Feasibility of Hyperon Anisotropic Flow Studies at NICA/MPD. Current Status and Plans

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for the MPD collaboration

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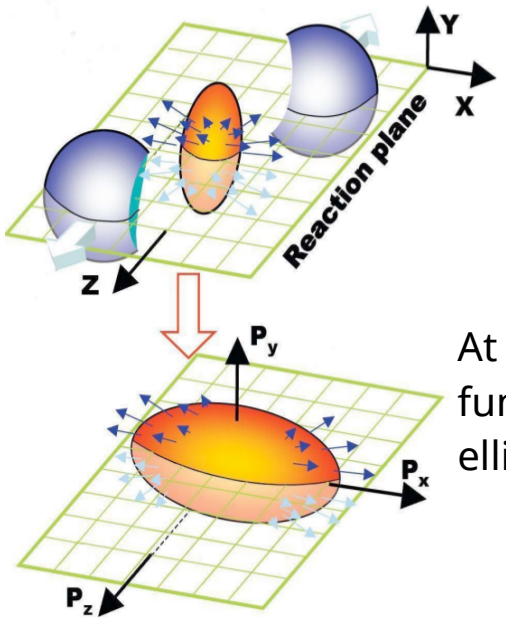
MPD PWG Round Table
15.04.2019

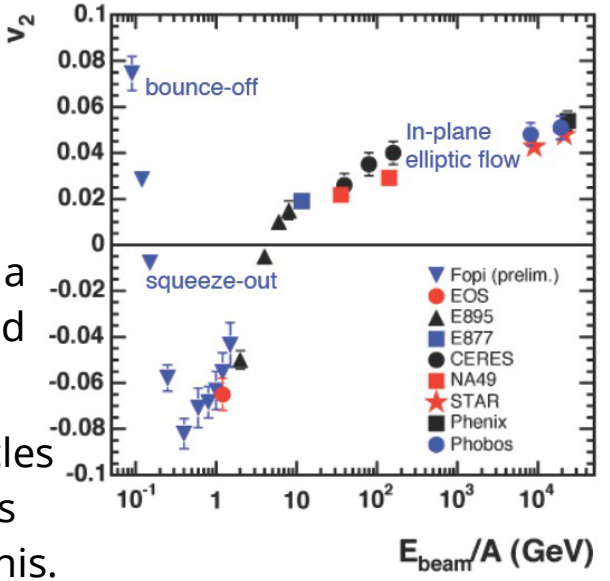
Anisotropic Flow @ NICA/MPD



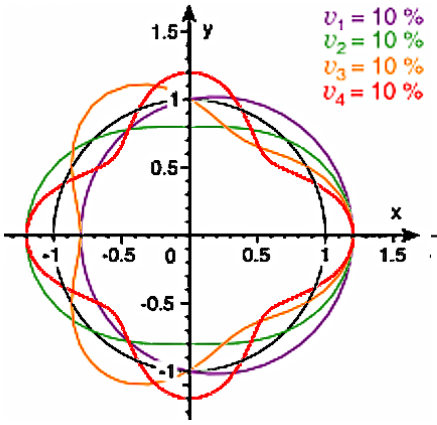
In HIC a non-zero b leads to:

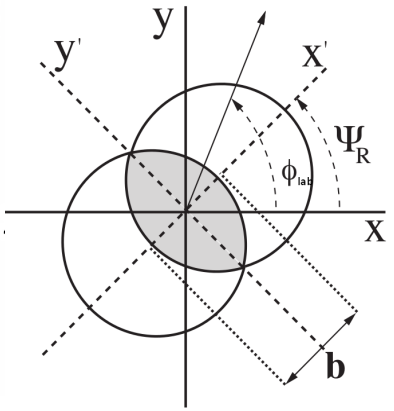
* Spatial anisotropy
* Pressure gradiet
* Momentum anisotropy
* Fourier expansion → Flow v_n

At Nuclotron-NICA energy range elliptic flow as a function of energy changes sign. Both directed and elliptic flow can signal a first order phase transition.



