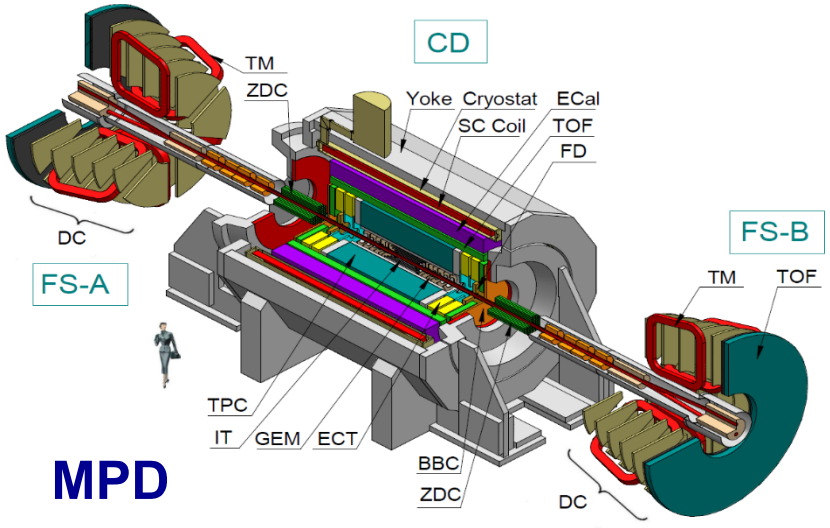
Endcap Time-of-Flight of MPD@NICA

Zebo Tang （唐泽波）

State Key Lab. of Particle Detection & Electronics

University of Science and Technology of China (USTC)

NICA Physics with MPD (and BM@N)



MPD

Physics goals:

- Onset of QGP
- 1st order phase transition
- Search for critical end point
- Chiral phase transition

Systematic study of pp, pA and AA

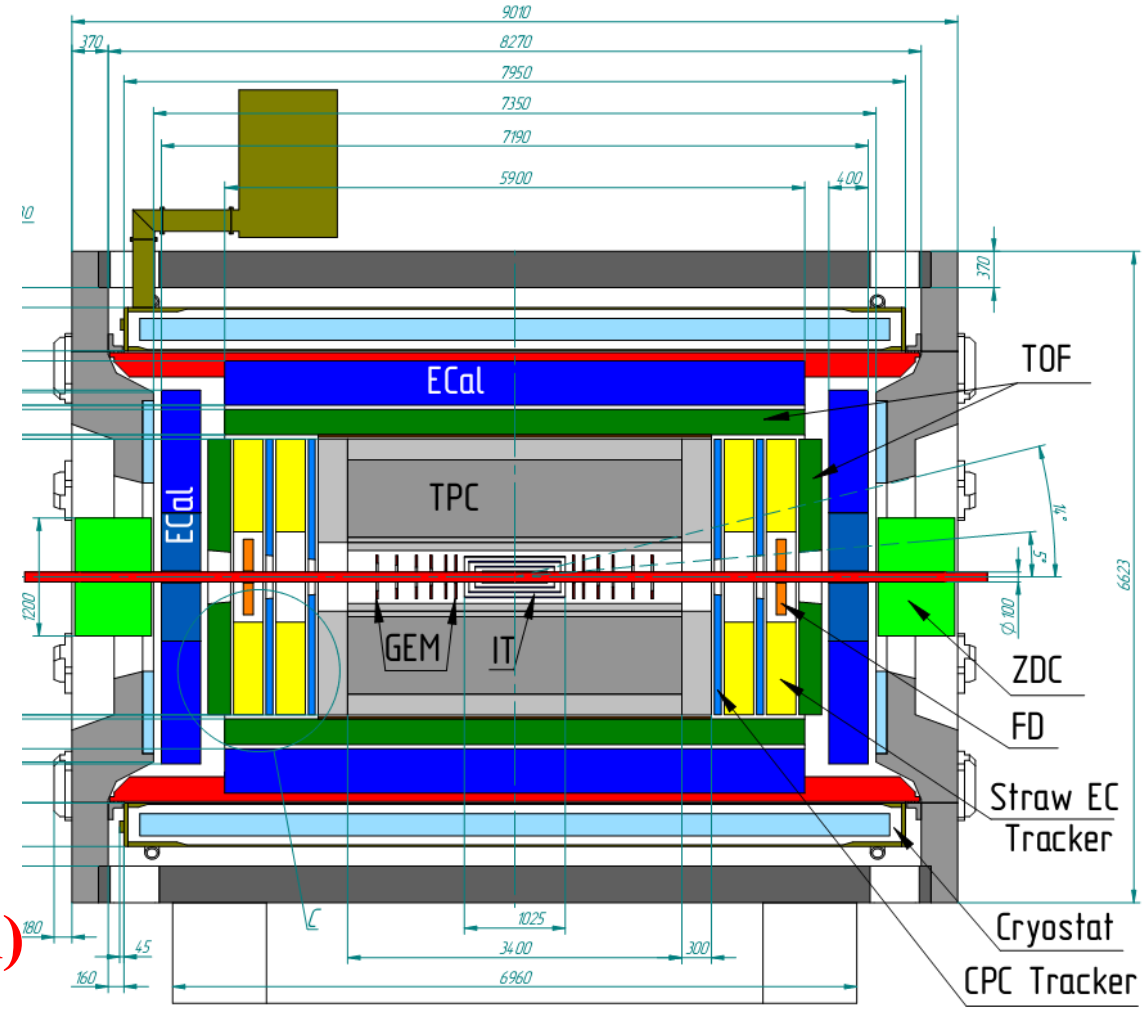
- **Bulk properties, EOS**
  - particle yields & spectra, fermtoscopy, flow
- **Search for QCD Critical Point**
  - event-by-event fluctuations & correlations
- **Onset of phase transition:**
  - deconfinement (QGP thermal radiation)
  - in-medium modification of hadron properties: $\rho, \omega, \phi \rightarrow e^+e^-$ and continuum at $m < 3$ GeV/c^2
- **Enhanced strangeness production**
- **Chiral Magnetic (Vortical) effect**
  - Λ polarization
- **Strangeness in nuclear matter**
  - hypernuclei

Multi-Purpose Detector (MPD)

Stage 1: TPC, TOF, ECal, FHCal and FD

- 9 m long, 6m diameter
- Low material budget
- Good tracking and PID

- Tracking (TPC):
  $|\eta|<1.2$, 2π in azimuth
- PID (TOF, TPC, ECAL):
  π, K, p, d, t, …, e, γ
- Event characterization (FHCAL):
  centrality & event plane



Stage 2: IT and Endcaps (tracker, TOF, ECal)

TDR: *http://nica.jinr.ru/files/mpd_tdr.htm*

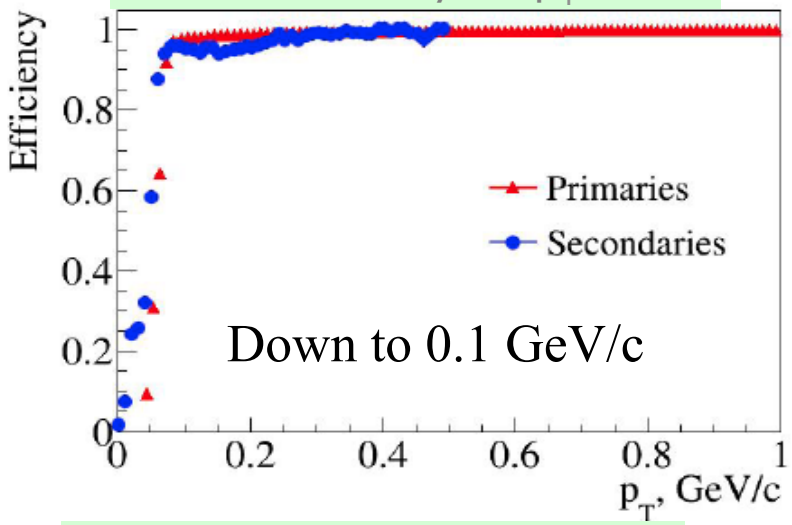
NICA Milestones

- **2018** – start of **BM@N** experiment
- **2018-2019** – **Booster** commissioning
- **2019** – **MPD** magnet commissioning
- **2019** – start of **MPD** detectors assembly
- **2020** – completion of civil constructions (**b. 17**)
- **2020** – **MPD** commissioning (**Stage I**)
- **2021** – **Collider** commissioning
- **2023** – **MPD** commissioning (**Stage II**)
- **2025** – **SPD** commissioning (**Stage I**)

