Simulations of direct photon yield at NICA energies

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What's new

Latest reports:

PWG4 & MPD ECal Meeting on March 25th

Dir gamma yields vs pT and y, dir gamma v1 and v2 vs pT and y

Vth MPD Collaboration Meeting on April 24th

Dir gamma yields vs pT and y, dir gamma to pi0 ratio vs y

Today:

- Study statistical error on Rγ
- Study direct gamma flow fluctuations

Projections on statistical error

"The rate of Pb–Pb collisions in 2010 and 2011 was well below the ALICE limits and ALICE was able to take data at the highest achievable luminosity, on the order of 10^{25} $s^{-1}cm^{-2}$ in 2010 and 10^{26} $s^{-1}cm^{-2}$ in 2011"
"Performance of the ALICE Experiment at the CERN LHC" Int. J. Mod. Phys. A 29 (2014) 1430044

- In discussion with the NICA Accelerator division the following initial beam parameters were proposed:
  - Bizmuth beams ($^{209}Bi+^{209}Bi$ collisions) – stability of the heavy-ion source, efficiency of the beam accelerator complex
  - Initial beam energy: √s=9 GeV – maximum reasonably safe energy without the need for acceleration/deceleration in NICA
  - Initial luminosity – at least 10^{24} $cm^{-2}s^{-1}$ with reasonably fast ramp-up to at least 10^{25} $cm^{-2}s^{-1}$.

A.Kisiel talk at Vth MPD collaboration meeting

7 kHz trigger rate for MPD is expected

We would expect similar performance in terms of statistics for MPD as for the ALICE in 2010-2011: some tens of millions events

10^6 – 10^7 events are good estimate for performance Simulations studies

Year	System, $\sqrt{s_{NN}}$ (TeV)	Running mode	Peak $\mathscr{L}$ ($\mu b^{-1}s^{-1}$)	Duration beam [run] (h)	Delivered $\mathscr{L}$	Recorded statistics (10^6events)	Data read [recorded] (TB)
2009	pp 0.9	MB	5.2×10^{-4}	n.a. [26.8]	19.6 μb^{-1}	MBor: 0.5	0.41 [0.43]
	pp 2.36	MB	1.0×10^{-4}	n.a. [3.1]	0.87 μb^{-1}	MBor: 0.04	0.01 [0.01]
2010	pp 0.9	MB	1.5×10^{-2}	15.7 [13.0]	0.31 nb^{-1}	MBor: 8.5	5.74 [5.97]
	pp 7.0	MB+rare (mixed)	1.7*	847 [613]	0.5 pb^{-1}	MB: 825 HM: 26 MSL: 132	755 [773]
	Pb–Pb 2.76	MB	2.8×10^{-5}	223 [182]	9 μb^{-1}	MB: 56	810 [811]
2011	pp 2.76	rare	4.4×10^{-1}	35 [32]	46 nb^{-1}	MBor: 74 HM: 0.0015 E0: 0.78 MSL: 9.4	100 [101]
	pp 7.0	rare	9 (450 kHz)	1332 [841]	4.9 pb^{-1}	MBor: 608 MBand: 163 EJE: 27 EGA: 8 MUL: 7.6	1981 [1572]
	Pb–Pb 2.76	rare	4.6×10^{-4}	203 [159]	146 μb^{-1}	MBZ: 9 CENT: 29 SEMI: 34 MSH: 23 EJE: 11 CUP: 7.9 MUP: 3.4	3151 [908]

Projections on statistical error

Stat error is estimated for $R\gamma = Y\gamma^{inc}/Y\gamma^{dec} = (Y\gamma^{dir} + Y\gamma^{dec})/Y\gamma^{dec}$

