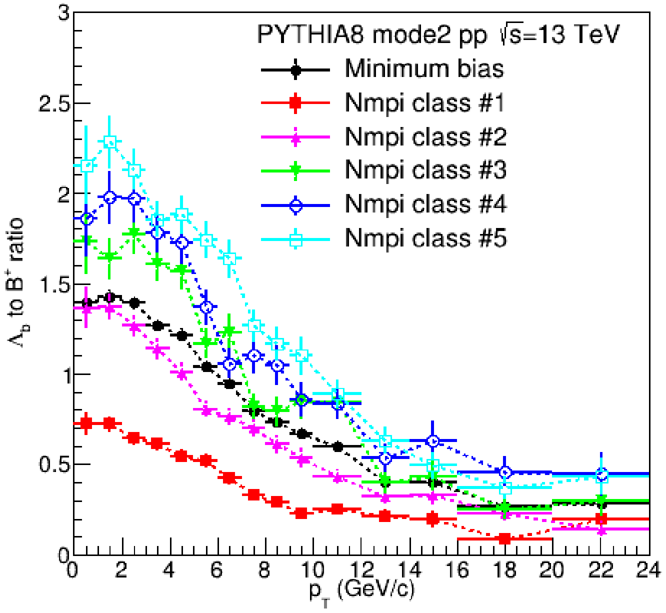


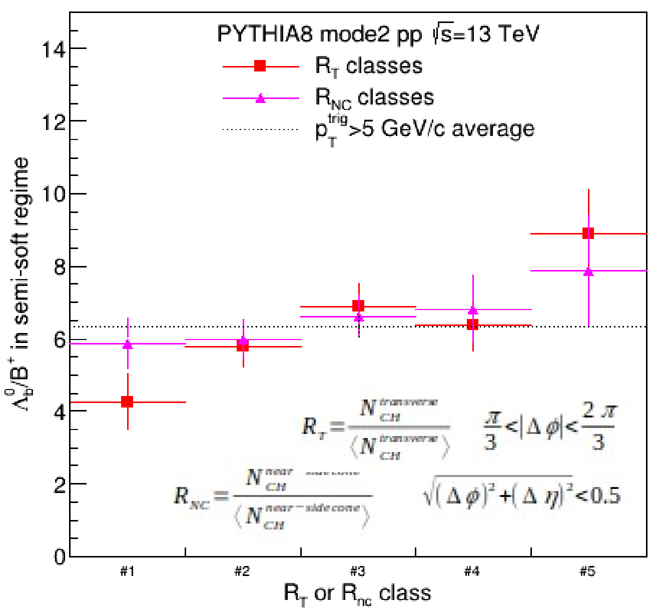
- Traditional assumption: fragmentation are **universal** for different collision systems
  - **FF** often determined from e^-e^+ (or e^-p) collisions, where **PDF** plays no (or less important) role
- Recent experimental results (ALICE, CMS, LHCb) on charmed baryon production **do not support** this assumption!

Charm and Beauty baryon enhancement

Z.V., R.V., J. Phys. G: Nucl. Part. Phys. 49 (2022) 075005 [arXiv:2111.00060] Z.V., A.M., R.V., J. Phys. G: Nucl. Part. Phys. 50 (2023) 075002 [arXiv:2302.09740]





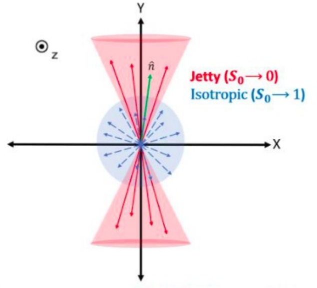


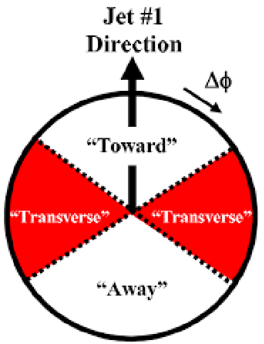
- **Experimental results: significant enhancement in the Λ_c/D^0 ratio** in the low p_T range compared to predictions from e^+e^-: **no universality!**
- **Multiplicity dependence**: connected to the event activity. Needs to be better understood!
- **Figure 1: String formation beyond leading color** (CR-BLC) (arXiv:1505.01681 [hep-ph]) can describe the Λ_c/D^0 enhancement in simulations.
- The Λ_c/D^0 ratio in the CR-BLC model depends on the event-activity, and the enhancement is connected to the underlying event activity, and does not depend significantly on the processes inside the jet region. What is the prediction for the Λ_b/B^+ ratio?
- **Figure 2:** The Λ_b/B^+ ratio increases with the number of MPI.
- **Figure 3:** Using event classifiers we showed that the **beauty enhancement** is **connected to the underlying event activity** (**R_T**), and **not to the jet region activity** (**R_{NC}**)!

Many different event-activity classifiers can be utilized!

- **N_{CH}** – multiplicity at mid-rapidity ($|\eta| < 1$): number of final state charged particles, describing the activity of the whole event.
- **N_{fw}** - forward multiplicity at forward rapidity ($2 < \eta < 5$),
- **R_T** $= N_{CH}^{transverse} / \langle N_{CH}^{transverse} \rangle$: **underlying event** activity, region excluding jets from the leading process. ($\pi/3<|\Delta\phi|<2\pi/3$)
- **R_{NC}** $= N_{CH}^{near\text{-}side\ cone} / \langle N_{CH}^{near\text{-}side\ cone} \rangle$: activity connected to the **jet region**, containing the leading process. $\sqrt{\Delta\phi^2+\Delta\eta^2}<0.5$
- **S_0**: **spherocity**, measures how spherical or jet-like the event is.
- **Flatenicity (ρ)**: the relative standard deviation of the p_T^{cell} distribution (event-by-event):

$$\rho = \sigma_{p_T}^{cell} / \langle p_T^{cell} \rangle$$





$$S_0 = \frac{\pi^2}{4} \times \min_{\hat{n}=(n_x,n_y,0)} \left(\frac{\Sigma_i |\vec{p}_{T_i} \times \hat{n}|}{\Sigma_i \vec{p}_{T_i}} \right)^2$$

On the poster: many interesting results on the other event classifiers!

Thank you for your attention!

Heavy-flavor electron production in Au+Au collisions at $\sqrt{s_{NN}}$ = 54.4 GeV at STAR

Veronika Prozorova *(for the STAR Collaboration)*

Czech Technical University in Prague

23rd Zimányi School Winter Workshop On Heavy Ion Physics

December 7th, 2023

Supported in part by

U.S. DEPARTMENT OF ENERGY | Office of Science

MINISTRY OF EDUCATION, YOUTH AND SPORTS

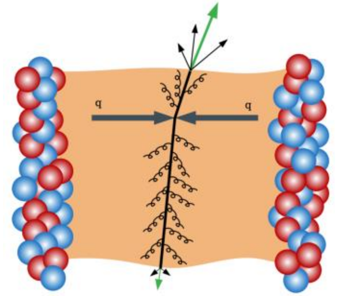
The work was supported by the Grant Agency of the Czech Technical University in Prague, grant No. SGS22/174/OHK4/3T/14 and by the Ministry of Education, Youth and Sports of the Czech Republic through the project LM2023034 Brookhaven National Laboratory - the participation of the Czech Republic.

Motivation

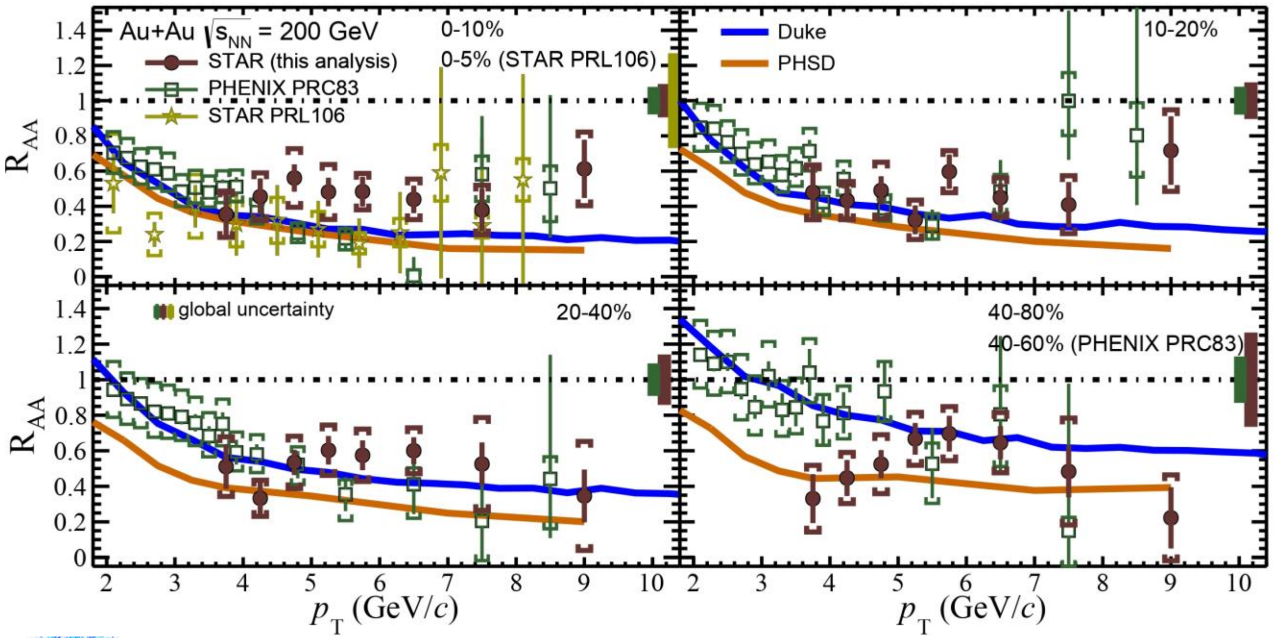
Heavy quarks

- Dominantly produced in initial hard scatterings
- Heavy quarks: $m_q >> \Lambda_{QCD}$, $m_q >> T_{QGP}$
- Production cross-sections can be calculated in perturbative QCD
- Participate in the whole medium evolution

→ Ideal probes of QGP



Heavy-flavor electrons (HFE) - Electrons from semi-leptonic decays of open heavy-flavor hadrons



HFE suppression in the QGP in Au+Au @ 200 GeV within $3.5 < p_T < 8$ GeV/c

↓

Significant energy loss of heavy quark (HQ) in QGP

↓ lower collision energies?

Explore HQ energy loss at lower collision energy (54.4 GeV)

STAR: JHEP06(2023)176
PHENIX: V, Phys. Rev. C 84 (2011) 044905
STAR: Phys. Rev. Lett. 98 (2007) 192301.