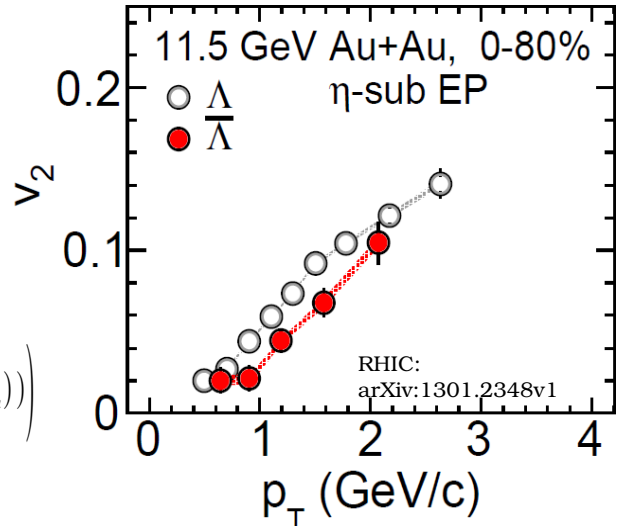
At RHIC a difference between v2 of particles and their corresponding antiparticles was observed. NICA is expected to measure this.



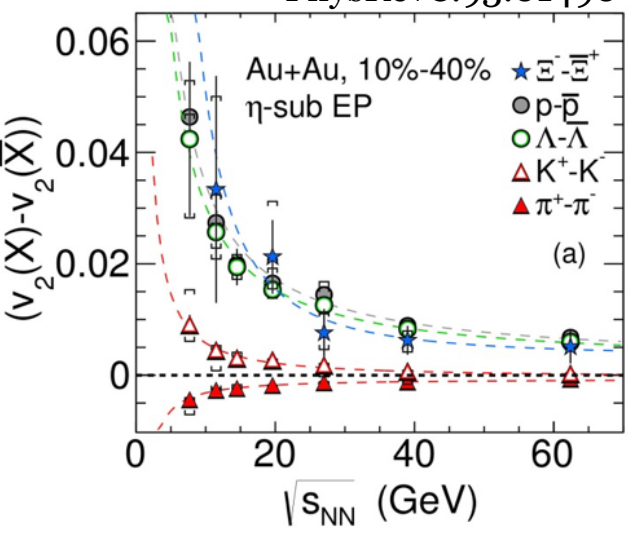


$$E\frac{d^3N}{d^3\boldsymbol{p}} = \frac{dN}{2\pi\, p_T dp_T dy}\left(1 + 2\sum_{n=1}^{\infty} v_n(p_T, y)\cos\left(n(\phi - \Psi_n)\right)\right)$$