Y is the invariant yield per unit rapidity per 1 event

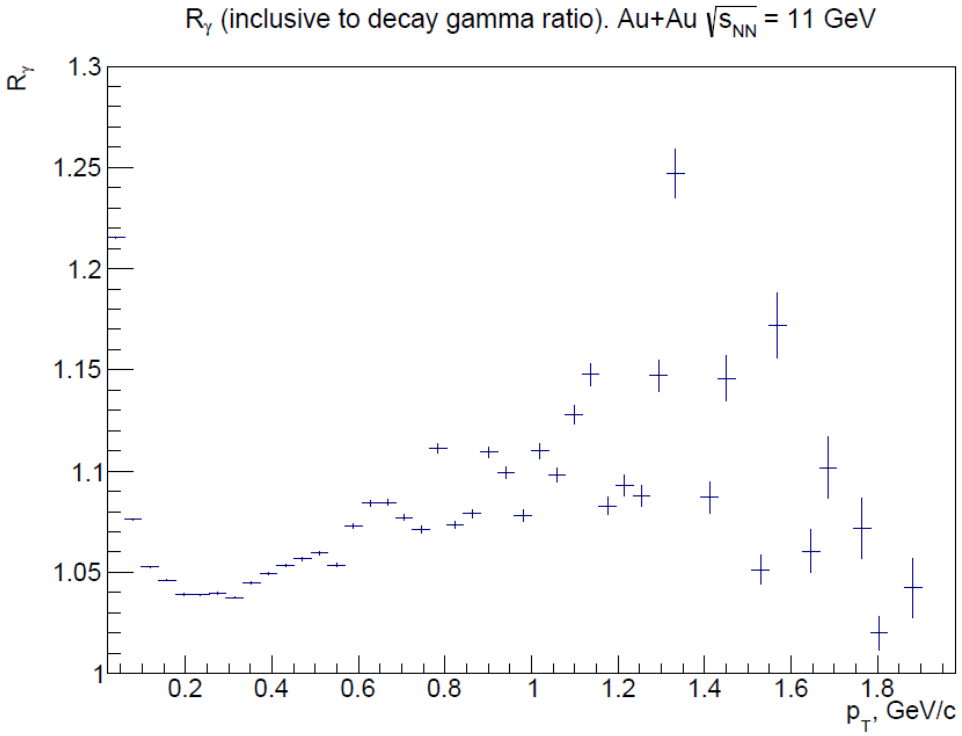
$N_{raw} = Y*pTbinwidth*pT*2\pi$

$e1 = sqrt(Y\gamma^{inc} /pTbinwidth/pT/2\pi/N^{events})$

$e2 = sqrt(Y\gamma^{dec} /pTbinwidth/pT/2\pi/N^{events})$

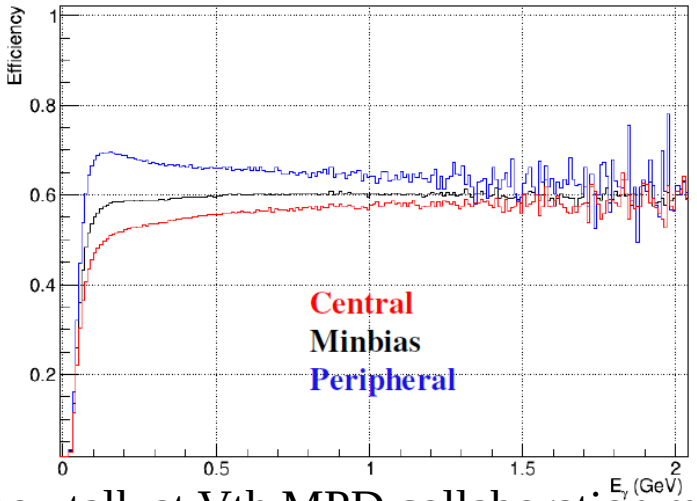
$Error = sqrt((e1/ Y\gamma^{dec})^2+(e2* R\gamma / Y\gamma^{dec})^2)$

For 1 GeV/c stat error is less than 1% for $N^{events} = 10^6$

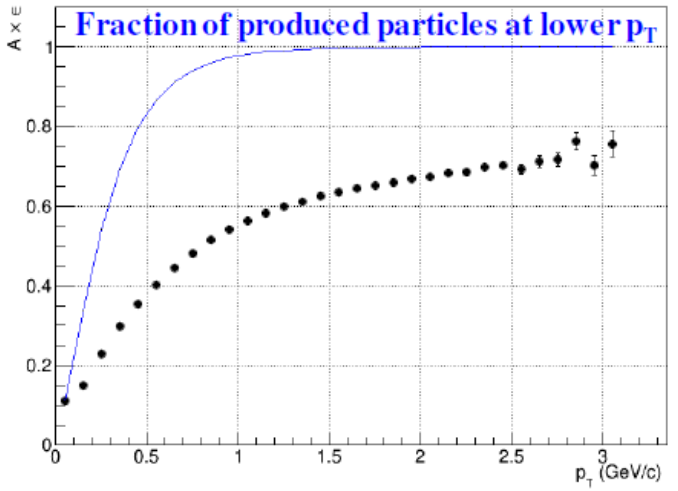


Gamma efficiency is about 0.6 and pi0 efficiency is more than 0.4 above 0.5 GeV/c