General idea of the analysis

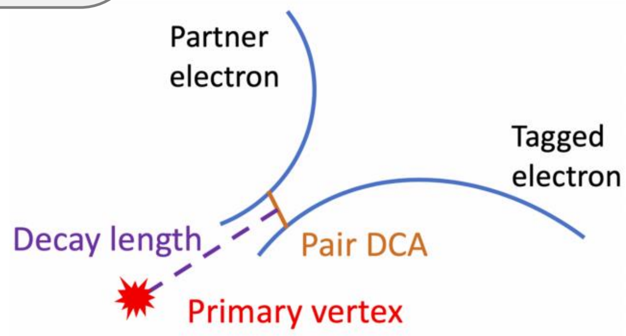
$$N_{HFE} = \underbrace{\frac{N_{INCL} \cdot \text{purity} - N_{PE}/\varepsilon_{PE}}{\varepsilon_{tot}}}_{N_{NPE}} - N_{HDE}$$

Photonic electron (PE) sources:
1. Dalitz decays ($\pi^0/\eta \rightarrow \gamma e^+ e^-$)
2. Gamma conversion ($\gamma \rightarrow e^+ e^-, \pi^0/\eta \rightarrow \gamma\gamma$)

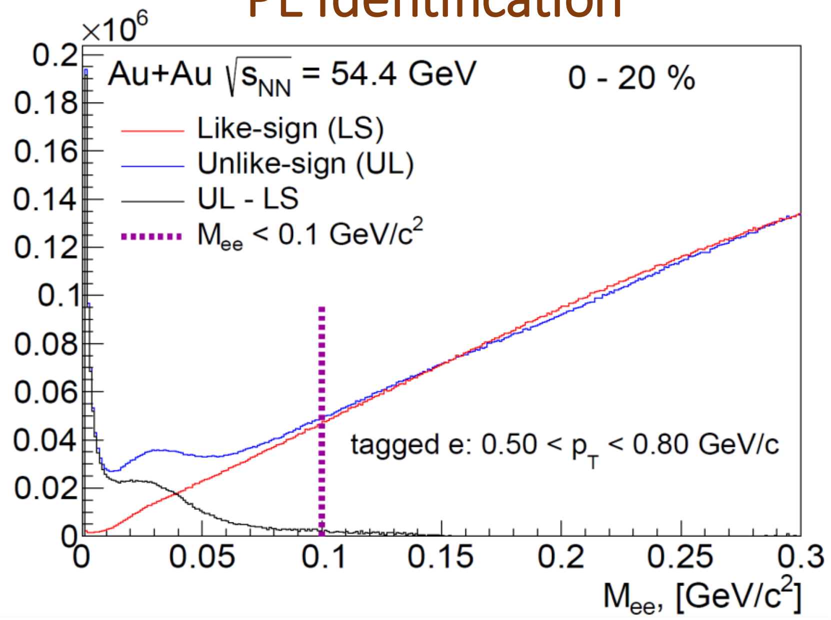
Hadron-decayed electrons (HDE):
- ρ, ω, ϕ
- J/ψ, Υ
- Drell-Yan
- K_{e3}

- N_{INCL} - inclusive electron yield
- **purity** - purity of inclusive electrons
- N_{PE} - photonic electron yield
- ε_{PE} - photonic electron identification efficiency
- ε_{tot} - total efficiency of electron identification and reconstruction

→ Ongoing + correction for HDE is planned



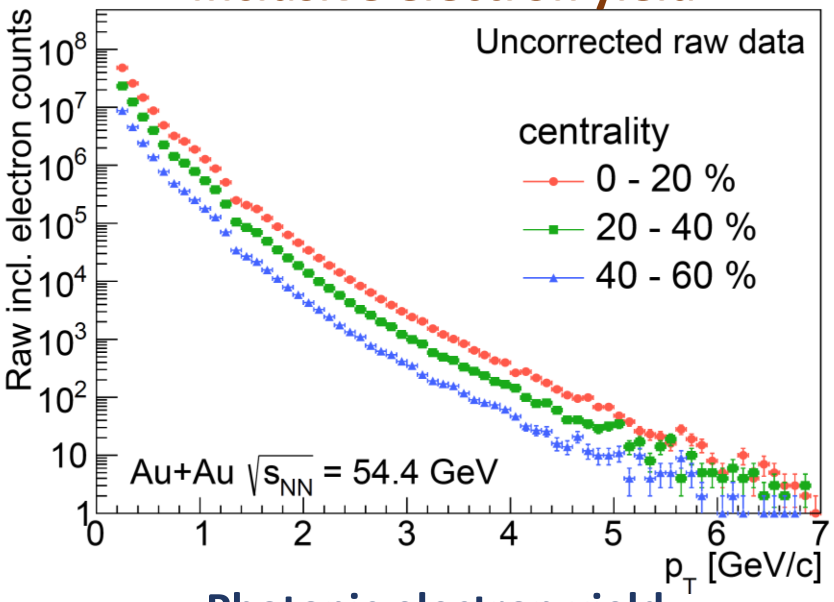
PE identification



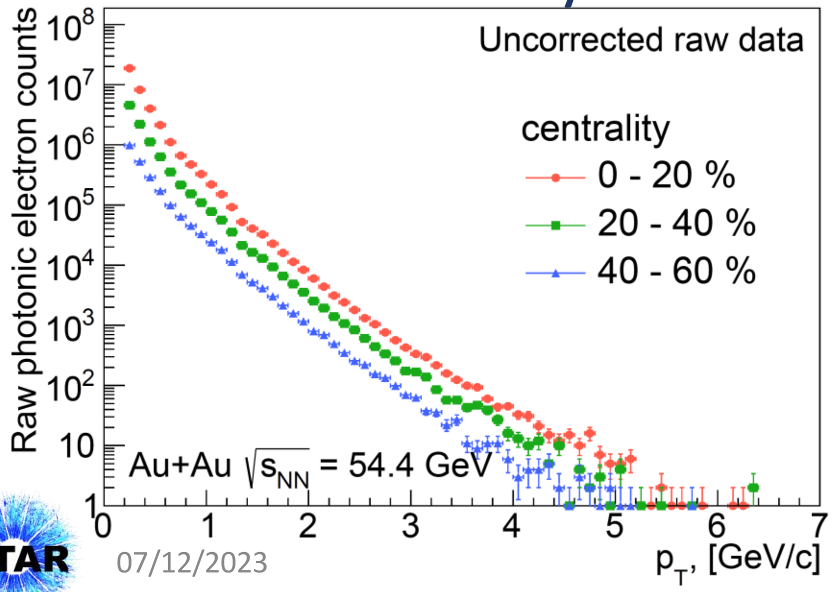
Results

Analysis ongoing in STAR

Inclusive electron yield

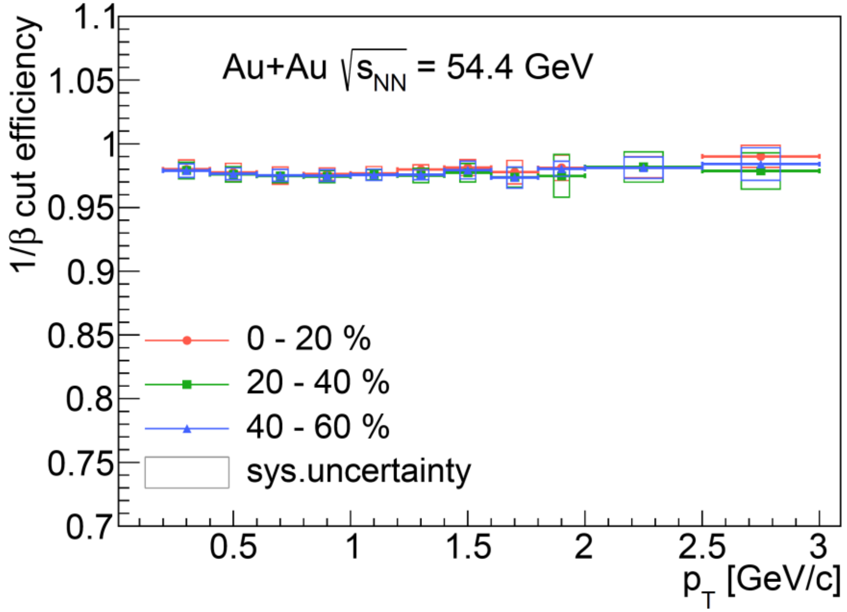


Photonic electron yield



data

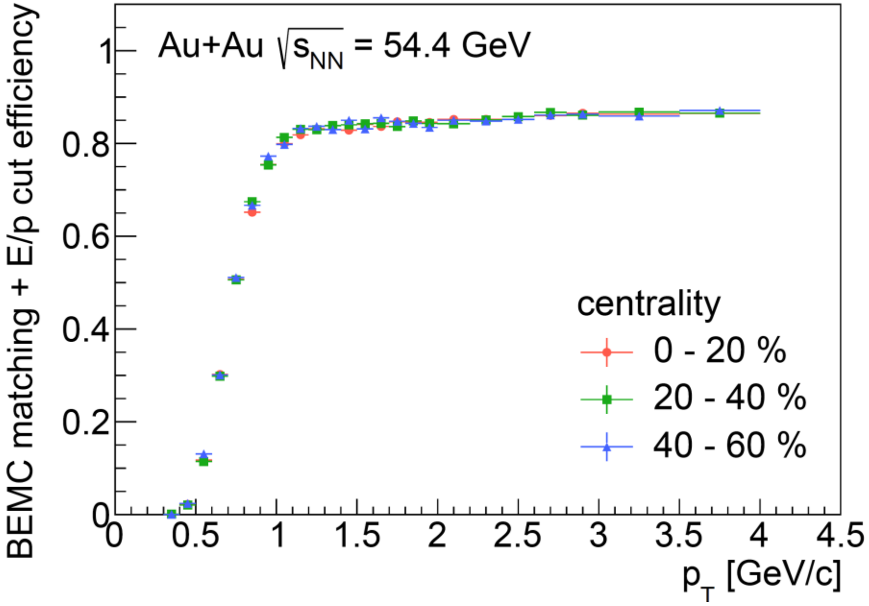
ε_{total}



- $1/\beta$ cut
- $n\sigma_e$ cut
- TOF matching

Ongoing

Simulation



- BEMC matching
- E/p cut
- TPC tracking

Flash talk

Current status and future prospects of measuring hadronic interactions in pp collisions at 13.6 TeV with ALICE