$$v_n(p_T, y) = \langle \cos[n(\phi - \Psi_n)] \rangle$$

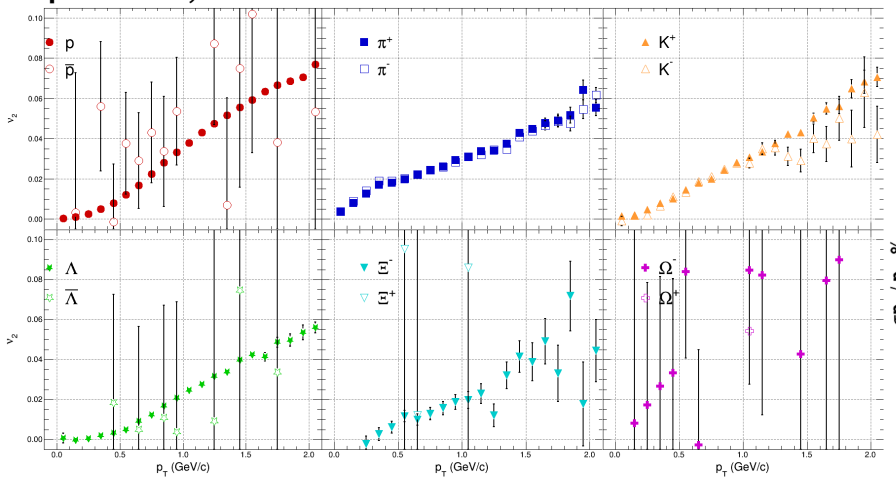


PhysRevC.93.01490

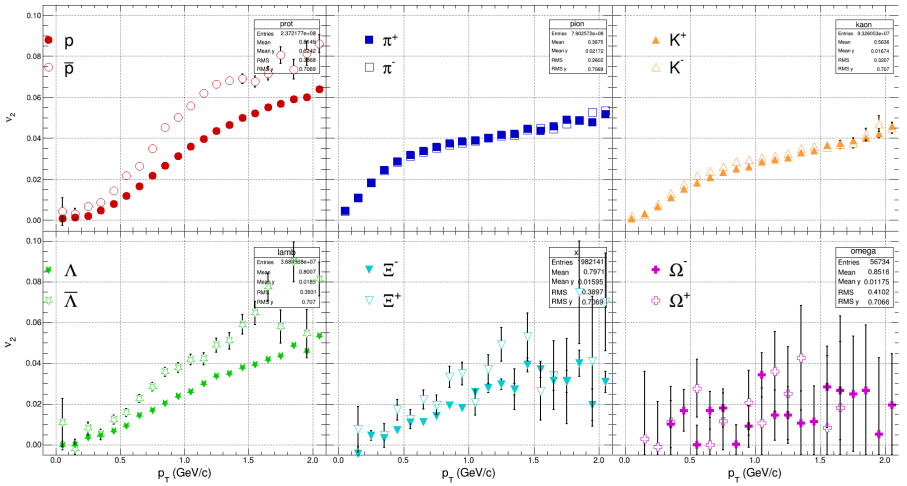


Requirements for Hyperon Flow @ MPD

10 million, UrQMD(non-hydro), AuAu, 4.0 GeV, 0..16 fm



10 million, UrQMD(non-hydro), AuAu, 11 GeV, 0..16 fm



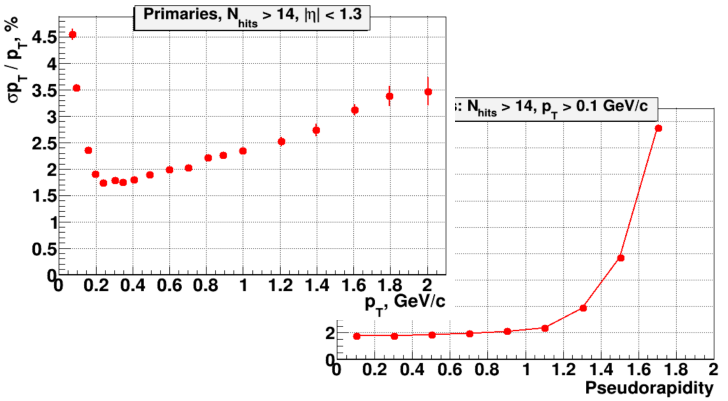
Precise tracking at both low and high p_T

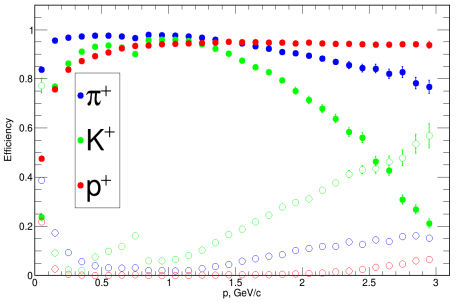
Good particle identification

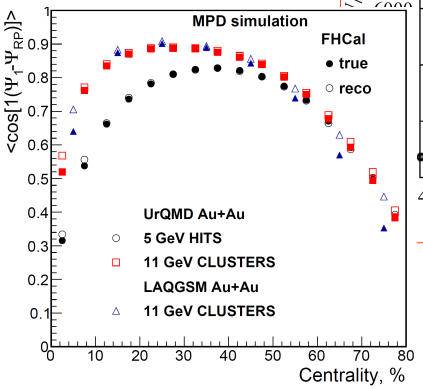
Precise vertexing with good efficiency of cuts