γ efficiency Au-Au 11 GeV



V.Riabov talk at Vth MPD collaboration meeting

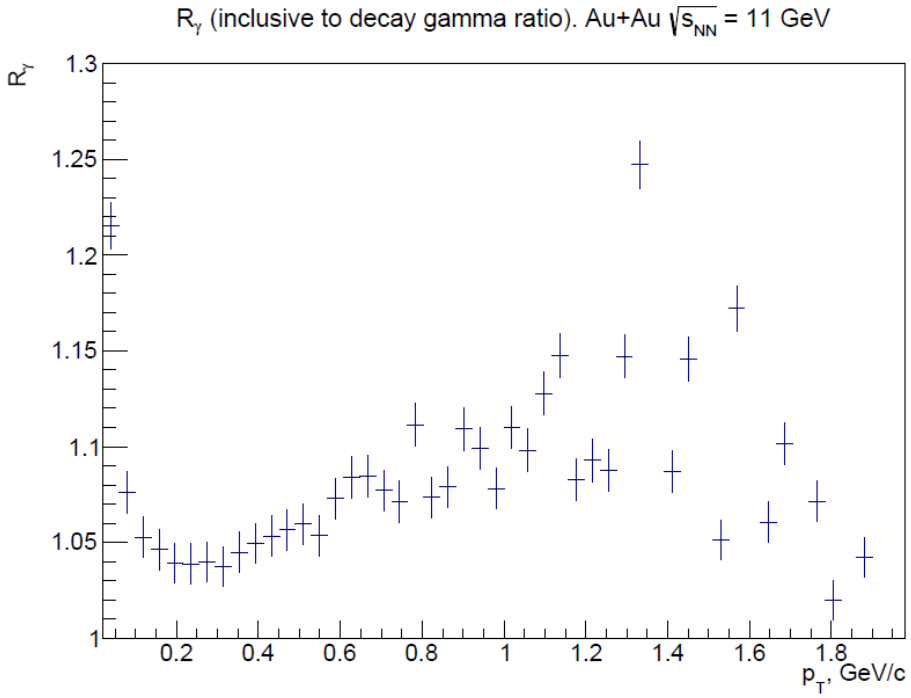


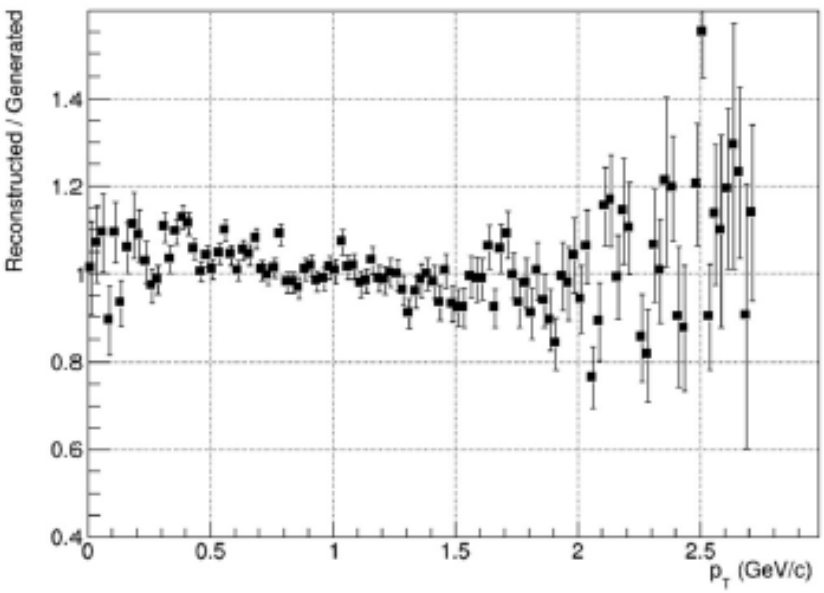
- Efficiency for π^0 is > 10% at p_T > 50-100 MeV