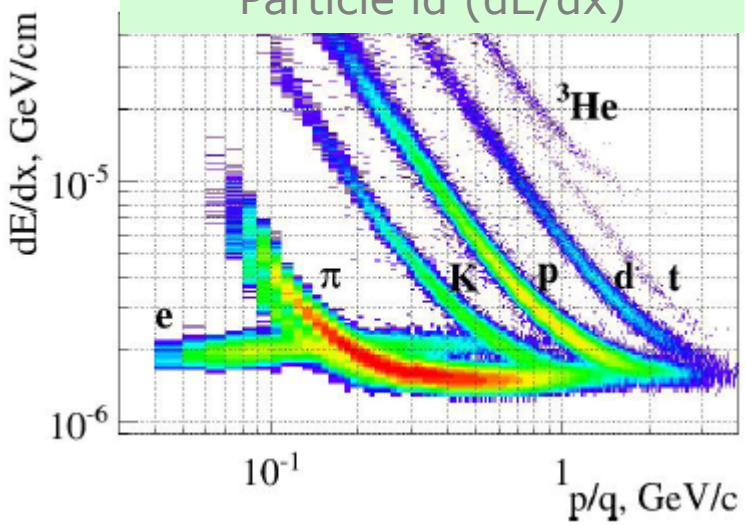
From Kekelize

MPD Performances at Barrel (Stage I)

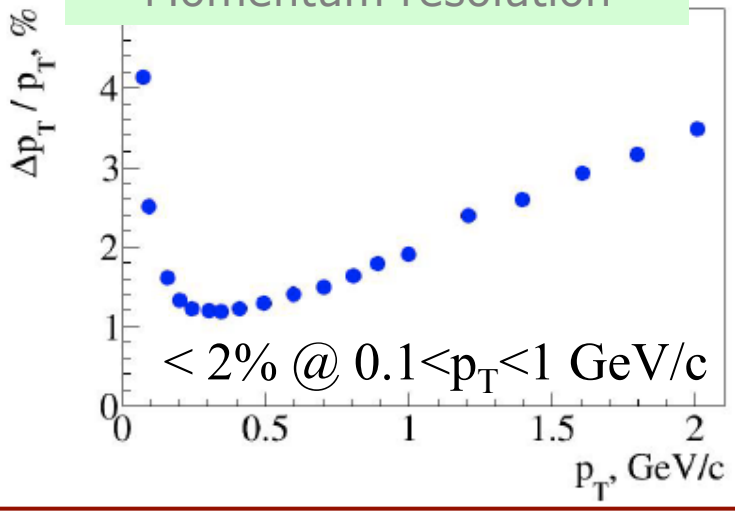
Efficiency vs p_T



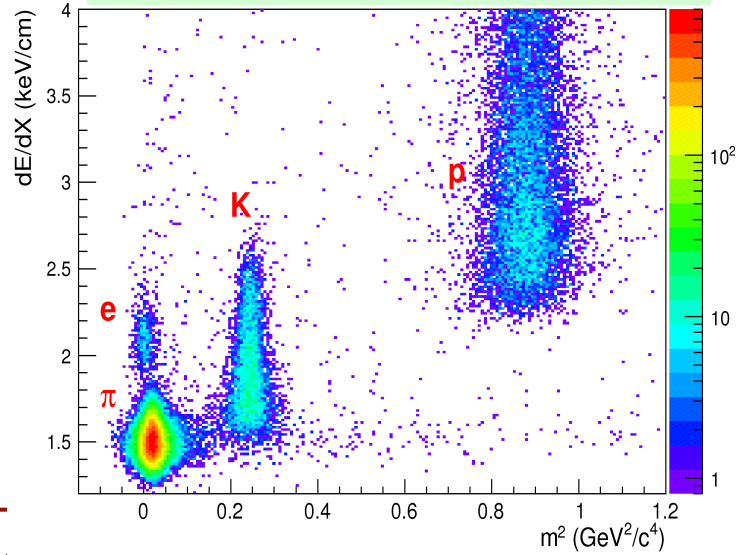
Particle id (dE/dx)



Momentum resolution



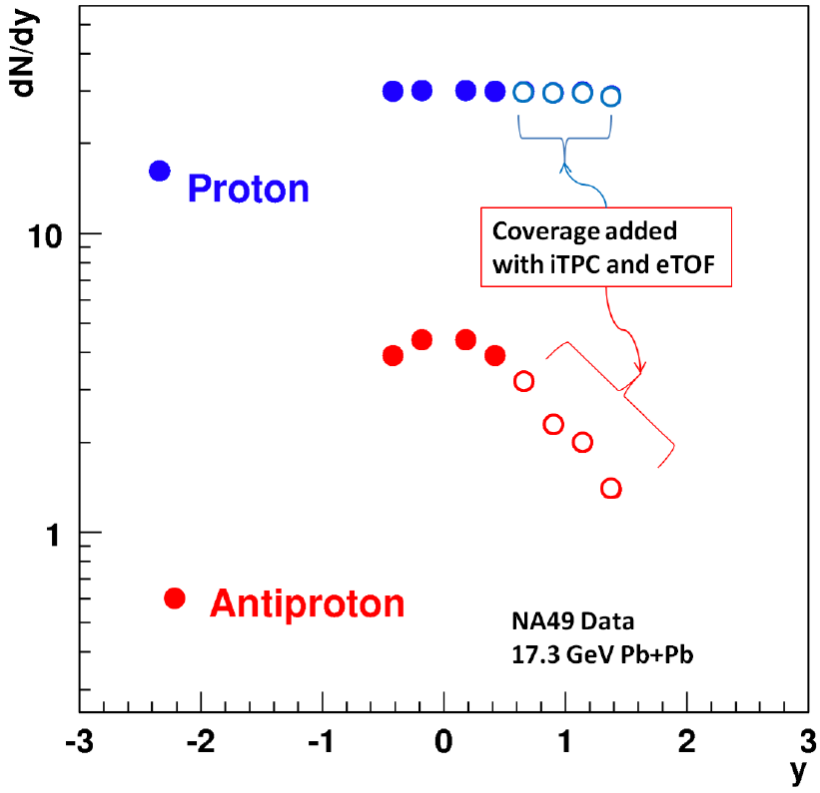
Particle id (dE/dx and ToF)



Benefits of Forward PID Detector

- Increase acceptance for identified particle measurements
  - Especially for 2,3-body decays
- Enlarge η coverage/gap for correlation studies
- Unique physics opportunities at forward-rapidity