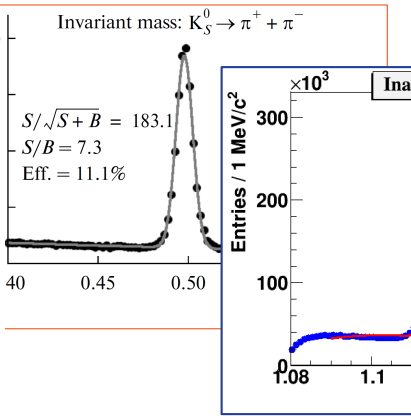
Event-plane determination and correction

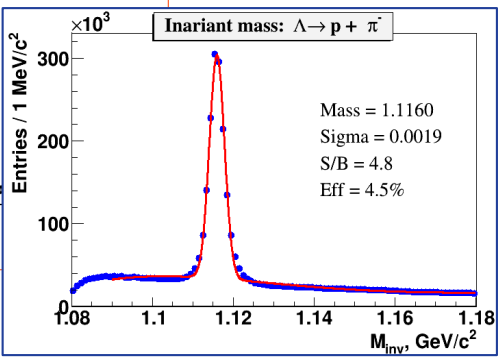
Hyperon flow requires much larger statistics (read: disk space and cpu/human time)











MpdParticleRecoTask

Seperate reco-macros for each particle is not always convenient...
... so let's do all particles of interest in a single run over the event (during reconstruction or afterwards)

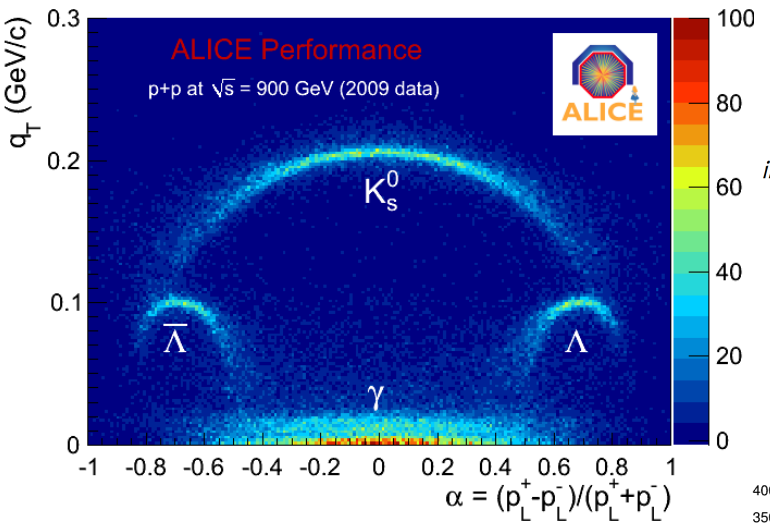
Based on code by A. Zinchenko (MpdParticle, MotherFitter, macros, etc.)

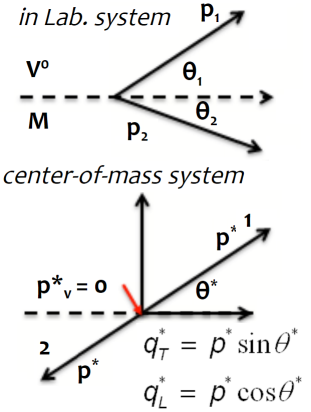
K_s^0, Λ, $\overline{\Lambda}$, Ξ^- and Ω^- are implemented ($\overline{\Xi}^+$, $\overline{\Omega}^+$ - simple to add)

```
FairRunAna *fRun = new FairRunAna(); //run_type proof_name ""
TFile fileMC(transportFile.Data());
fileMC.Get("FairGeoParSet");
FairSource* fFileSource = new FairFileSource(inFile.Data());
fRun->SetSource(fFileSource);
fRun->SetOutputFile(outFile.Data());

MpdKalmanFilter *kalman = MpdKalmanFilter::Instance("KF");
fRun->AddTask(kalman);

Int_t kaon0s_pdg = 310;
Int_t Lambda_pdg = 3122;
Int_t Xi_pdg = 3312;
Int_t Omega_pdg = 3334;

MpdParticleRecoTask* partReco = new MpdParticleRecoTask("PRT");
partReco->SetPID(4., 4., 11., 1., "UrQMD", "CF", .8);
partReco->SetRecoParticle(kaon0s_pdg);
partReco->SetRecoParticle(Lambda_pdg);
partReco->SetRecoParticle(-Lambda_pdg);
partReco->SetArmPodCut(kFALSE);
fRun->AddTask(partReco);

fRun->Init();
fRun->Run(nStartEvent, nStartEvent + nEvents);
```