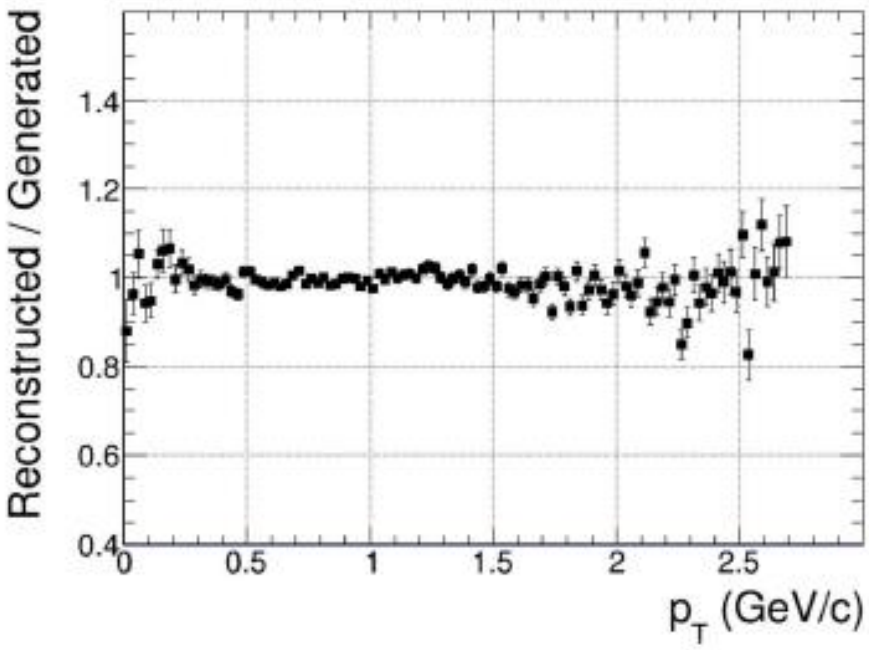
Projections on statistical error

Alternative estimation: stat error on Rγ is directly translated from pi0 yield error.
Viktor showed (25.06) that for MB events error in Reco/True ratio is ~5% for 4M events and decreases down to 1-2% for 15M events.

With 1% relative uncertainty it would be:



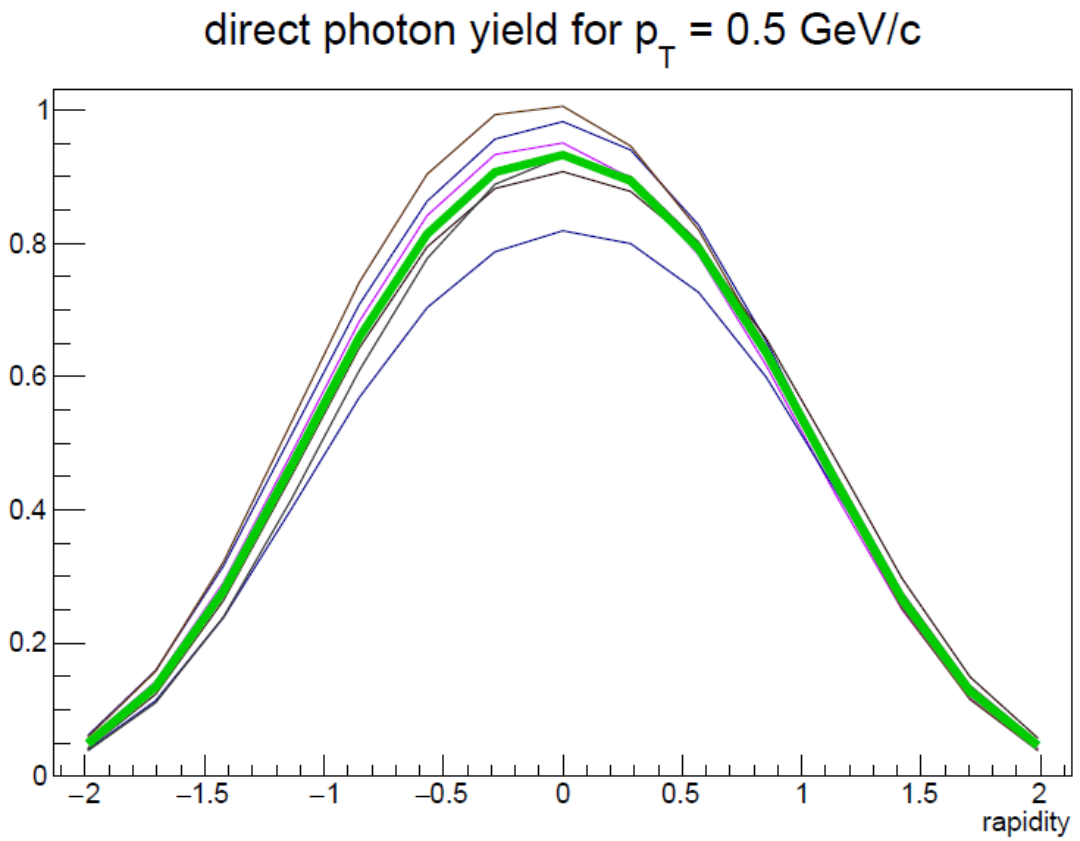




Direct gamma yield dependence on the initial geometry fluctuations

Previously shown results are for 1 generated event with UrQMD + hydro
Now we generated 10 events with the same input (Au-Au 11 GeV, b=4.5 fm), 6 events gave different output.

Due to initial state fluctuations yield differs about 10-20% from average (shown in green)

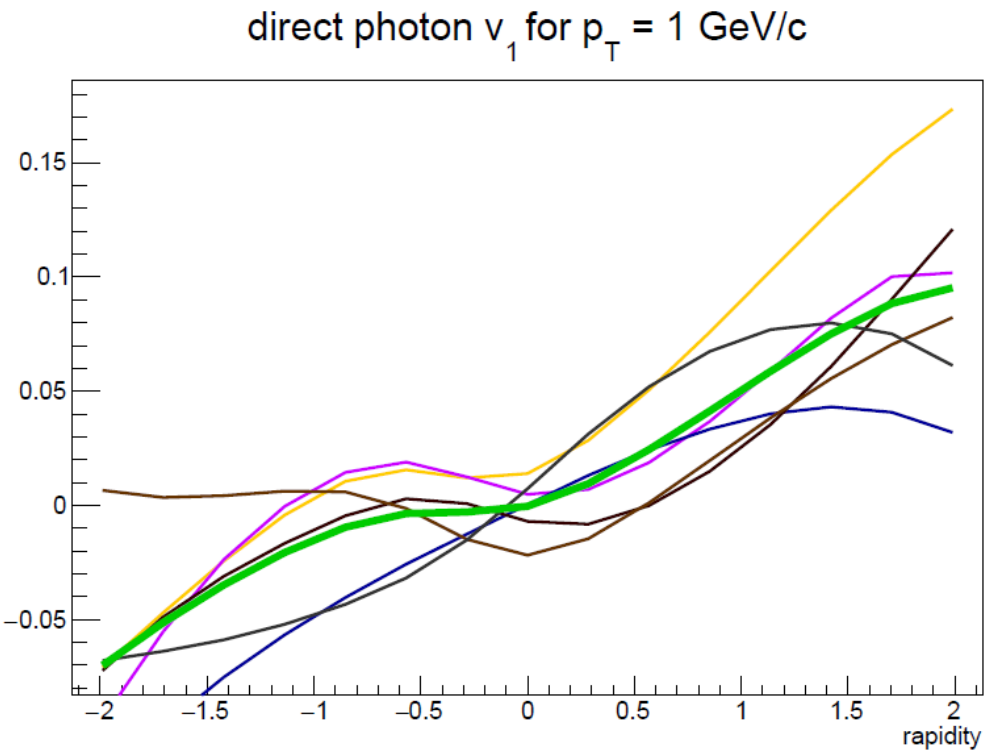


Direct gamma flow simulations
v1

Previously shown v1 and v2 vs pT and y for 1 generated event with UrQMD + hydro
Now we generated 10 events with the same input (Au-Au 11 GeV, b=4.5 fm), 6 events gave different output.