Georgios Mantzaridis
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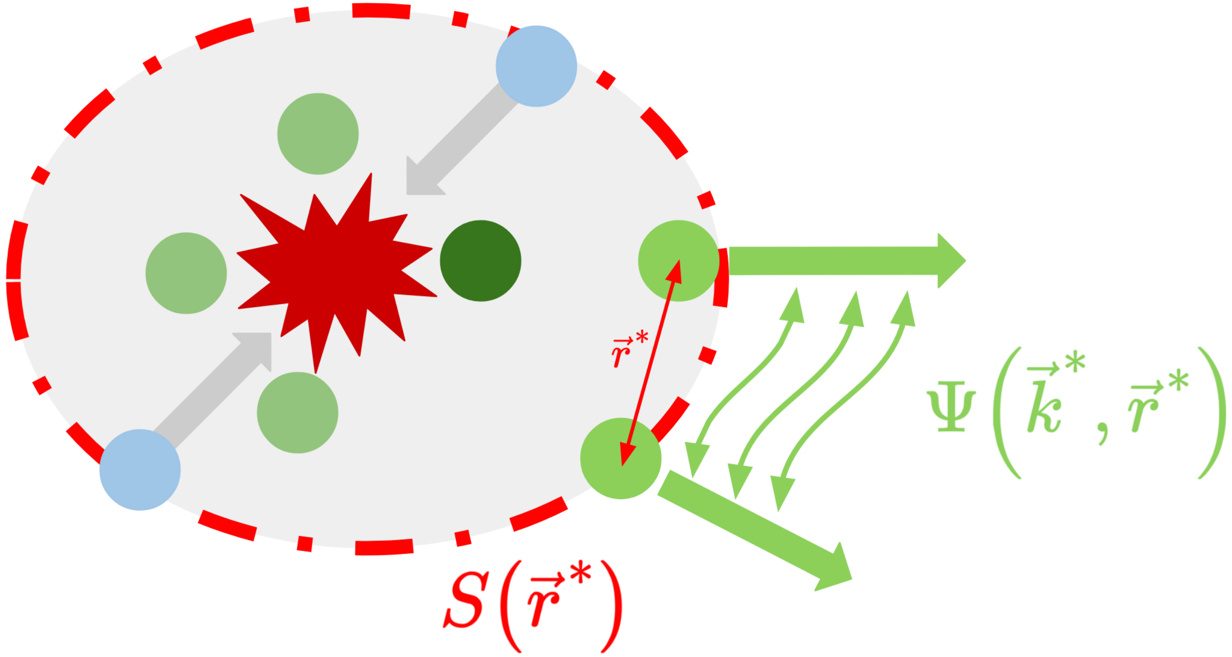
23rd Zimányi school
Winter Workshop on Heavy Ion Physics
December 4-8, 2023
Budapest, Hungary

Accessing hadronic interactions with femtoscopy

$$C(k^*) = \mathcal{N}\frac{N_{SE}(k^*)}{N_{ME}(k^*)} = \int S(r^*)\left|\Psi(k^*, r^*)\right|^2 \mathrm{d}^3 r^*$$



Workflow for fixing the source:

- Measure correlation function C(k*)
- Fix interaction Ψ(k*)
- Study source S(r*)

Accessing hadronic interactions with femtoscopy

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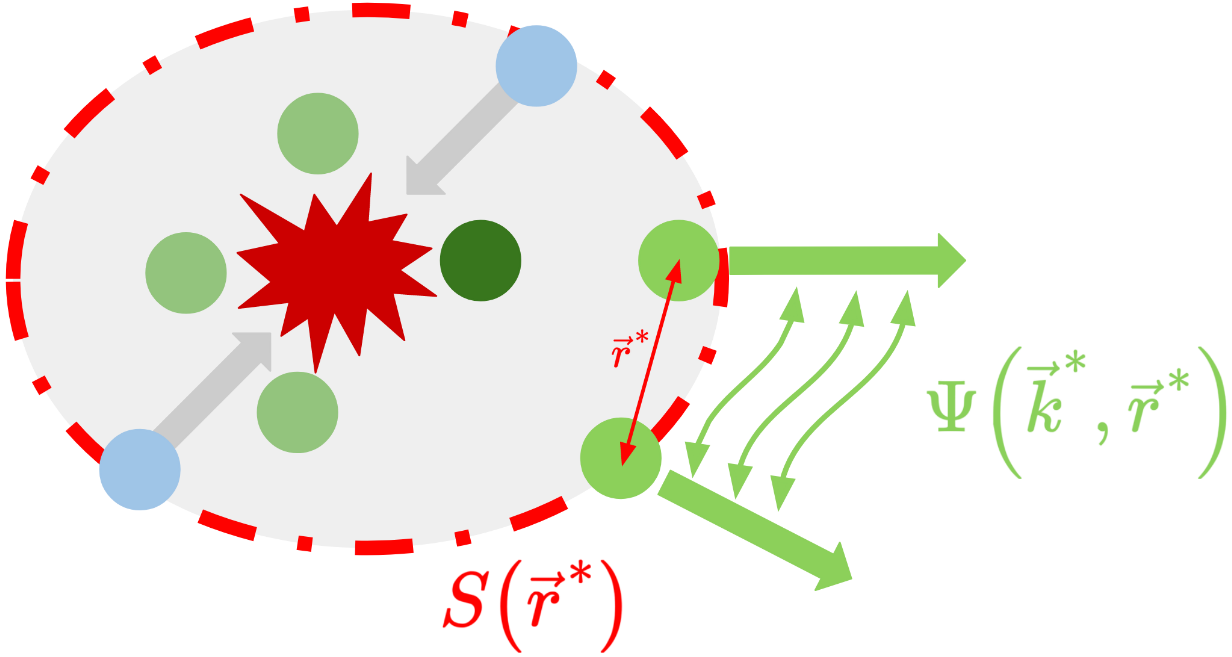


Workflow for accessing interaction:

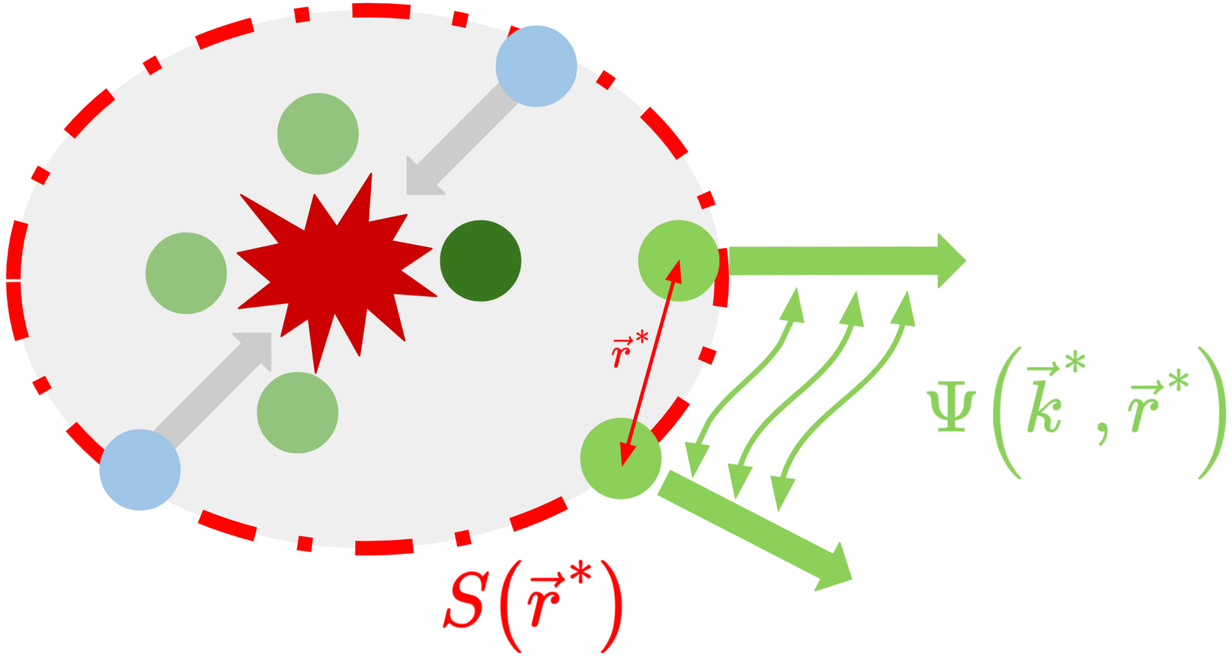
- Measure correlation function C(k*)
- Fix source S(r*)
- Study interaction Ψ(k*)

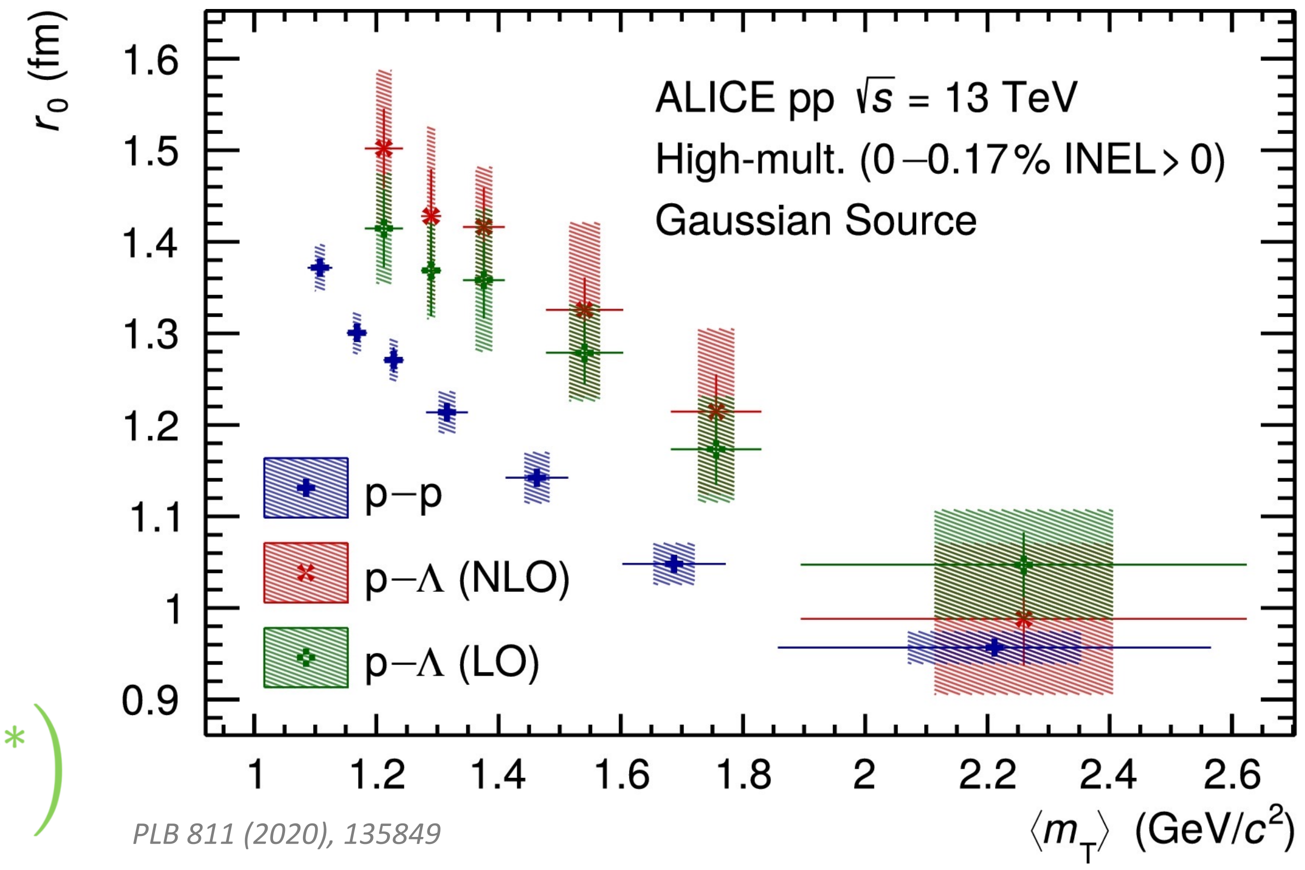
⇒ Accessing exotic interactions, e.g.:
p–Ω and Λ–Ξ (multi-strange)
p–D^+ (charmed)

Common baryonic source in pp collisions

How to constrain the source size:

- Measure **correlation function C(k*)**
- Fix **interactions Ψ(k*)** -> **p–p & p–Λ**
- Take **short-lived resonances** into account
- Extract **source as a function of m_T**





PLB 811 (2020), 135849

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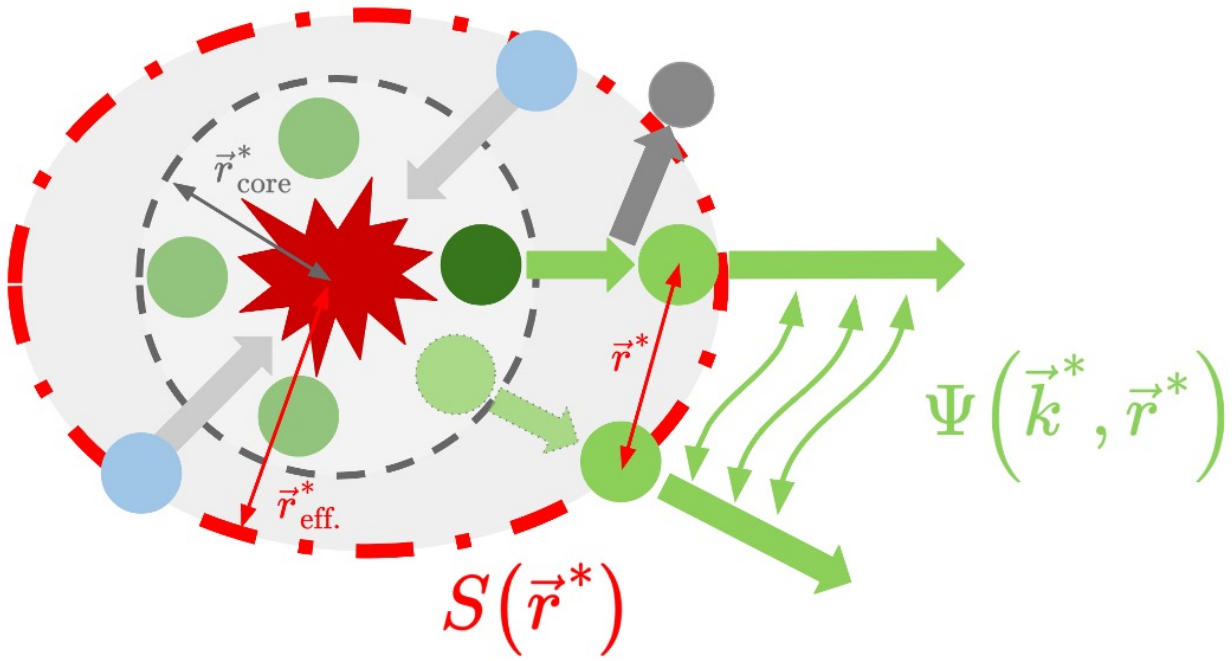
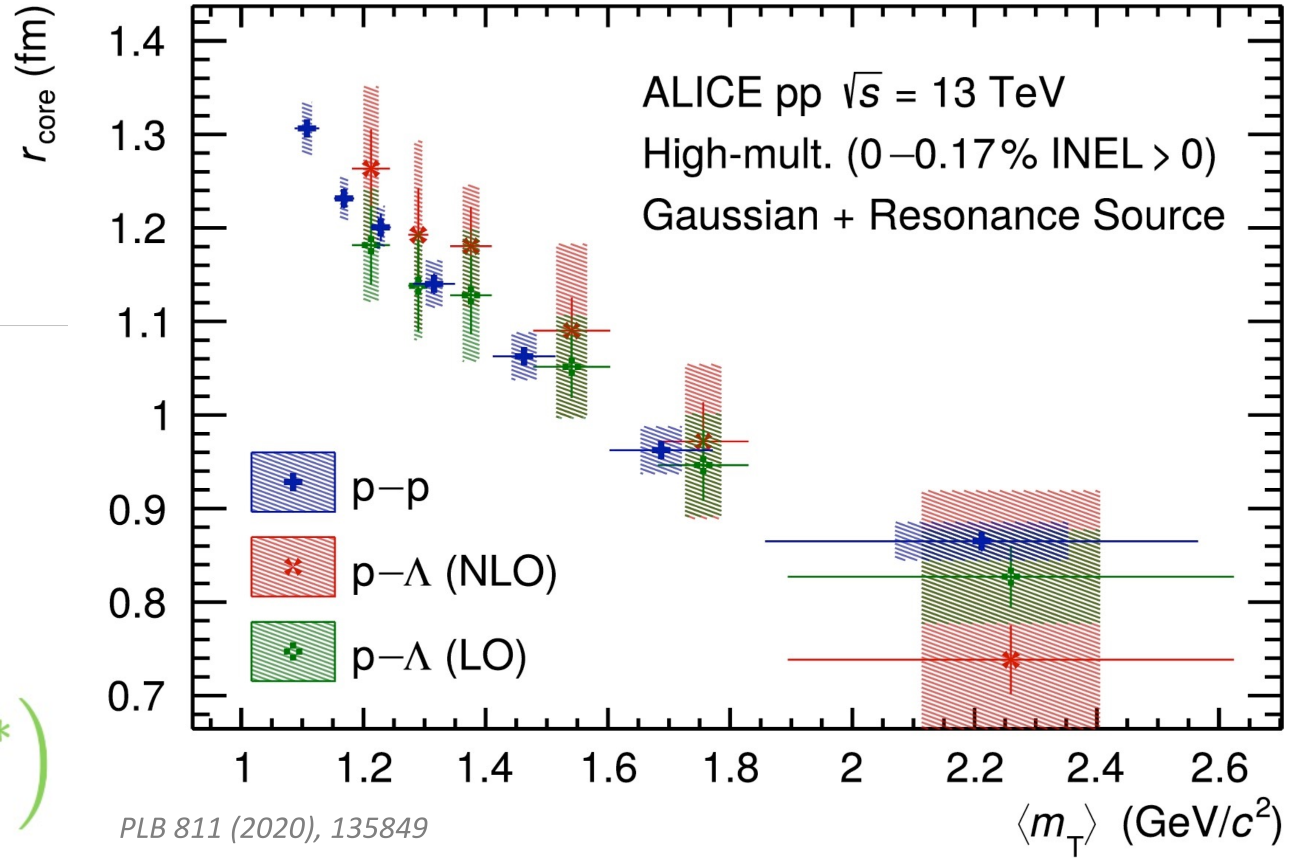
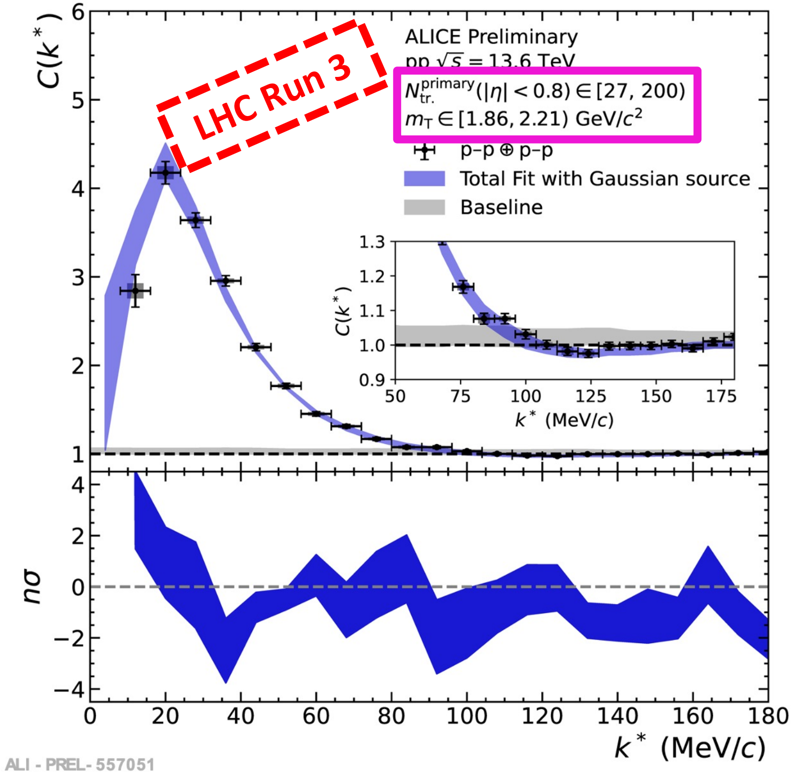




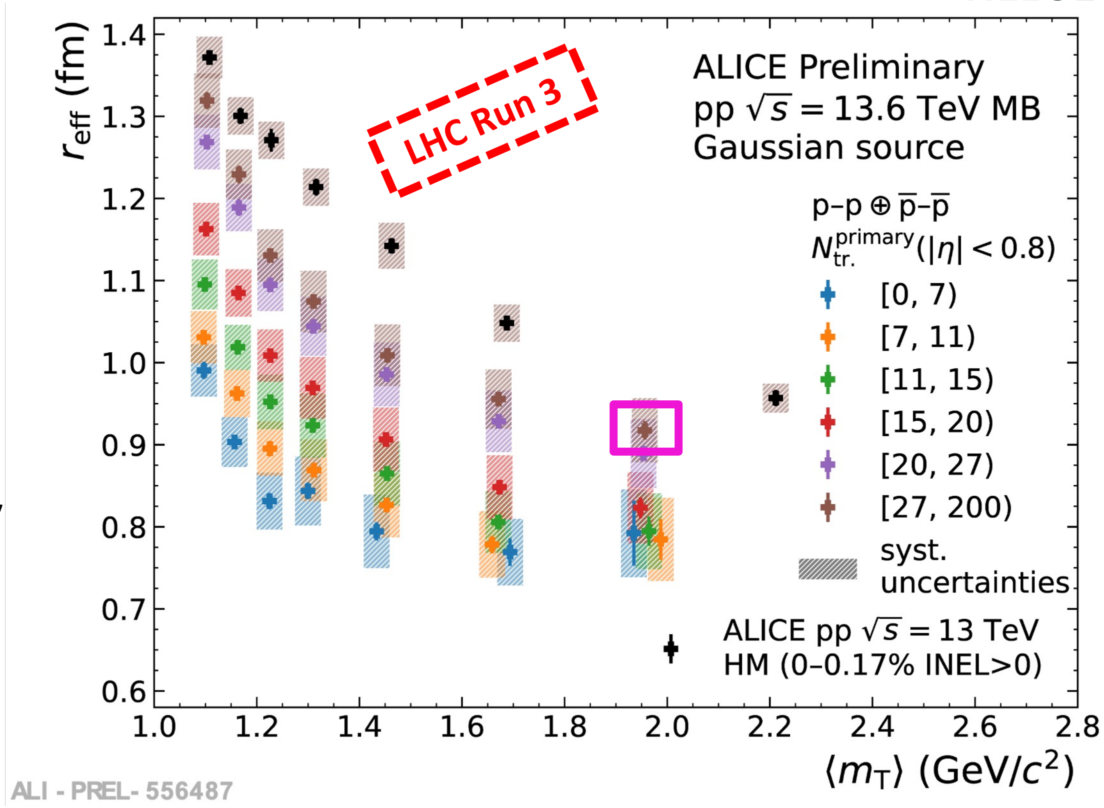
PLB 811 (2020), 135849

Current status: Starting femtoscopy in Run 3



600 billion MB events collected in 2022 alone

Observation:
Source radius increases with increasing multiplicity and decreases for increasing m_T