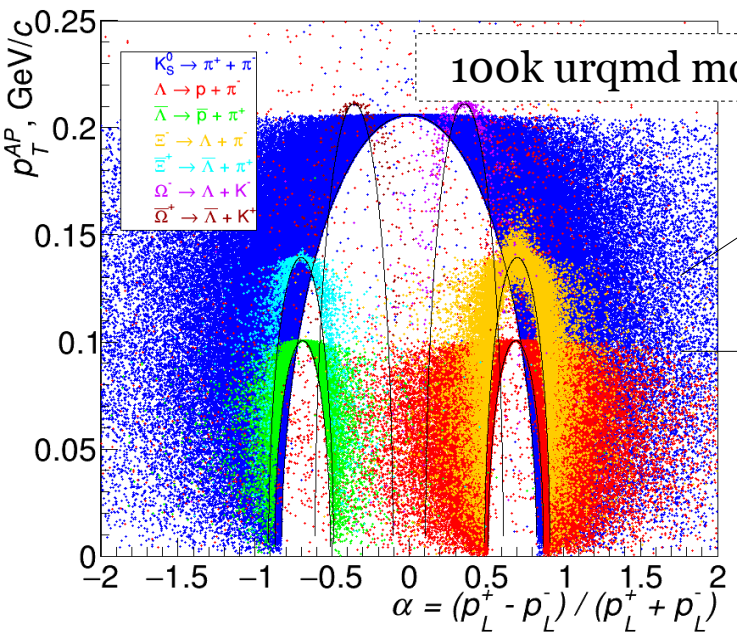
1. Initial cuts on event and tracks
2. Tracks are identified using MC/MpdPid and refitted
3. Converted to TClonesArrays(MpdParticle) for later
4. Daughter arrays are combined to produce mothers
5. Cuts applied on daughters and mother
6. Reconstructed mother array registered as a Branch