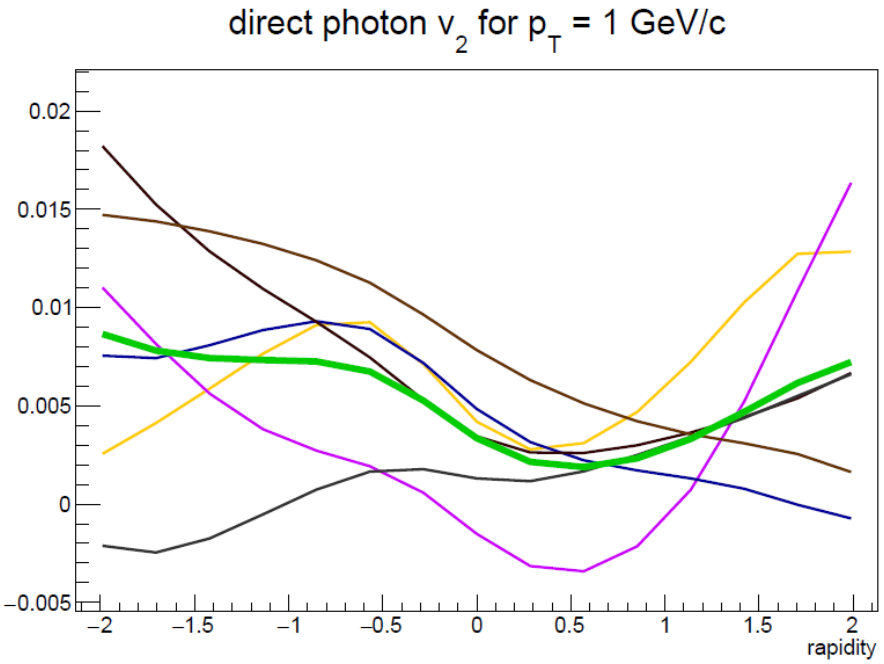
Positive slope of v1 for γdir at midrapidity is predicted for b=4.5 fm

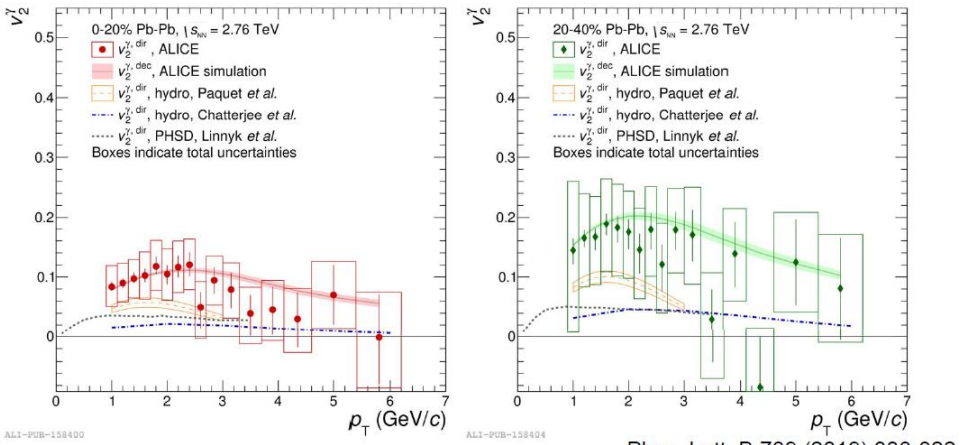
Fluctuations due to initial state are large (due to first timesteps in hydro evolution)



Direct gamma flow simulations
v2

v2 for γ^{dir} is about 1% which is consistent with hydro models predictions (note: for LHC) where v2 for γ^{dir} is predicted 2-4 times smaller than $v2^{\gamma dec} \approx v2^{had}$