- First multiplicity and m_T differential measurement of p–p correlations
- First baseline measurement for constraining the source for all future femtoscopy studies in Run 3 with ALICE
  ➔ statistically limited channels and three body correlations accessible with Run 3 data
- Next steps: Extend source measurement to p–Λ and core source

Calculation of Coulomb interacting Bose-Einstein correlations in Fourier space

ELTE
EÖTVÖS LORÁND
UNIVERSITY

Bose-Einstein correlation function

- Source function: $S(x, p)$
- Single- and two-particle momentum distributions:

$$N_1(p),\ N_2(p_1, p_2)$$

- Bose-Einstein corr. function:

$$C_2(p_1, p_2) = \frac{N_2(p_1, p_2)}{N_1(p_1) N_1(p_2)}$$

- Non-interacting particles:

$$C_2(\boldsymbol{k}, \boldsymbol{K}) = 1 + \frac{\left|\tilde{S}\left(2\boldsymbol{k}, \frac{\boldsymbol{K}}{2}\right)\right|^2}{\left|\tilde{S}\left(2\boldsymbol{k}, \frac{\boldsymbol{K}}{2}\right)\right|^2}$$

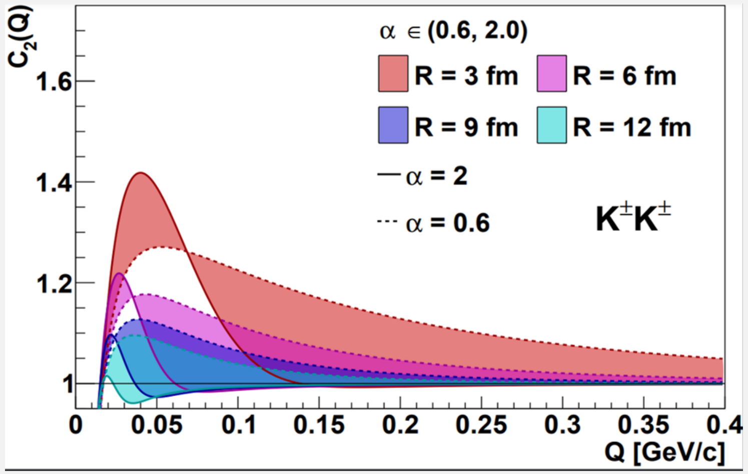
New formula for Lévy-stable sources

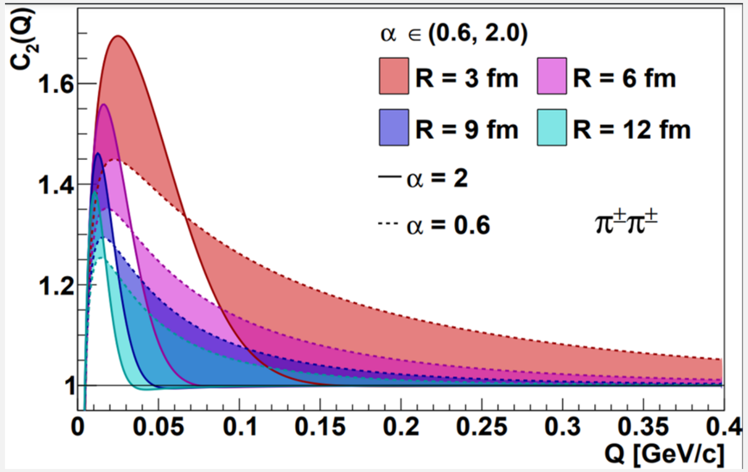
- Koonin-Pratt formula:

$$C_2(k) = \int d^3r\, D(r)|\psi_k(r)|^2$$

- Key assumptions: spherical symmetry and Lévy-stable distribution of the source
- Calculation was done by inserting an exponential „regularization", $e^{-\lambda r}$, and taking $\lambda \to 0$ at the end
- Result :

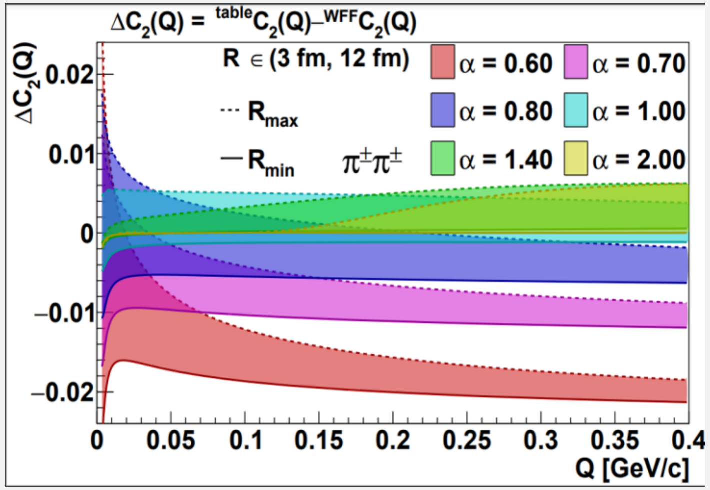
$$C_2(k) = |\mathcal{N}|^2 \left(1 + f_s(2k) + \frac{\eta}{\pi}[\mathcal{A}_{1s} + \mathcal{A}_{2s}]\right)$$

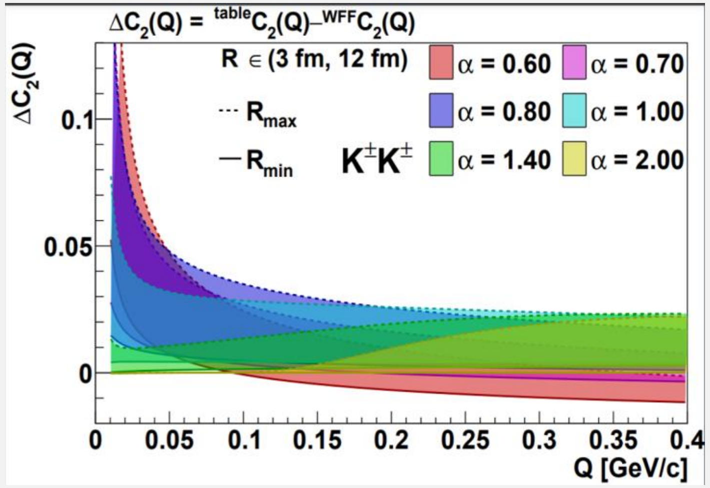




Comparison with the original numerical method

- Previous method: the values of the correlation function were pre-calculated for various parameters, and saved in a large table
- New method: simple and more exact handling of the Coulomb final state interaction
- Natural next step: extend the methodology to non-spherical sources





Multi-dimensional investigation of the pion pair-source in heavy-ion collisions with EPOS

Emese Árpási
(in collaboration with Márton Nagy, Dániel Kincses)
Eötvös Loránd University, Budapest

23rd ZIMÁNYI SCHOOL WINTER WORKSHOP ON HEAVY ION PHYSICS
December 4-8, 2023
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Theoretical framework and methods

- EPOS: event generator of heavy-ion collisions
- Event-by-event and 3 dimensional investigation to see if the Lévy shape is the result of event-averaging or direction averaging
- Pion pair source function fitted with Lévy distribution

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

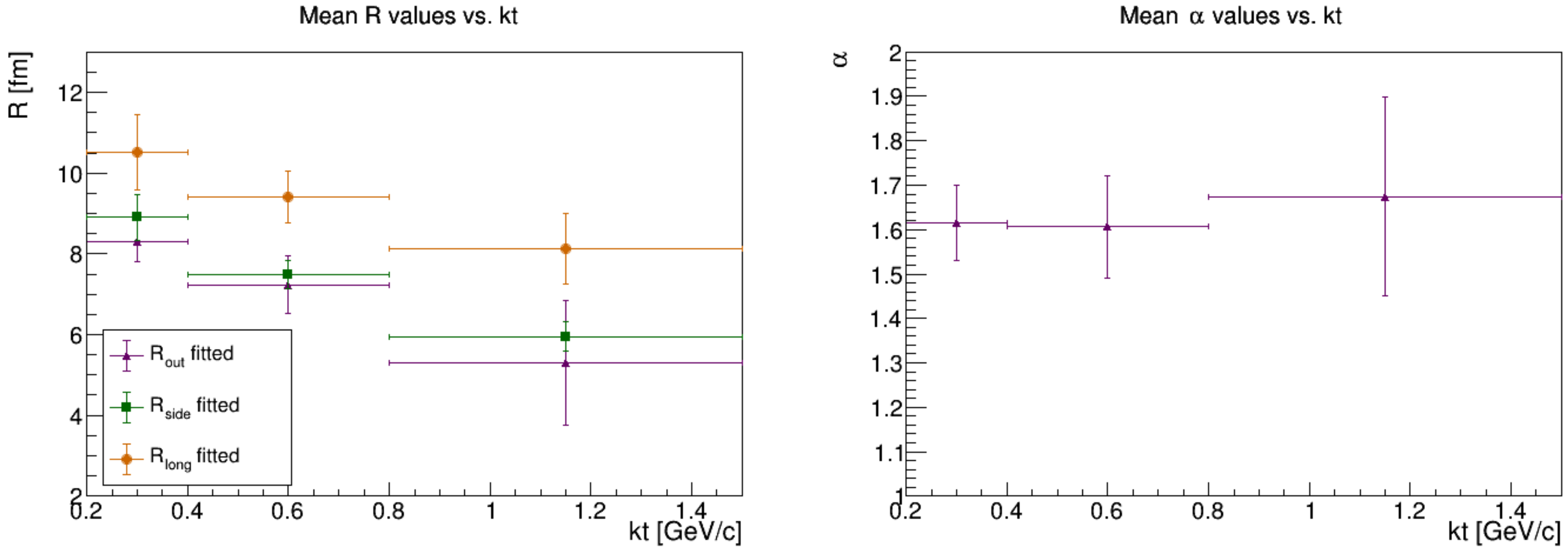
- Event-by-event distributions of pion pairs
- Separated the measurements into centrality and k_T classes
- 3 dimensional pair-distribution ⇒ 1 dimensional projections according Bertsch-Pratt-coordinates ⇒ fitting 1 dimensional Lévy-functions to the projections

$$\mathcal{L}(r, R_{out,side,long}, \alpha) = \frac{1}{\pi}\int_0^\infty dq \cos qr\, e^{-\frac{1}{2} q R_{out,side,long}}$$

- For the 3 projection of a 3 D distribution: fitting simultaneously with same Lévy exponent but different Lévy scales

Results

- Lévy-exponent: $\alpha \approx 1.6 - 1.7$, not Gaussian ($\alpha \neq 2$)
- Lévy-scale: different values for the different projections (with the same α-s)
- Lévy shape is not the result of event-averaging or direction averaging
- Results agree with 1D analysis of Ref. D. Kincses, M. Stefaniak and M. Csanád, Entropy 24 (2022) no.3, 308



Thank you for your attention!