Forward is Different



Proton: flat rapidity distribution

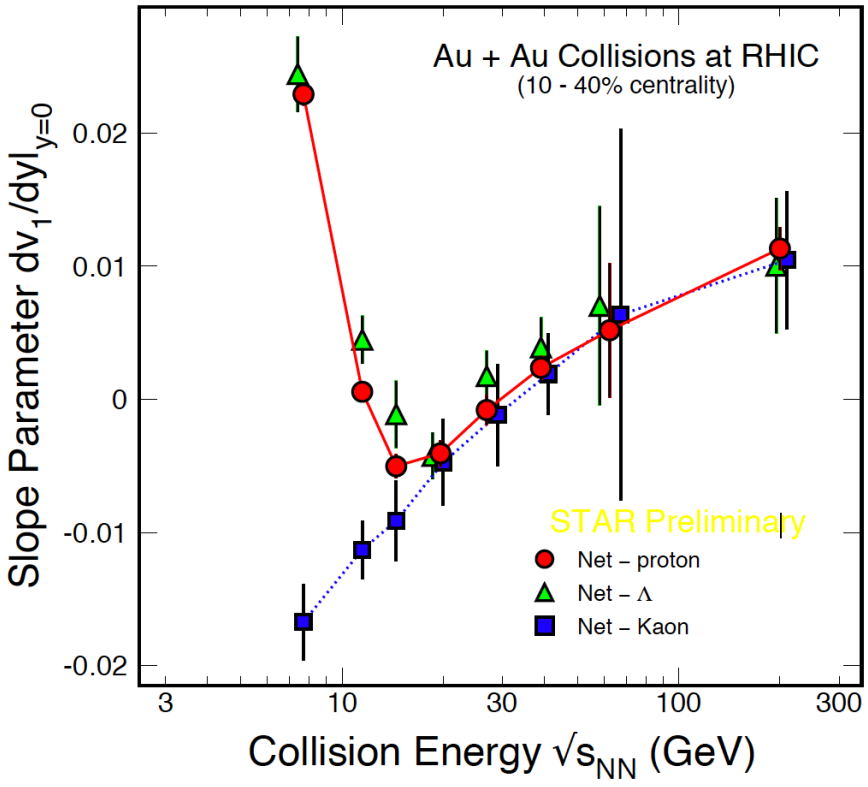
Anti-proton: decreasing rapidly

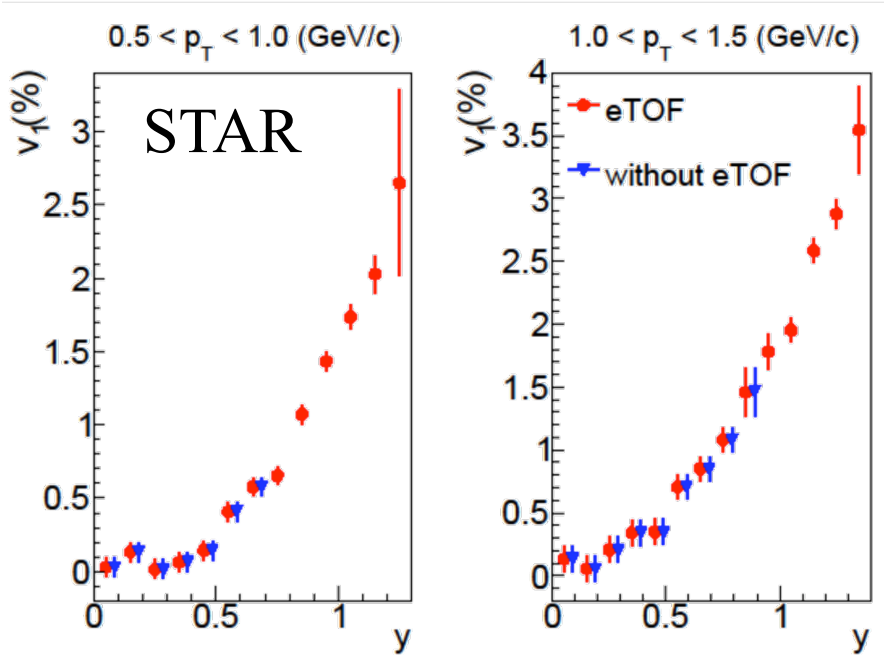
μ_B increases with rapidity

~50 MeV from mid- to forward

- Explore different μ_B at different rapidity
- Possible mixture of different phases at forward rapidity due to non-uniform compression *M. Gyulassy and L. P. Csernai, NPA460,723(1986)*

Energy Dependent Directed Flow



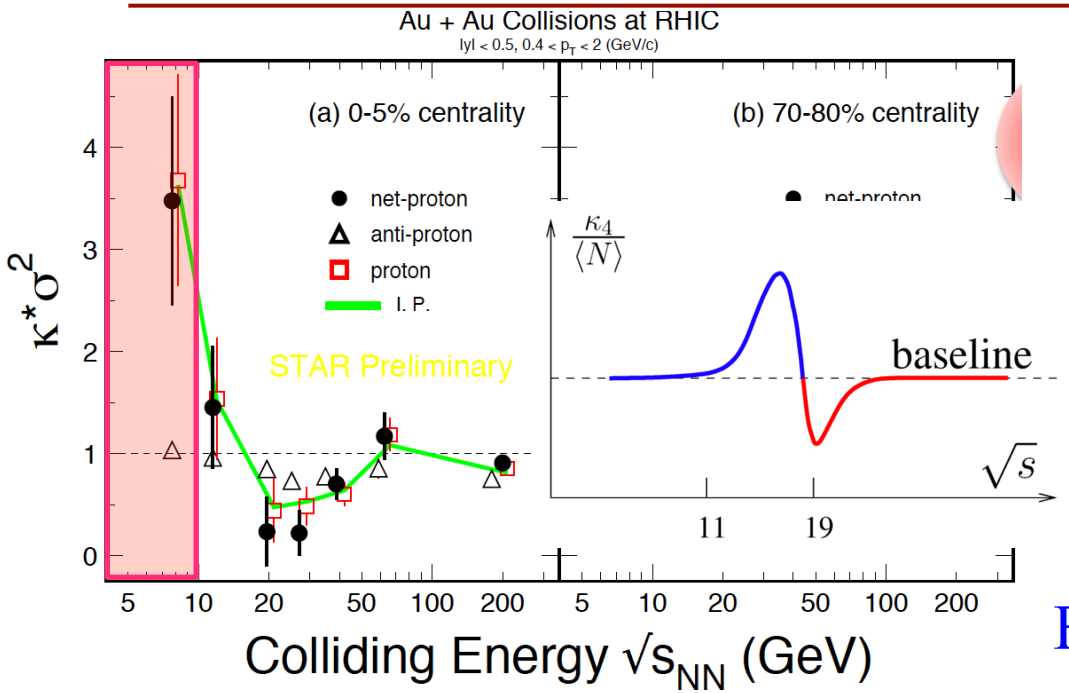


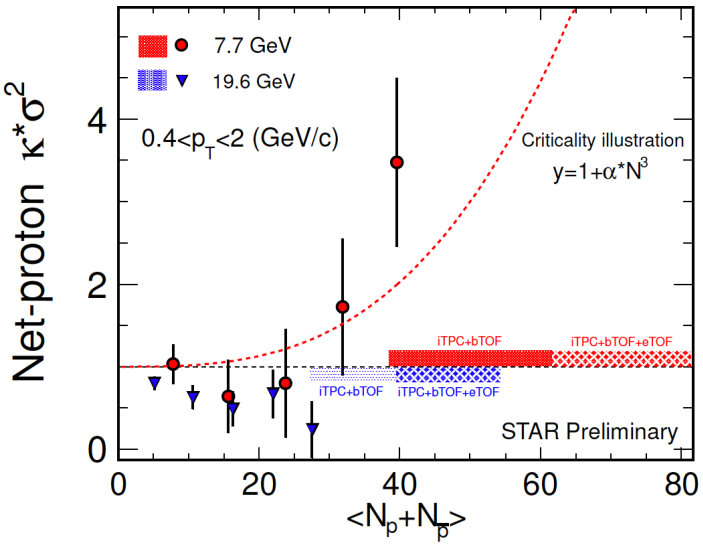
Forward PID detectors:

Significantly extend the rapidity coverage of v_1 measurement

- v_1 slope of identified particles
- Closely related to EOS
- Non-monotonic dependence for net-baryons

Critical Point Search





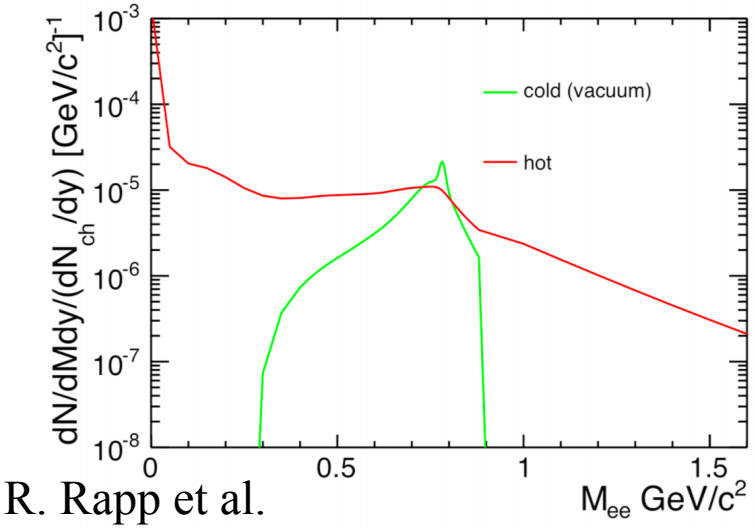
- Higher moments of conserved quantities is a unique tool for critical point search
- Need higher precision and lower beam energy

Forward PID detectors:

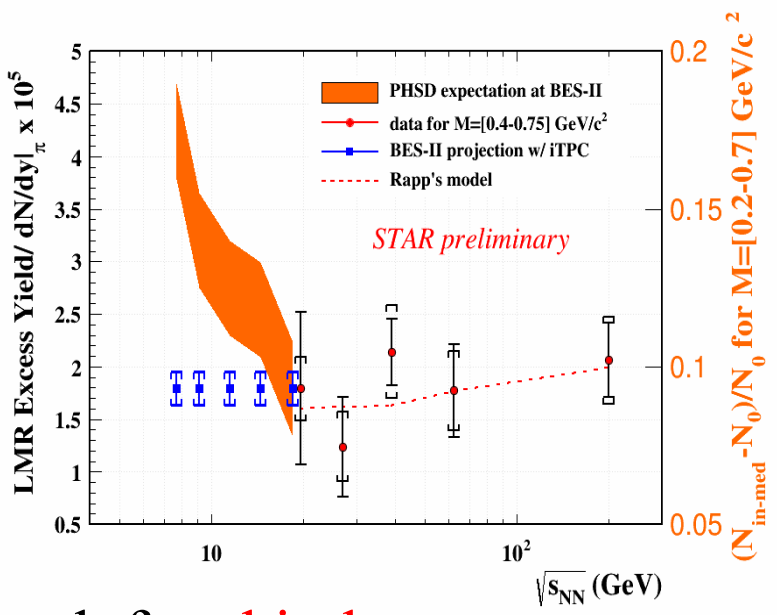
Enhance fluctuation signal for net-proton, net-kaon etc.