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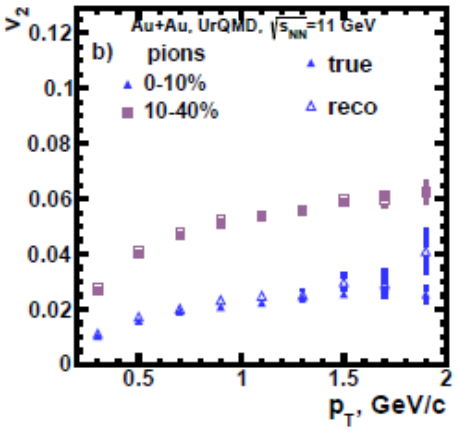
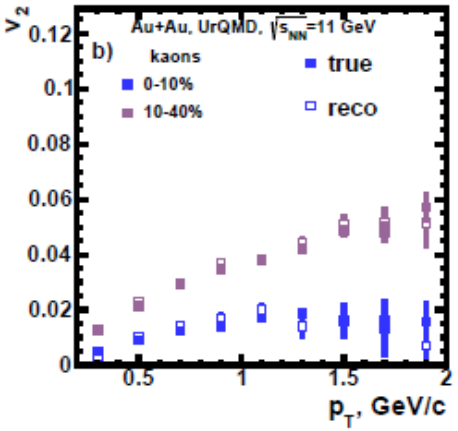
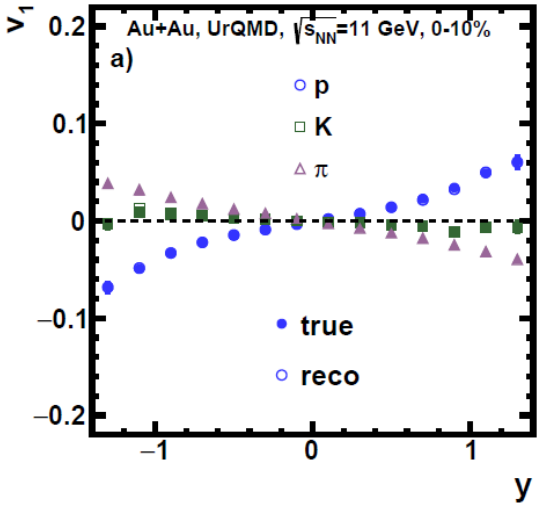
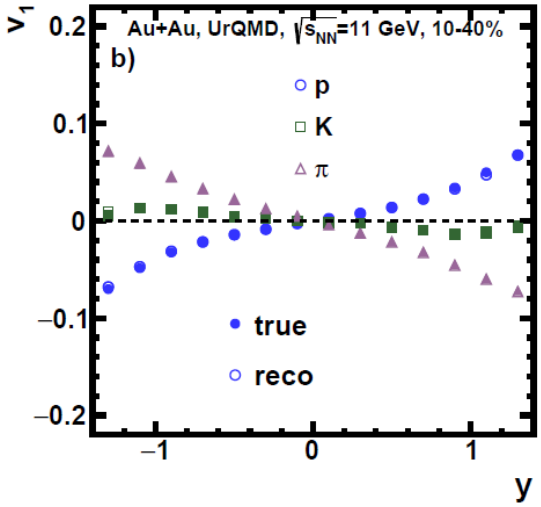
Flow simulations: hadrons

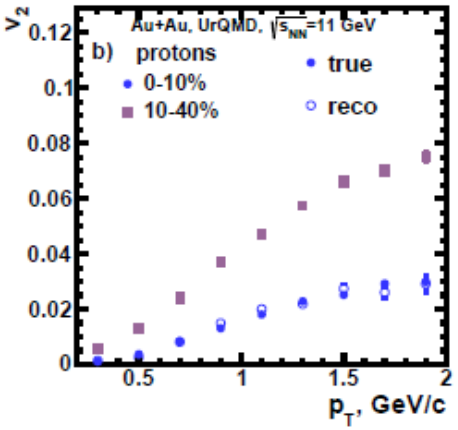
Results on hadron flow with MPD obtained within RFBR grant 18-02-40086 lead by A. Taranenko:
v1 – positive slope for protons
v2 – at 1 GeV/c about 2-5 percent depending on centrality and particle specie