Sensitivity of finite volume effects to the boundary condition and the vacuum term

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Zimányi School 2023
Poster Session
2023 December 7

Collaborators:
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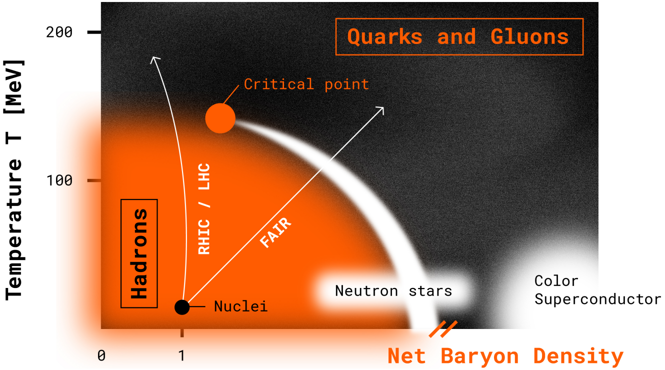
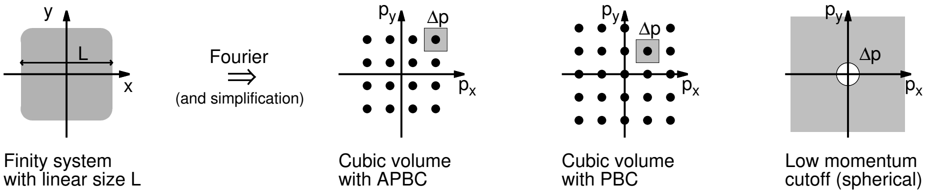
Pok Man Lo, Wroclaw U
Krzystof Redlich, Wroclaw U

- Finite size in lattice QCD infinite volume limit
- Infinite size in field theoretical calculations
- Finite size fireball in HIC (expanding, fluctuating ...)
- Core of a compact star "infinitely" large

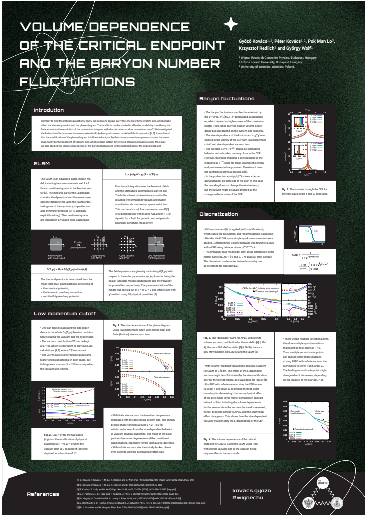


How to account for the finite system size?
In effective models usually via **momentum space constraints**



Do the different approaches give the same results?
Are these constraints enough or do we miss something?

SEE YOU THERE !



Localization of Dirac modes in the SU(2)-Higgs model at finite temperature

György Baranka

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December 07, 2023

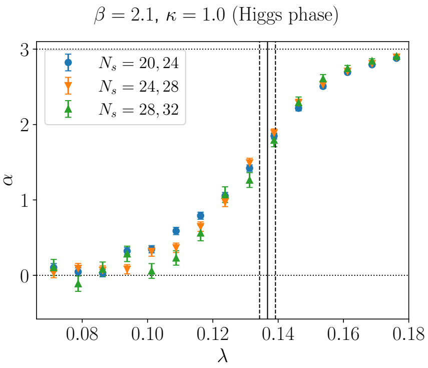
Based on arXiv:2310.03542 (to appear in *Phys. Rev. D*)
Work done in collaboration with Matteo Giordano

Motivation

- connection between deconfinement and chiral symmetry restoration in QCD is still not fully understood
- low Dirac modes could be key in understanding this connection
- chiral symmetry breaking is controlled by the density of low modes (Banks-Casher relation)
- deconfinement is signalled by the ordering of Polyakov loops
- islands of fluctuations in the sea of ordered Polyakov loops are favorable for Dirac modes ⇒ Dirac modes localize [Bruckmann *et al.* (2021)]
- this mechanism is general: test it in other gauge theories with a deconfinement transition ⇒ SU(2)-Higgs model [G. Baranka and M. Giordano (2023)]

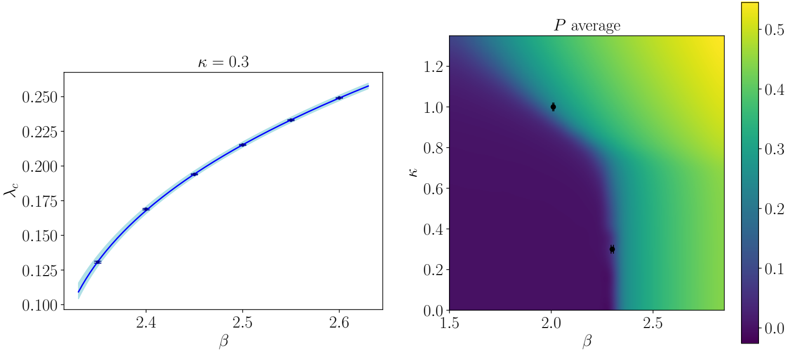
Localization in the SU(2)-Higgs model

- localized/delocalized modes occupy finite amount/fraction of volume
- mode size $\sim L^{\alpha}$ (α: fractal dimension)
- modes are localized up to the mobility edge λ_c



Phase diagram and localization

Localization absent in confined phase, $\lambda_c \to 0$ at the crossover



References

[Bruckmann *et al.* (2021)] F. Bruckmann, T. G. Kovács, and S. Schierenberg, *Phys.Rev. D* **84**, 034505 (2011)

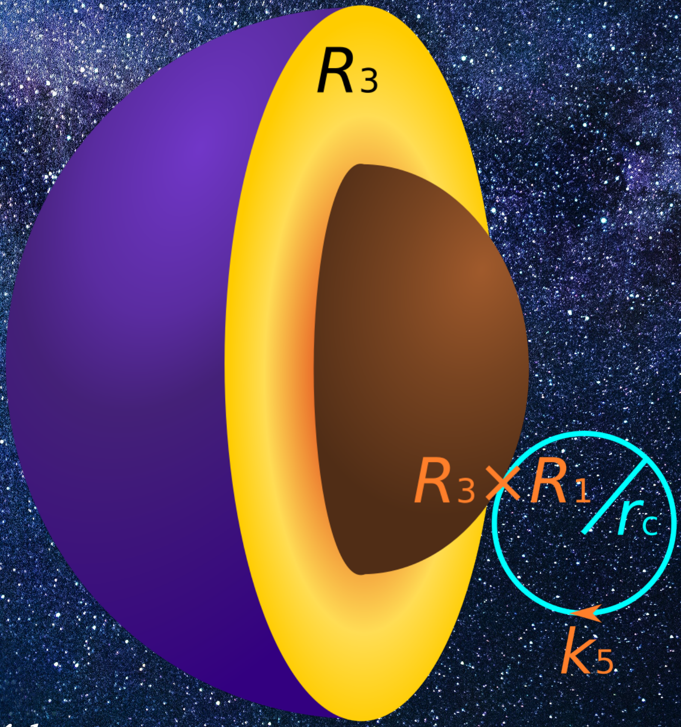
[G. Baranka and M. Giordano (2023)] G. Baranka and M. Giordano, arXiv:2310.03542 (2023)

What is a compact star?

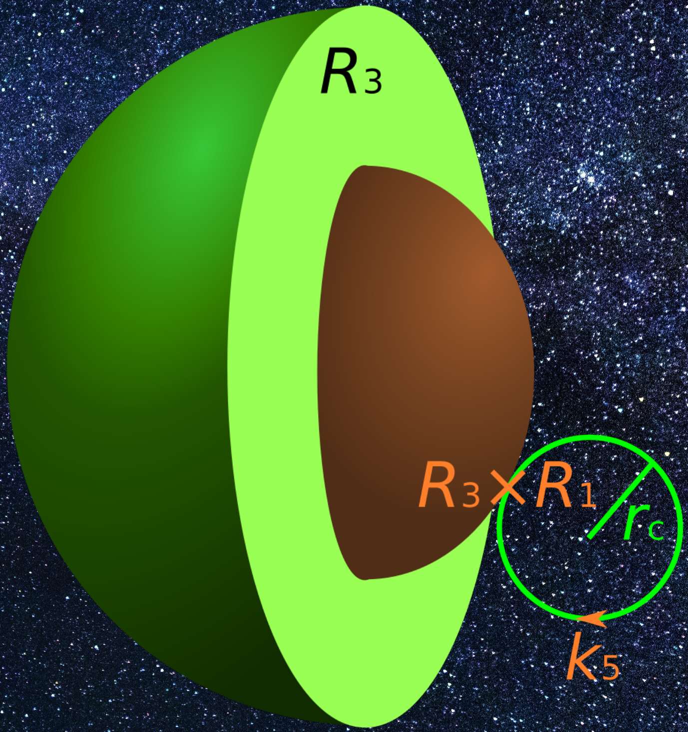
Anna Horváth

What is a compact star?

Is it a plum...



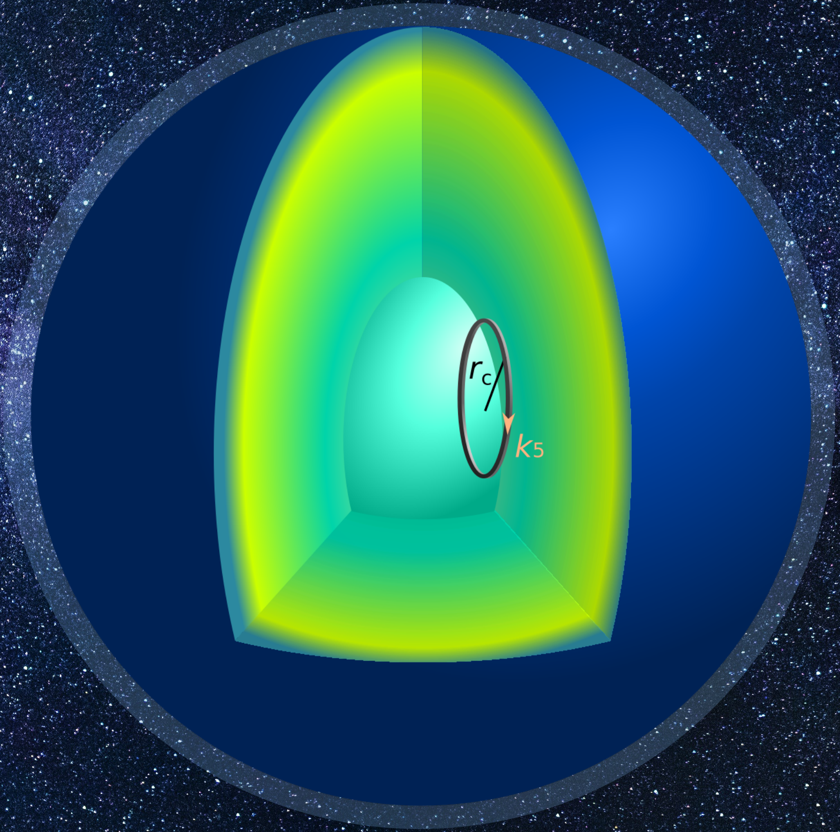
...or an avokado?