Provides cleaner and more significant indication of critical behavior

Dilepton Measurement at Forward

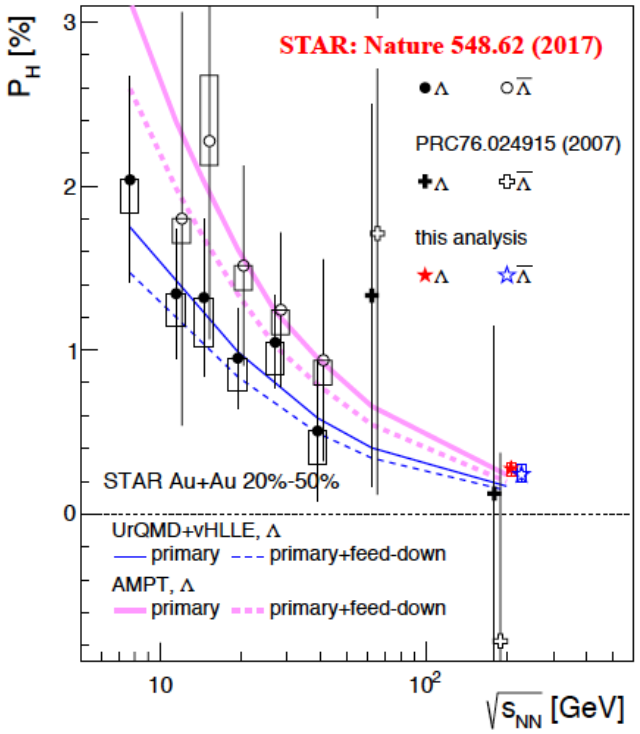


R. Rapp et al.



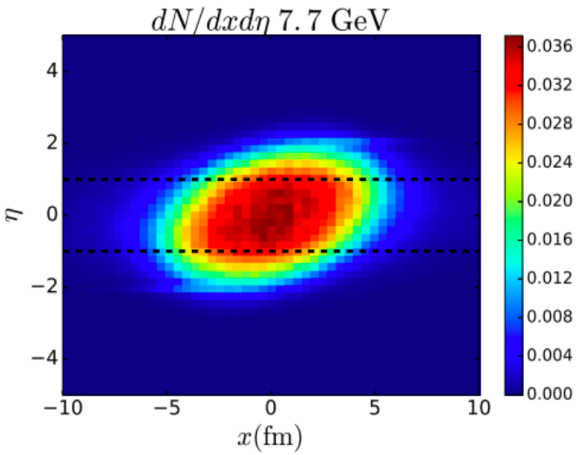
- In-medium modification of ρ: search for chiral symmetry restoration
- Low-mass-range (LMR) dilepton yields depend on temperature, lifetime and baryon-density
- Forward measurements provides for independent observable to study the baryon-density dependence

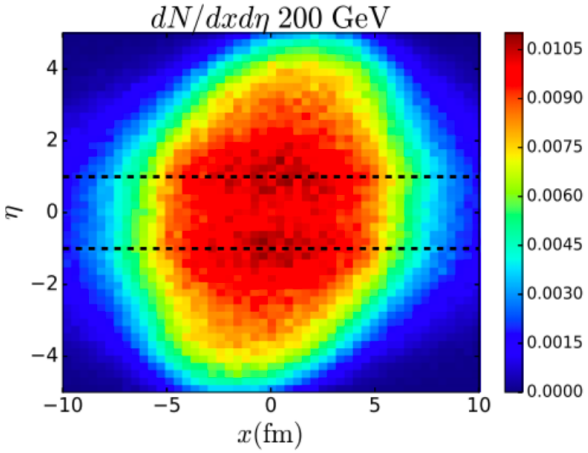
Lambda Polarization at Forward



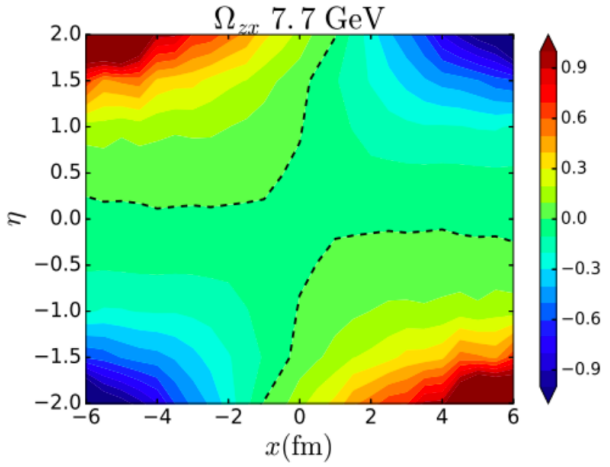
Significant energy dependence observed and explained