Conclusions

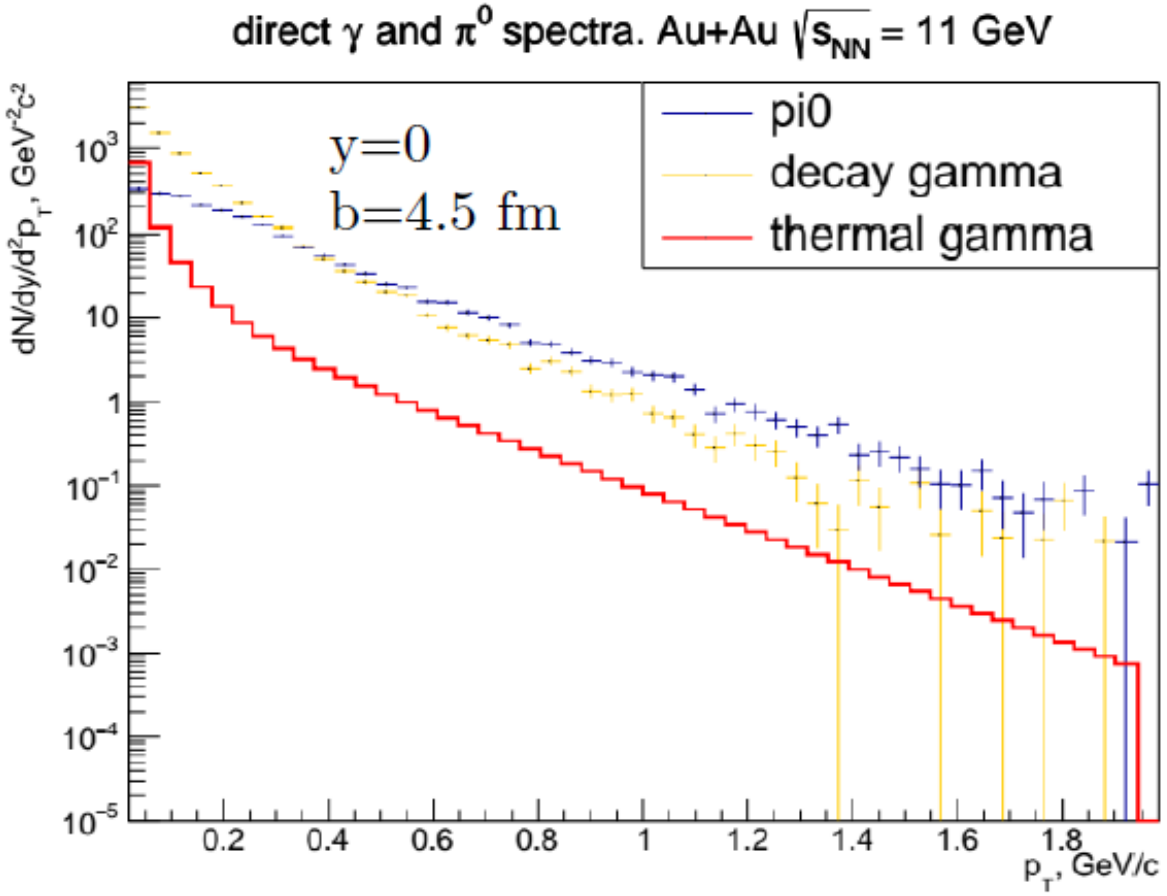
- Statistical error on Rγ is evaluated. With ~10^7 statistics signal of about 1-2% can be measured at pT = 1 GeV/c
- Systematical error should be evaluated with different pi0 yield extraction methods variations (different hypothesis about background shape, different fit range etc.)
- Direct gamma yield fluctuate about 10-20% at the same b from event to event
- Direct gamma v1 and v2 also fluctuate.
- On average, v1 has positive slope and about 5% at y=1 for pT=1 GeV/c which is similar to protons rather than charged mesons
- On average, v2 is positive about 1% which is 2-5 times smaller than for charged hadrons. This is similar to other hydro models predictions for LHC, for example.

Next steps:

- Prepare analysis framework for study systematics for pi0 extraction
- Estimate systematic error on pi0 extraction which is one of the largest uncertainties in Rγ
- Generate about 1000 events of UrQMD+hydro with the same input parameters for further study of flow fluctuations

backup

spectra


direct γ and π⁰ spectra. Au+Au √s_NN = 11 GeV
y=0
b=4.5 fm
pi0
decay gamma
thermal gamma
dN/dy/d²p_T, GeV⁻²c²
p_T, GeV/c