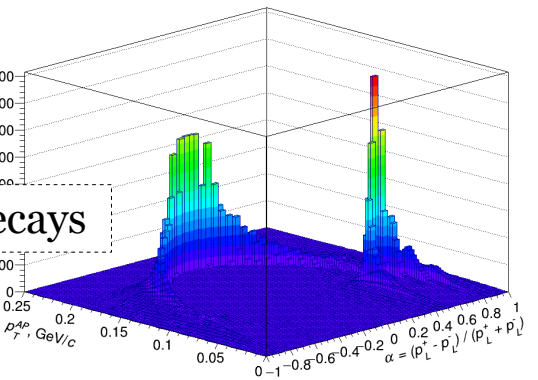
Armenteros-Podolanski Plot

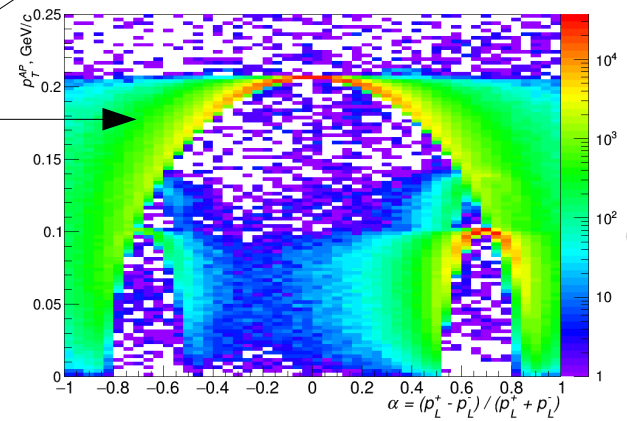


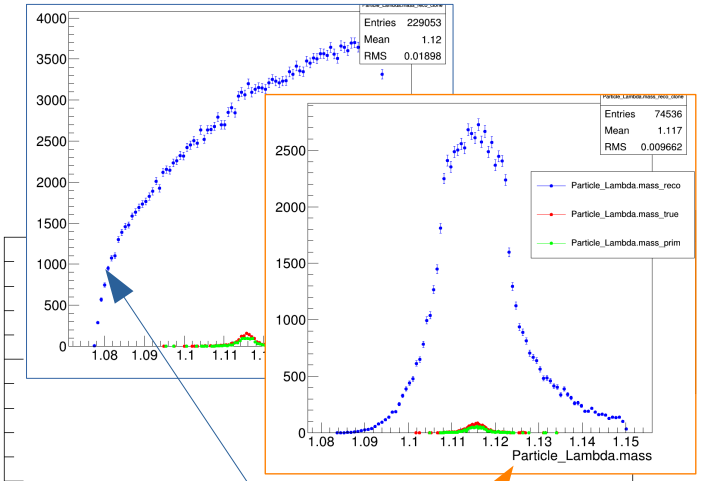


Implemented in MpdParticleRecoTask
Can be used for simple rectangular cuts or elliptical cuts (inner, outer, both) with 3 parameters α_0-center, α & q_T-radii







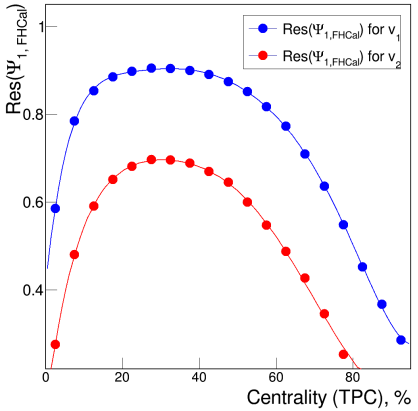


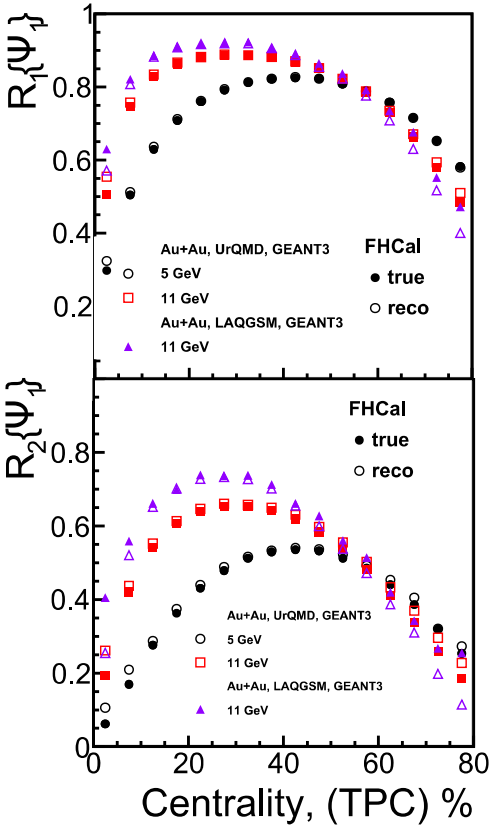
Data Set and Analysis

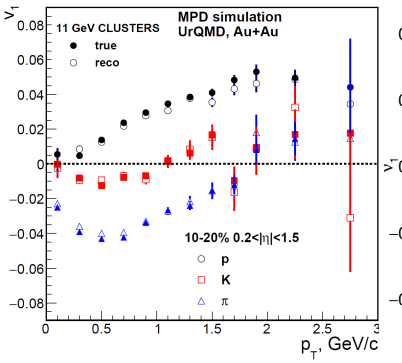
- UrQMD, AuAu, 11 GeV, minbias, 15×10^6 events
- Geant4: TPC (v. 6), TOF, FHCal
- TPC Clusters and ADC shaping, etc.
- Cluster Finder MLEM, Kalman Filter
- MC id used (1 line of code to switch to PID)
- MpdParticleRecoTask (for particle decay reco)
- Slightly modified MEPhi Flow
  (added decays and impar-based centrality)