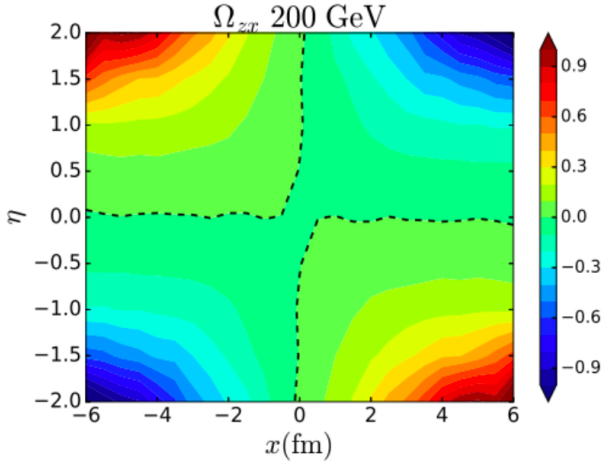
Λ freeze-out position





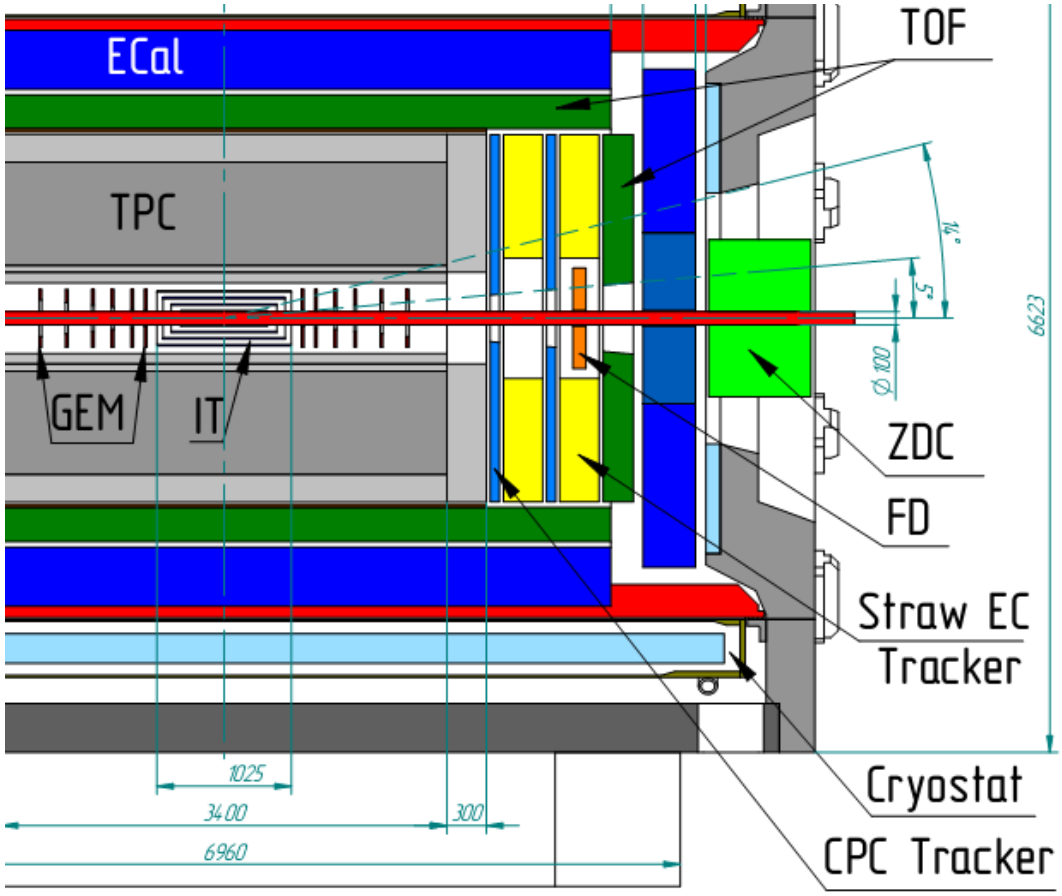
Vorticity





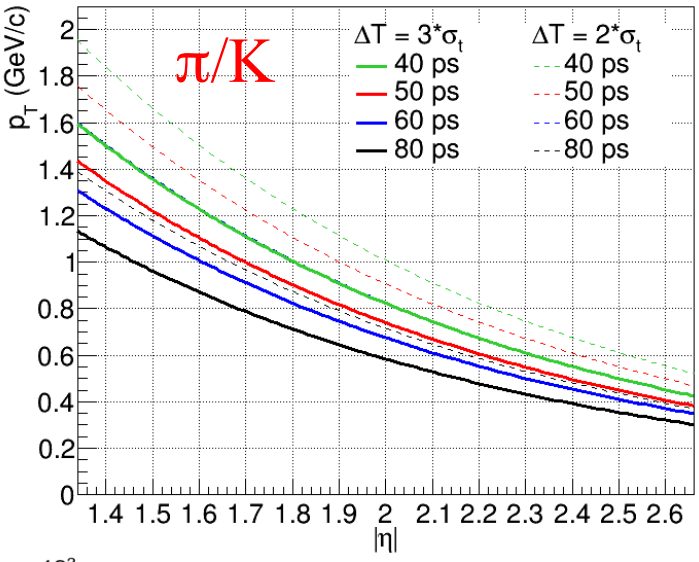
Differential measurements are crucial

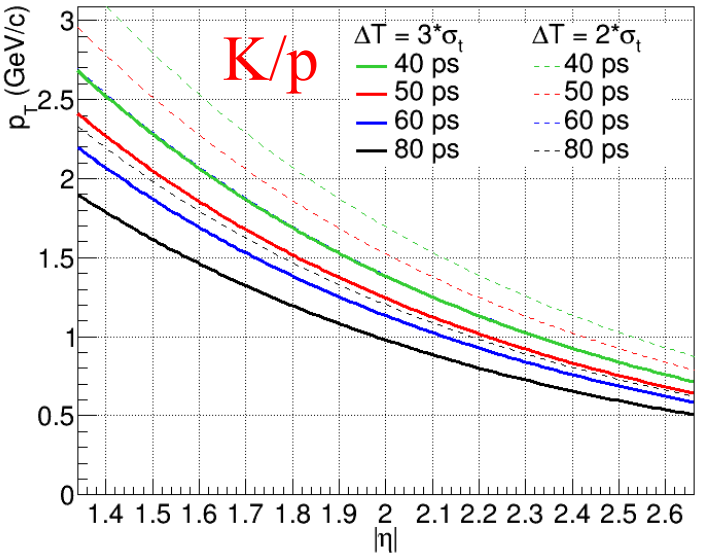
Challenges of Forward PID Detector

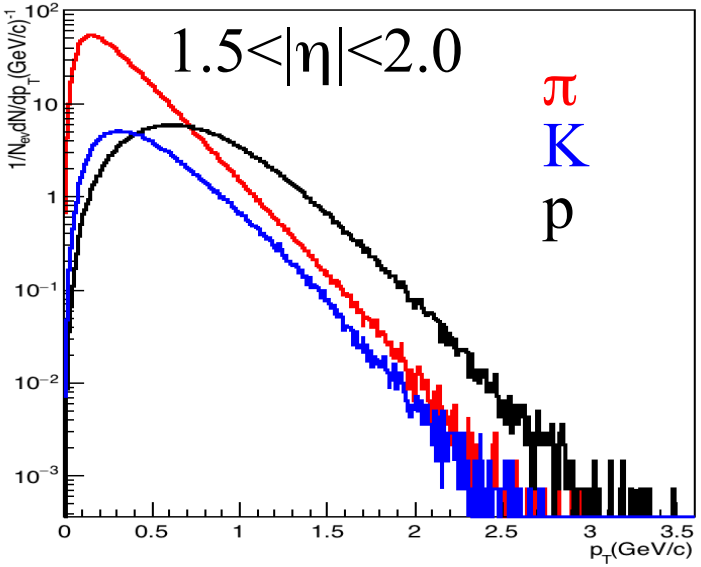


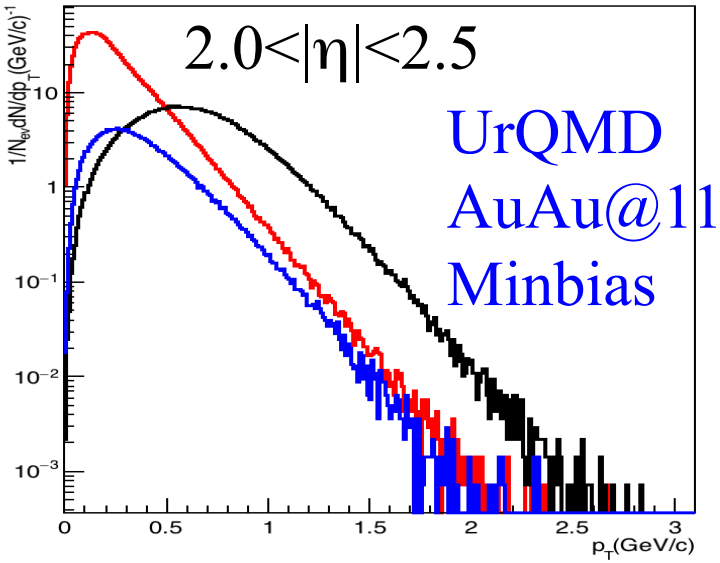
- dE/dx measurement getting worse at forward
- p getting larger at forward (at same p_T)
- eTOF is crucial
  Better resolution needed

Challenge of eTOF









Requirement of eTOF

High timing resolution eTOF system: 40-50 ps?

- High timing resolution eTOF detector (MRPC)

  <~ 30 ps? (intrinsic)

- High timing resolution electronics

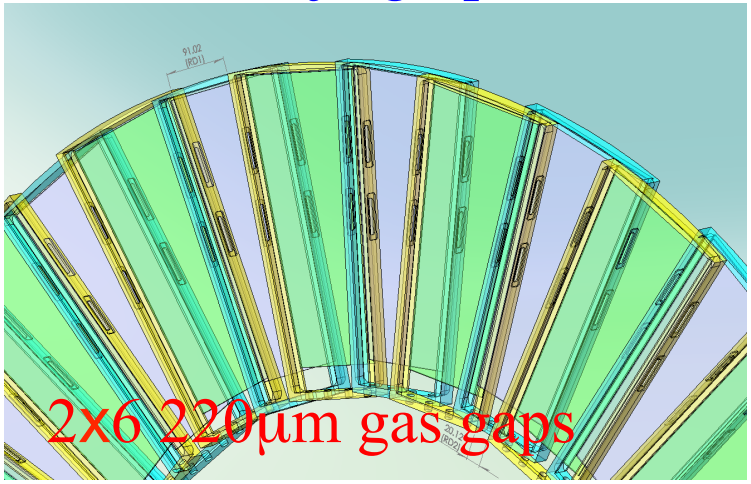
  10-15 ps

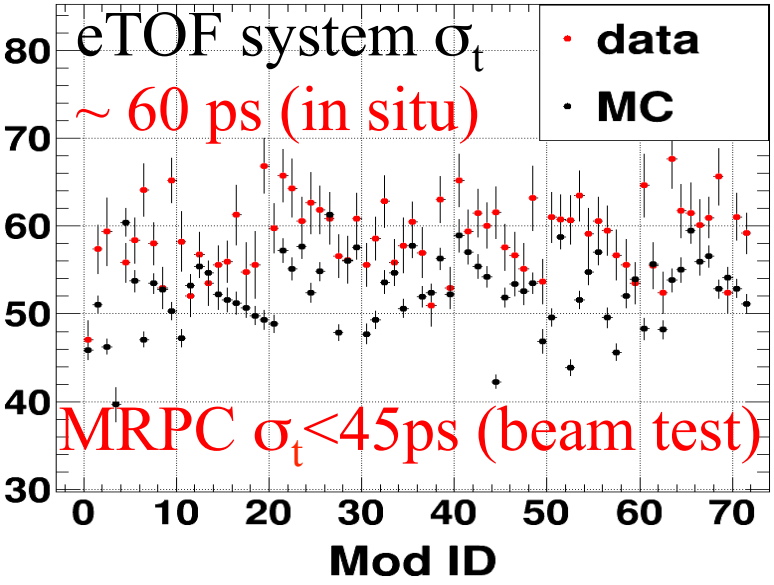
- High timing resolution T0 w/ low material budget

  <~30 ps?