Anna Horváth

Studying extra dimensions in compact stars

Spacetime with $1+3+1_c$ dimensions



Constraints on extra dimensions bases on compact star observations?

Anna Horváth

What neutron stars can tell us about QCD phase transitions

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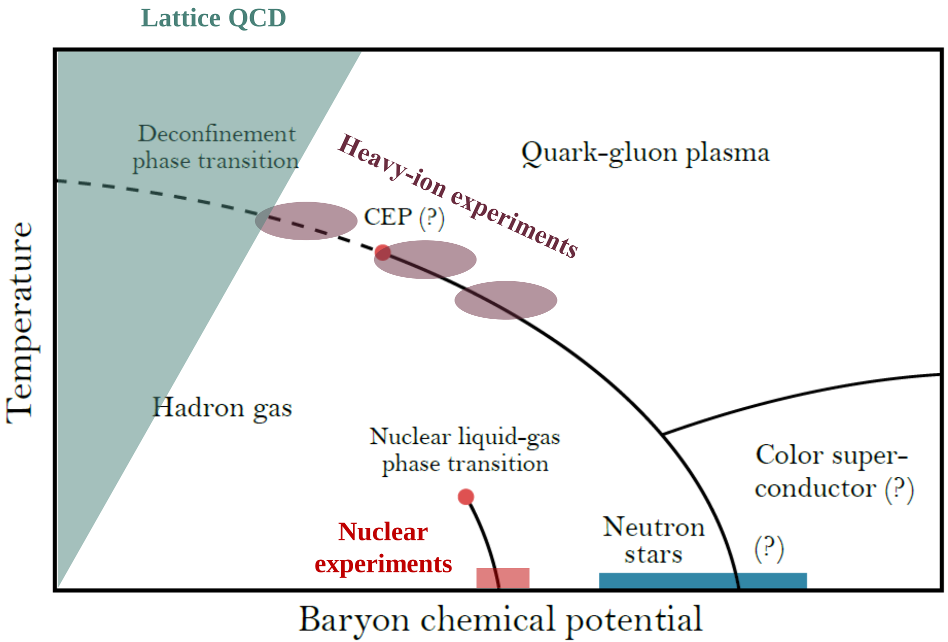
PhD supervisor:
Dr. Péter Kovács
Wigner RCP

Collaborators: Prof. György Wolf, Wigner Research Centre for Physics
Prof. Jürgen Schaffner-Bielich, Goethe Universität Frankfurt

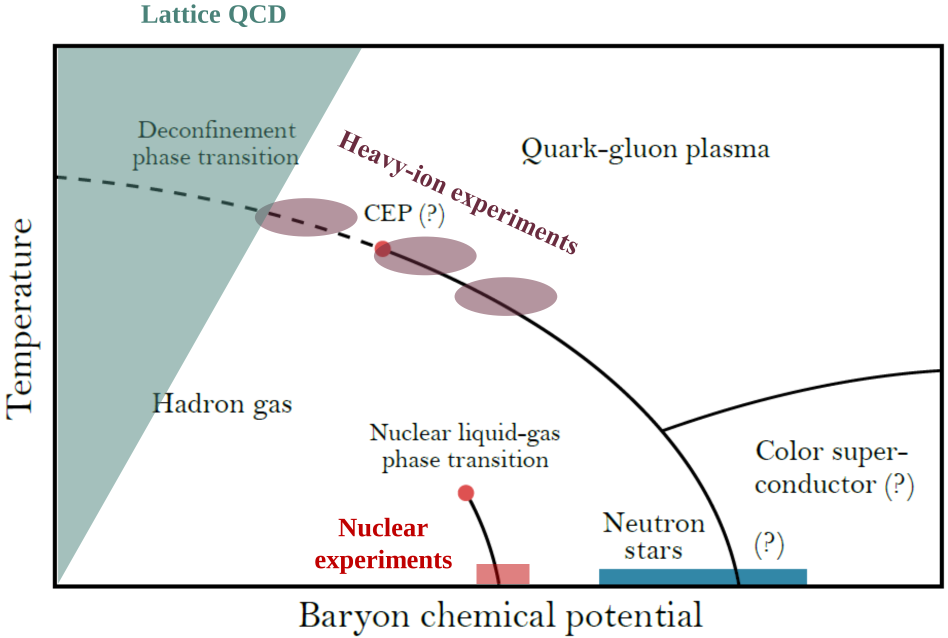
Zimányi Winter Workshop, Budapest, 2023.12.7.

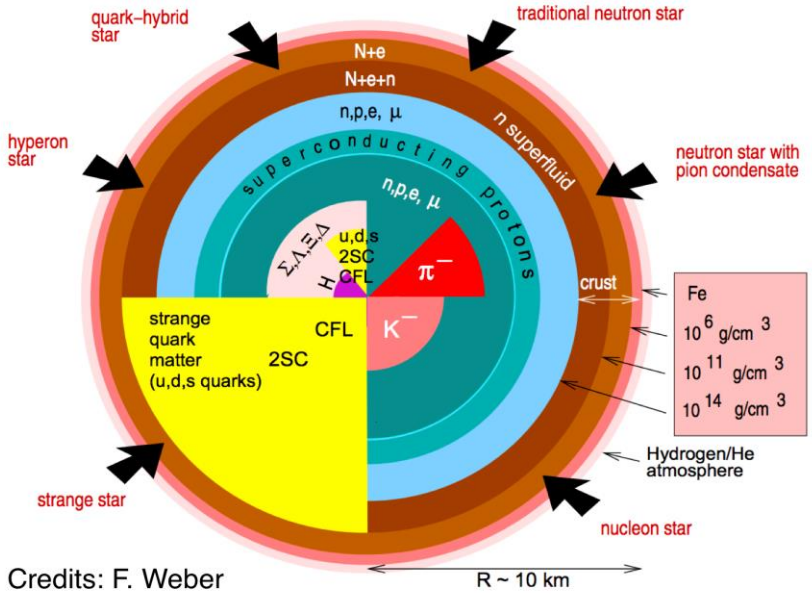
Why study neutron stars?



Why study neutron stars?

→ **is there quark matter inside the heaviest neutron stars?**





Credits: F. Weber

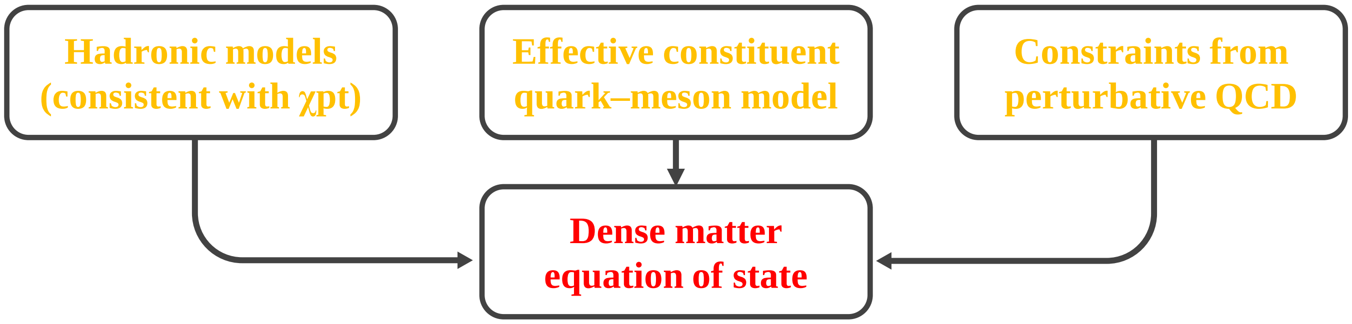
Bayesian inference

Hadronic models (consistent with χpt)