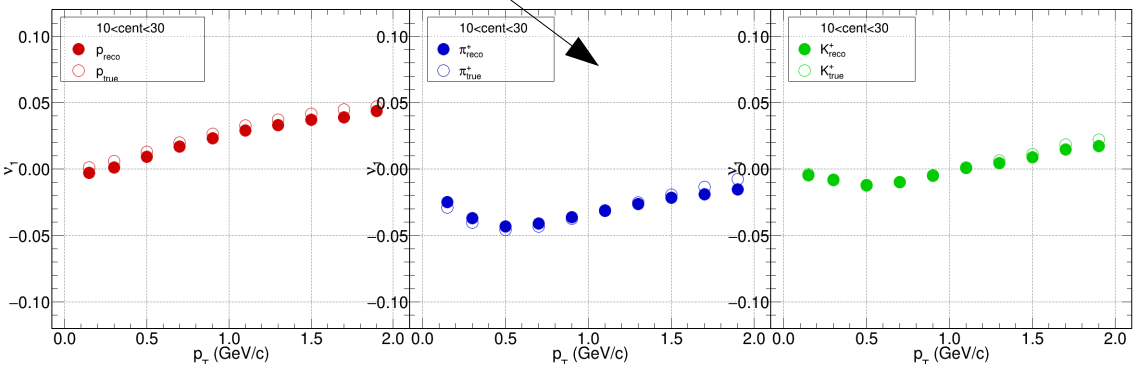
Flow Results Crosscheck

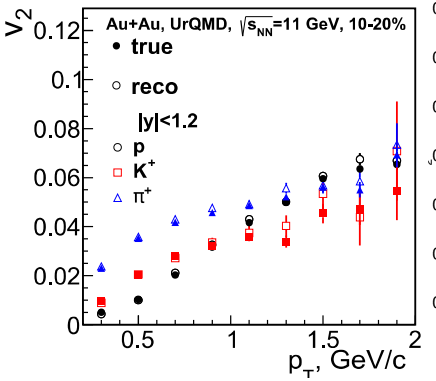
Results are in a good agreement (here MC ID was used)