High Timing Resolution MRPC

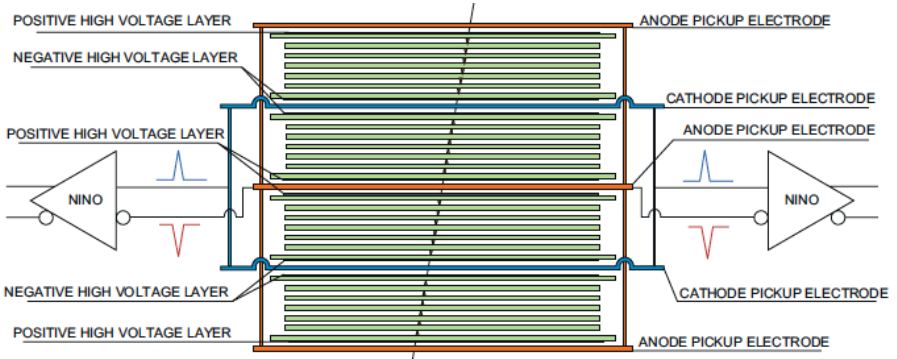
eTOF of Beijing Spectrometer



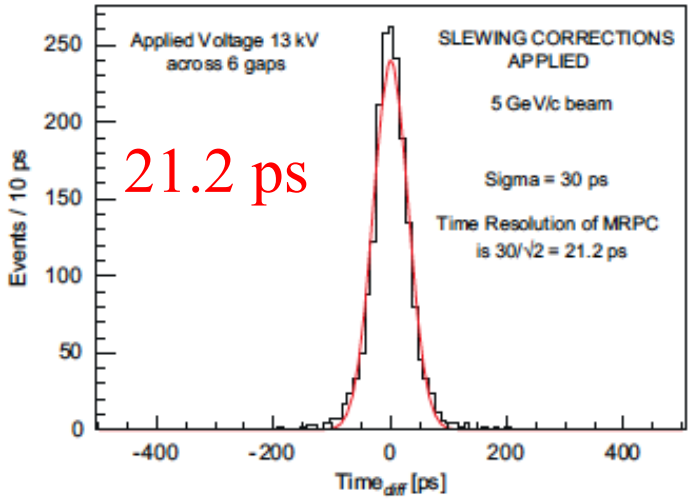


24-gaps MRPC

Shaohui An et. al, NIMA594, 39 (2008)



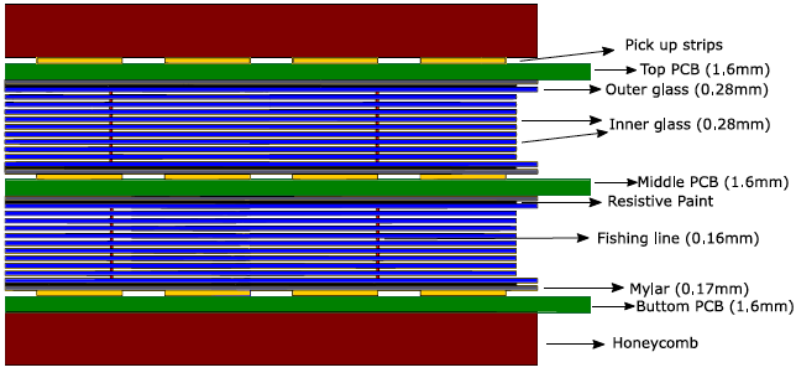
4x6 160μm gaps, NINO+Osci.



Recent Developments

20-gaps MRPC with thin glass

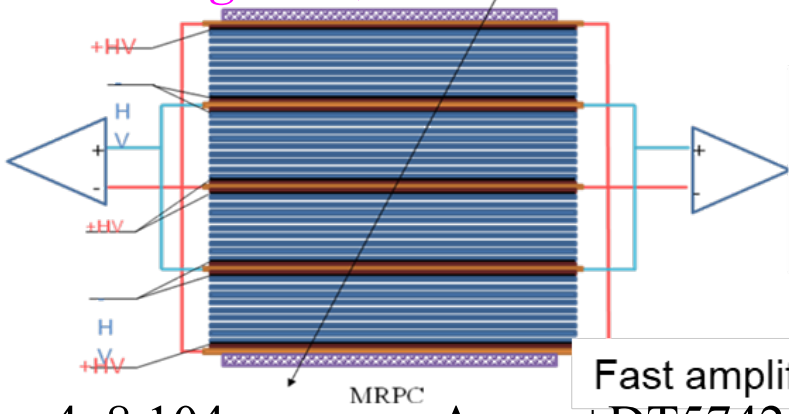
Z. Liu et. al, NIMA908, 383 (2018)