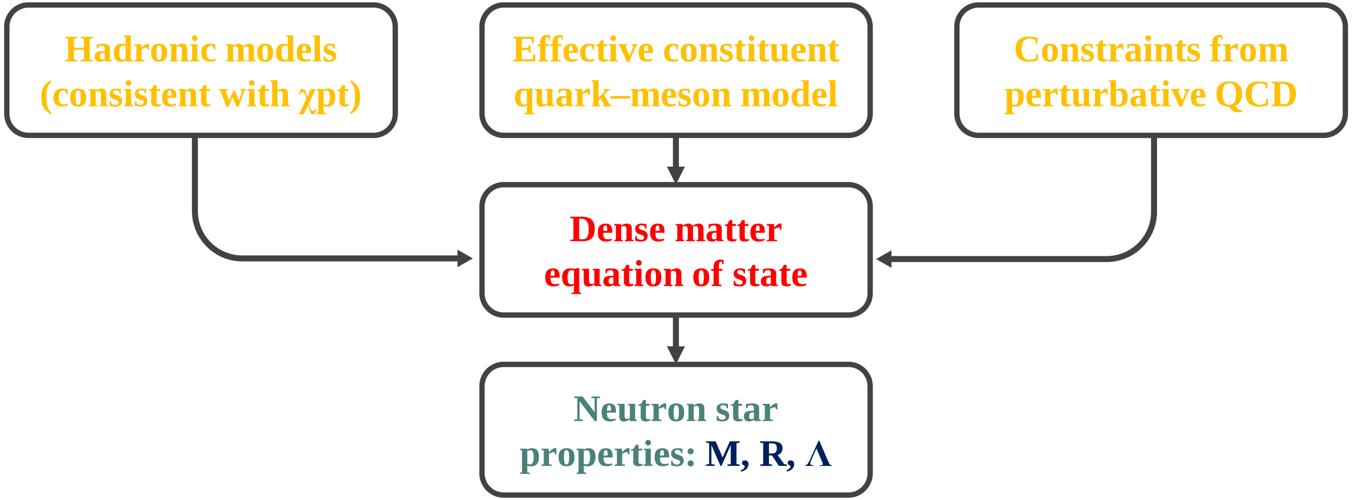
Effective constituent quark–meson model

Constraints from perturbative QCD

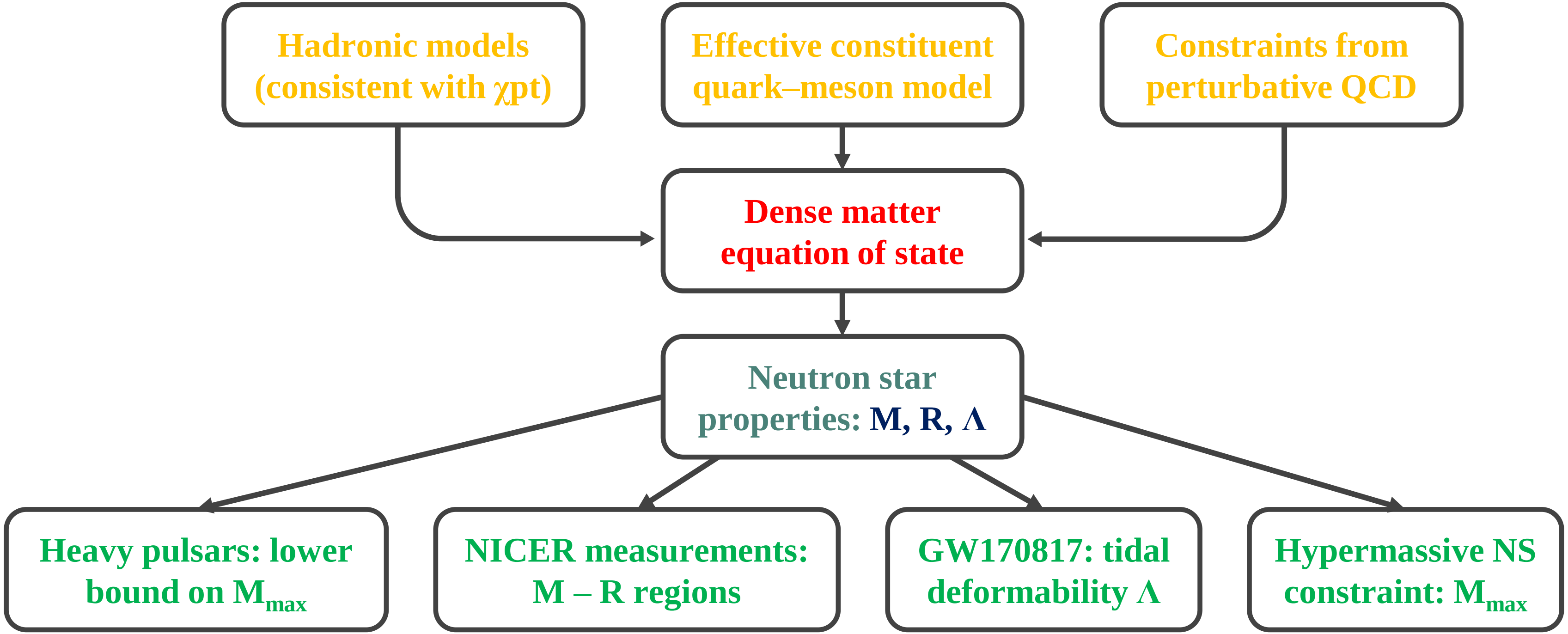
Bayesian inference



Bayesian inference

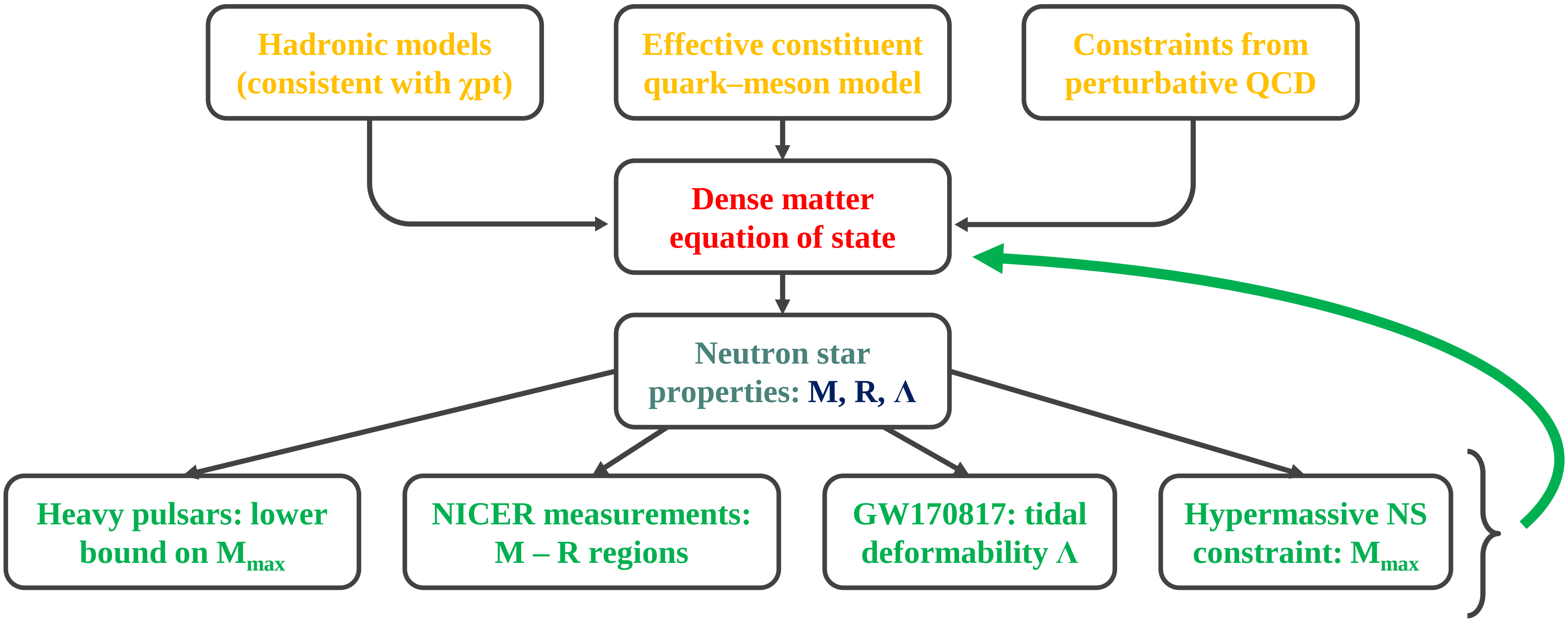


Bayesian inference

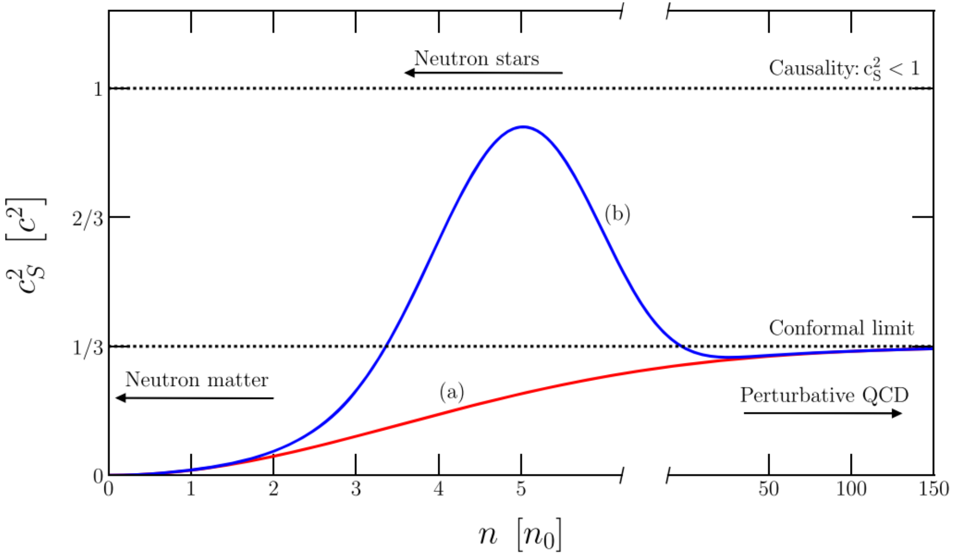


János Takátsy takatsy.janos@wigner.hun-ren.hu

Bayesian inference



Speed of sound and conformality



Source: I. Tews, et al. In: Astrophys.J. 860, 149 (2018)

Important measure: speed of sound

$$c_s^2 = \frac{\mathrm{d}p}{\mathrm{d}\varepsilon}$$

In the conformal limit (high density):

$$p \to \frac{1}{3}\varepsilon \qquad c_s^2 \to \frac{1}{3}$$

Empirical conformality measures:

$$\Delta = \frac{1}{3} - \frac{p}{\varepsilon} \qquad d_c = \sqrt{\Delta^2 + \Delta'^2}$$

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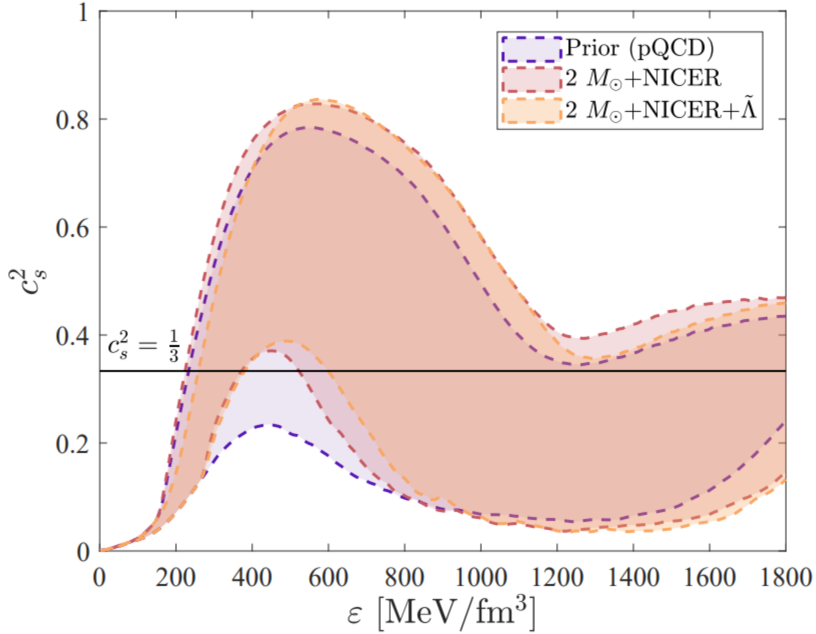
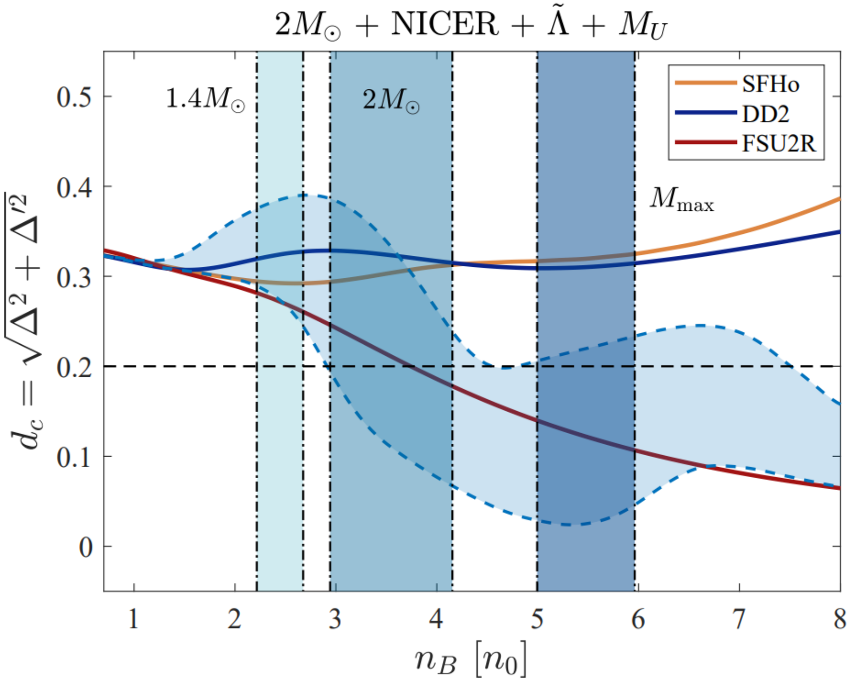
Speed of sound and conformality





Source: J. Takátsy, et al. In: **Phys.Rev.D 108, 043002 (2023)**

Thank you for your attention!