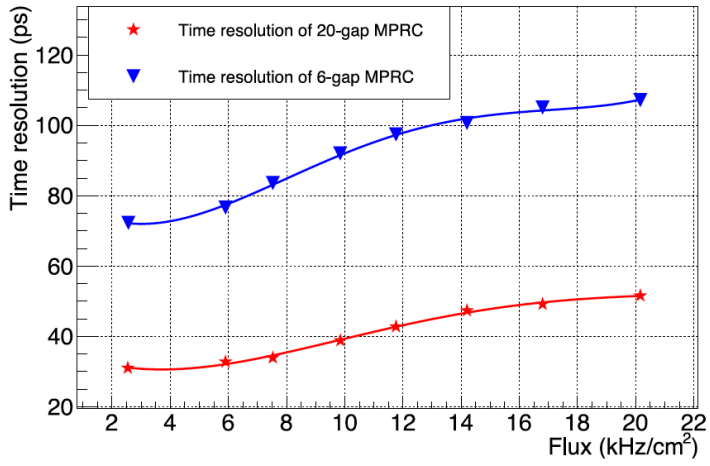
2x10 160μm-gaps, NINO+WaveCather

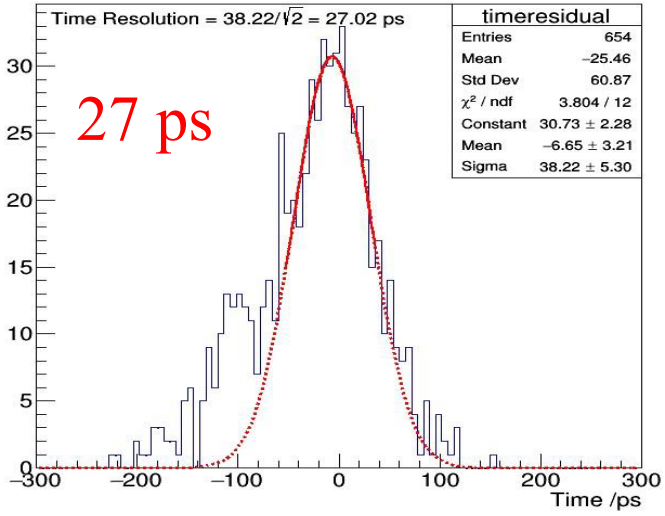
32-gaps MRPC

Y. Wang et. al, arXiv:1805.07922



4x8 104μm-gaps, Amp.s+DT5742

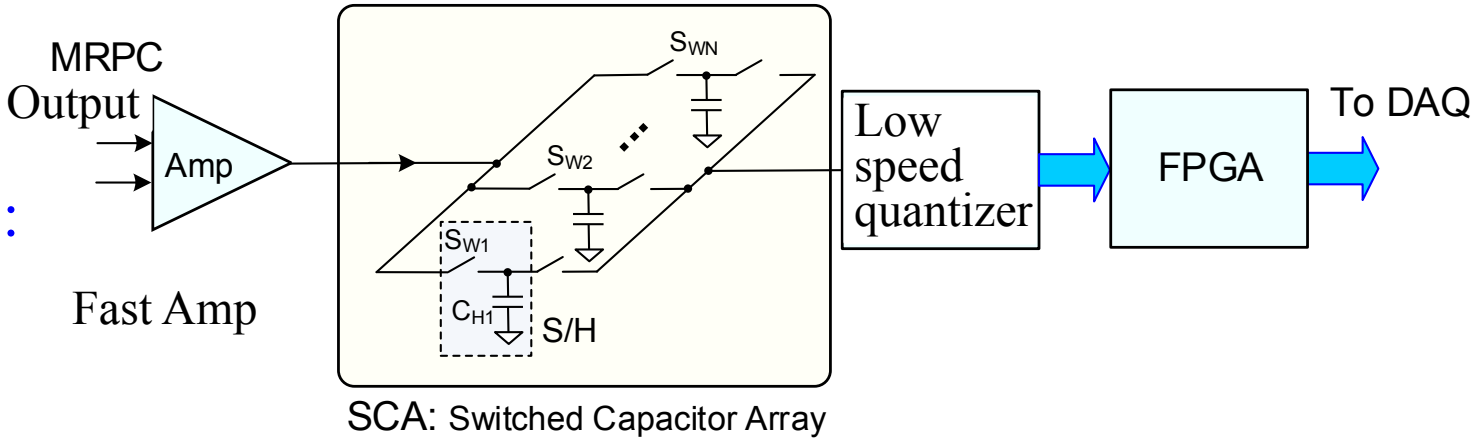




High Timing Resolution Electronics

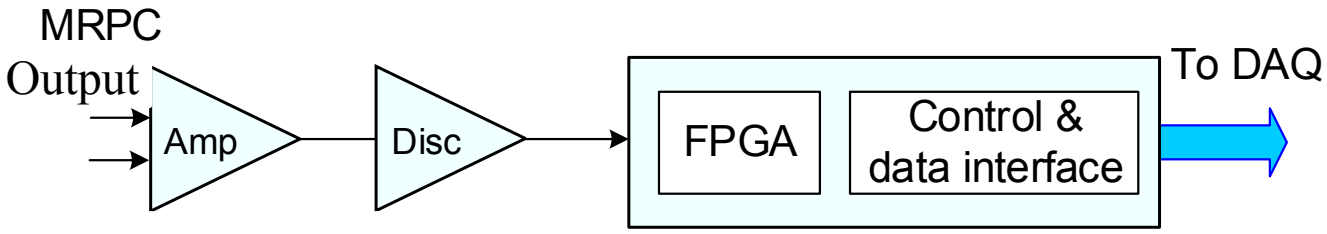
Lei Zhao from USTC

Option 1:



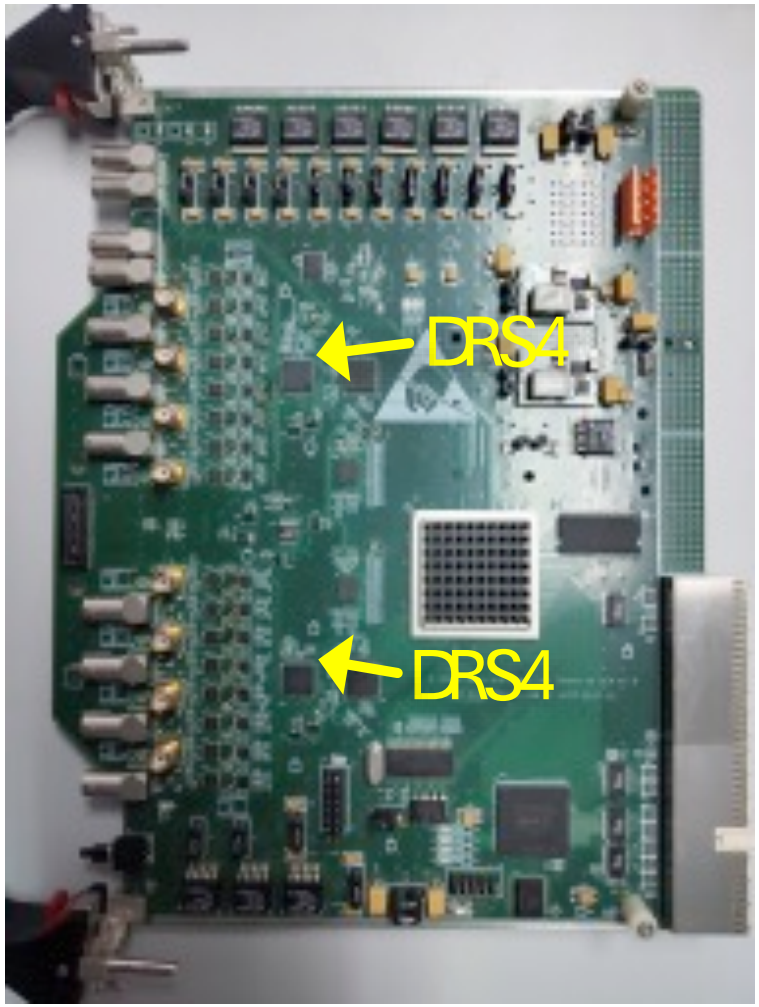
SCA: Switched Capacitor Array

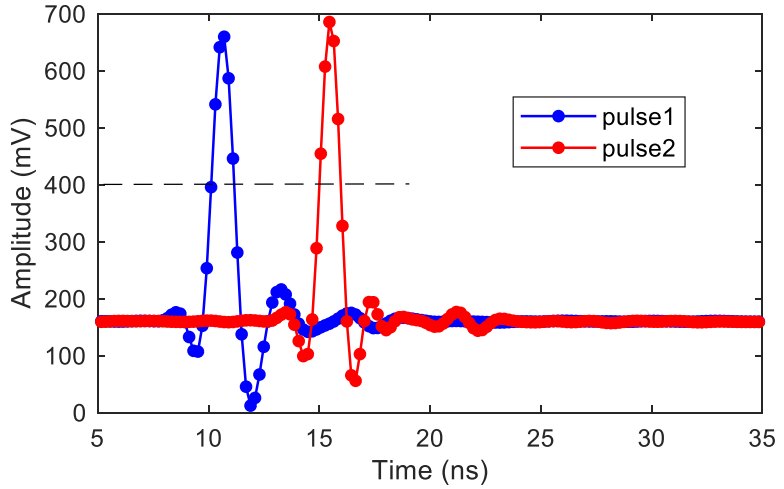
Option 2:

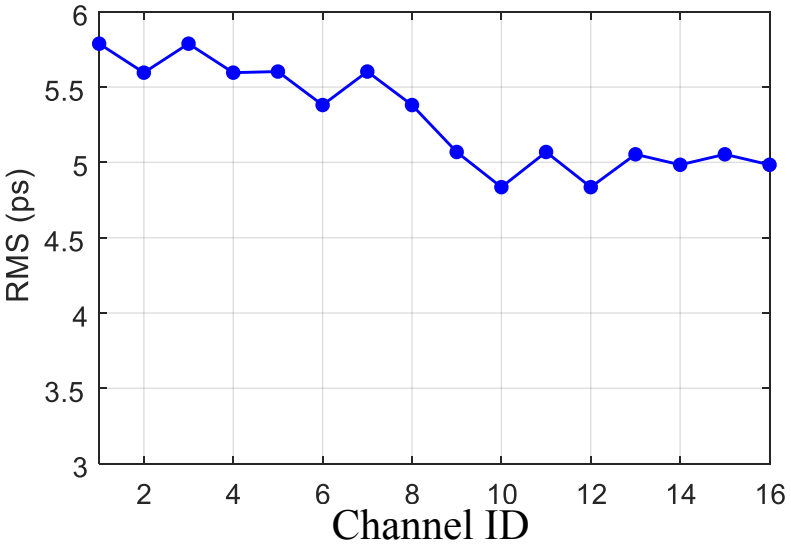


FPGA TDC (10ps achieved)

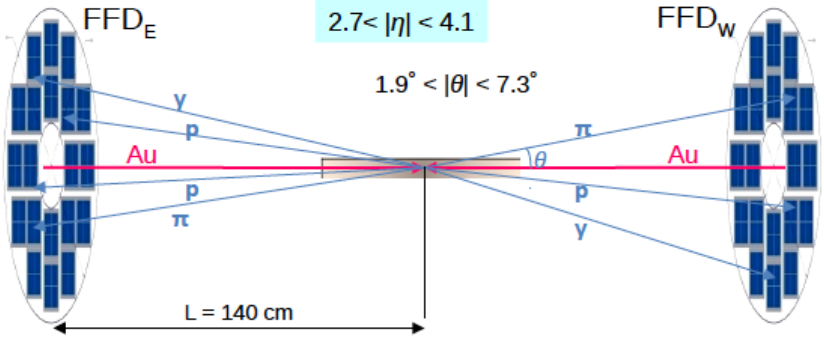
Digitizer Based on DRS4

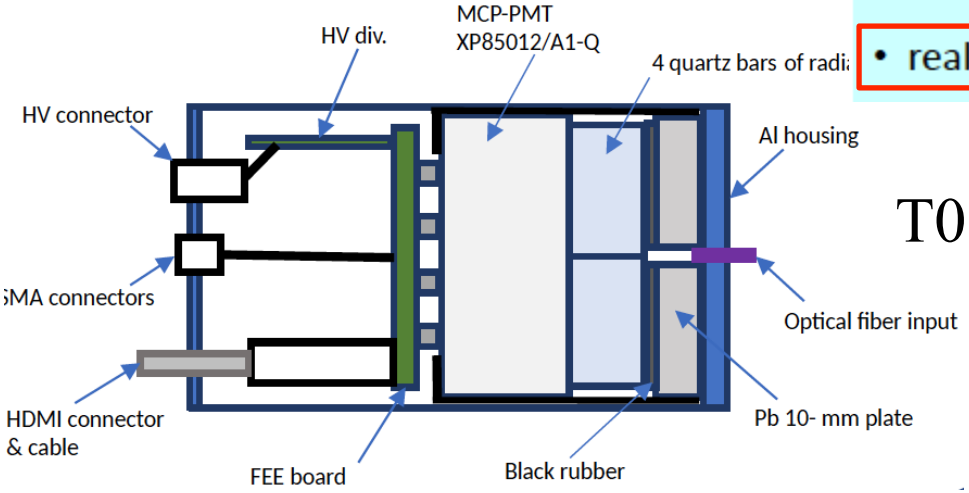






Forward Fast Detector (FFD) Detector





Trigger, vertex and T0

Detect photos and charged particles

- Time resolution of FFD module itself - 21.5 ps
- with readout by E.B. DRS4 digitizer - 24 ps
- with readout by digitizer CAEN mod.N6742 - 34 ps
- real chain with readout by TDC72VHL - 44 ps

T0 resolution improved by sqrt(1/N)

Material budget is large

Problem for forward detectors

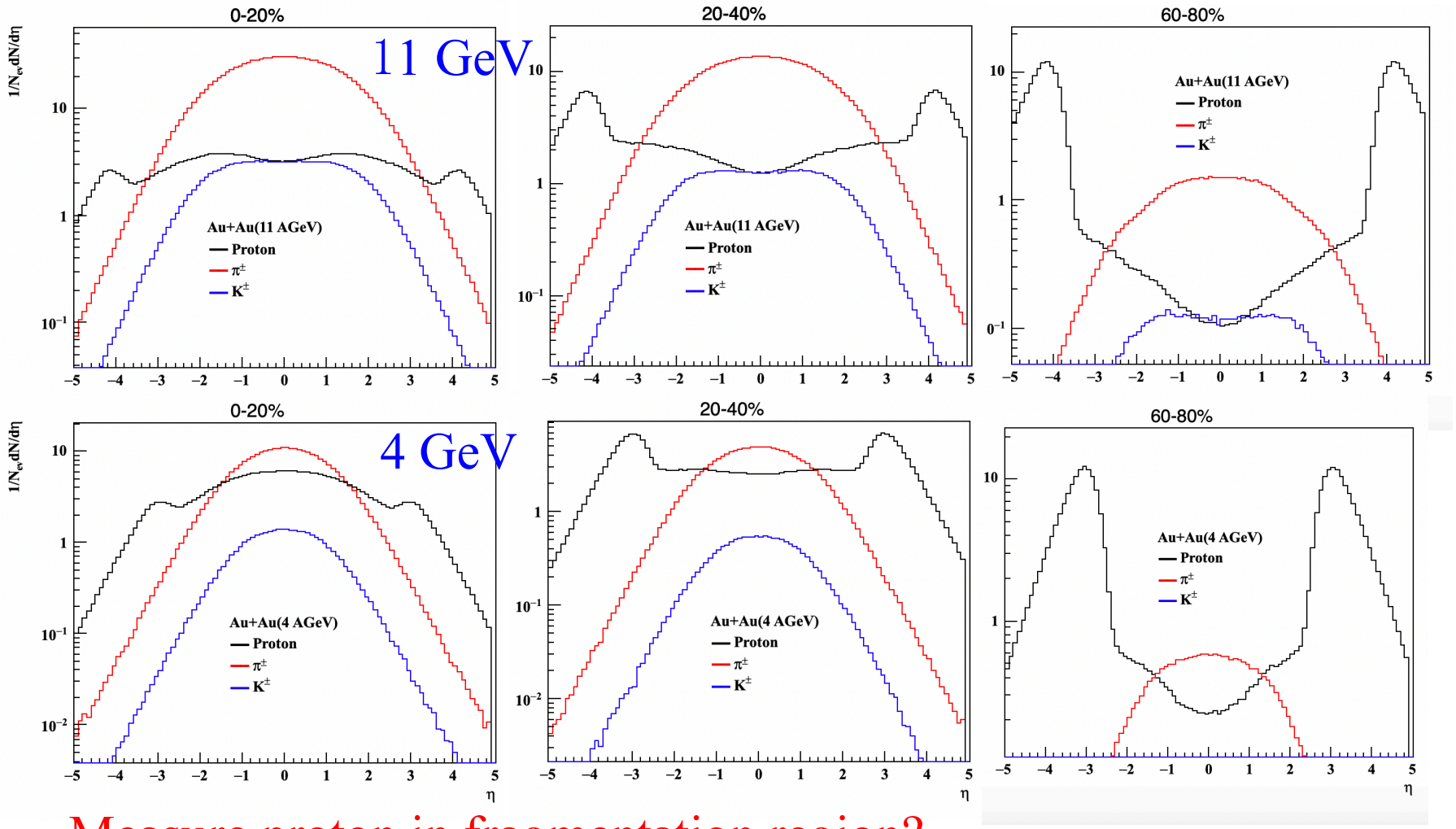
10 mm Lead converter

15 mm quartz radiator

Readout by MCP-PMTs

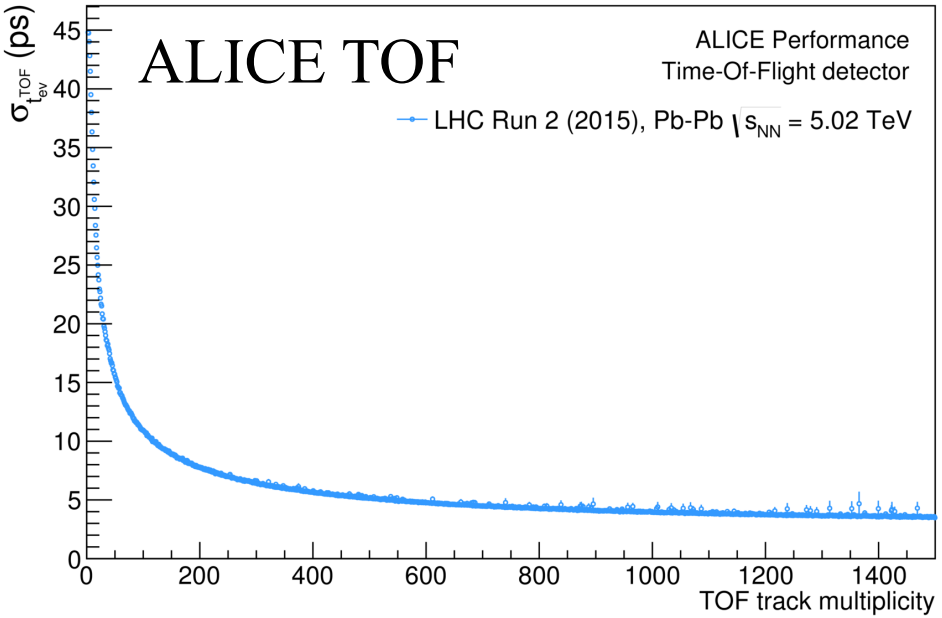
Low-material T0 Detector

Fast plastic scintillator + SiPM/MCP-PMT



Measure proton in fragmentation region?

T0 from TOF Itself



ALI-PERF-143047

With 2 or more tracks, T0 can be obtained directly from TOF itself

ALICE TOF can obtain:

- < 30 ps with 10 tracks
- < 10 ps with 150 tracks
- < 5 ps with 600 tracks

T0 from bTOF (+ eTOF)

Complementary to T0 detector

Especially for (semi-)central collisions

Summary

- Plenty of physics opportunities with forward PID detector at NICA-MPD
- eTOF is a good choice of forward PID detector
- Excellent timing resolution is required for eTOF system
- High timing resolution MRPC + fast electronics looks promising
- Low-material T0 detector may also needed to replace current FFD

Thanks!