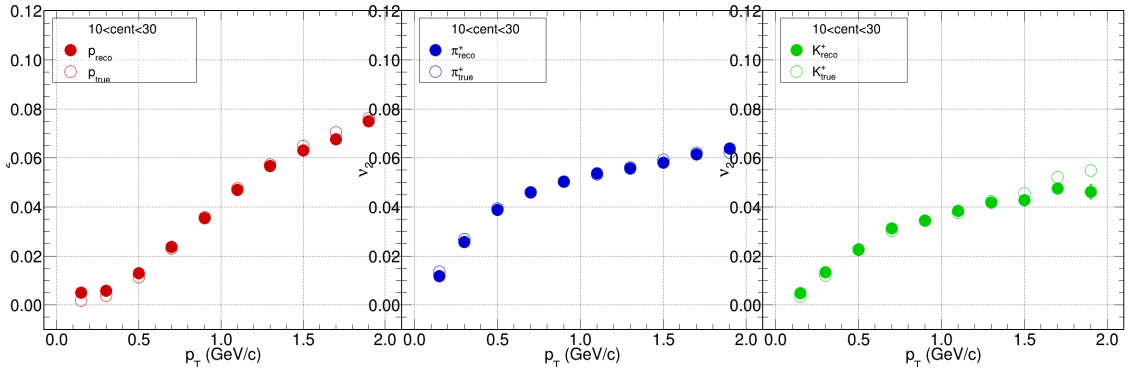


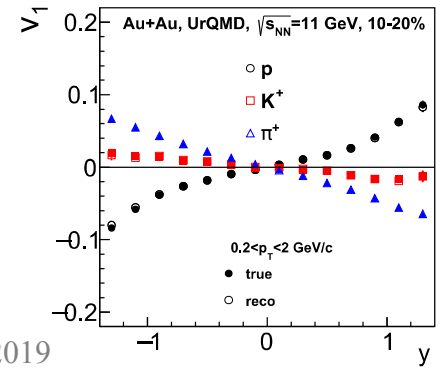


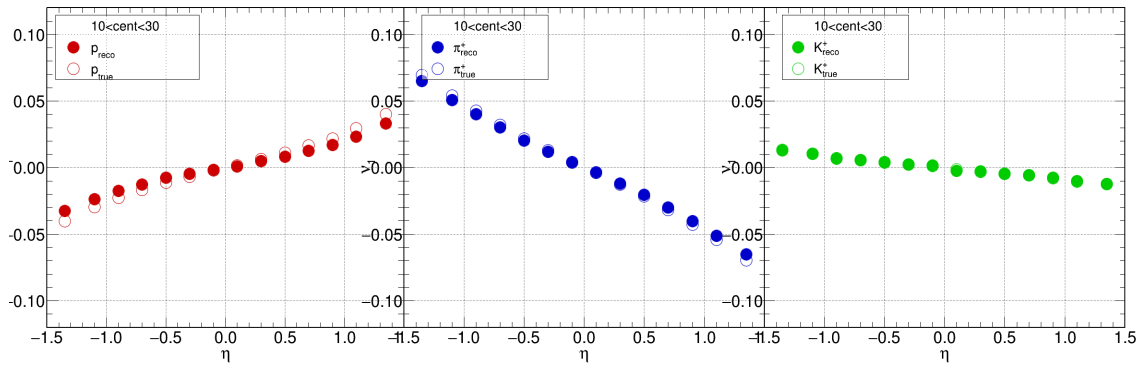






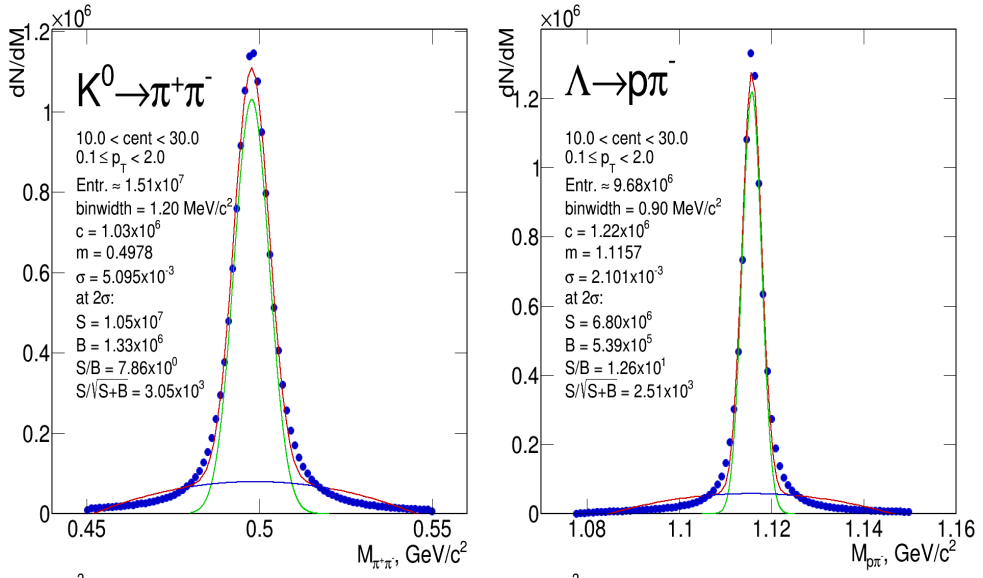


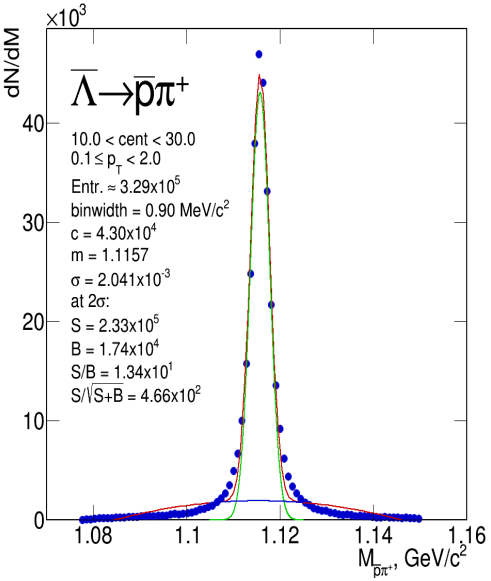


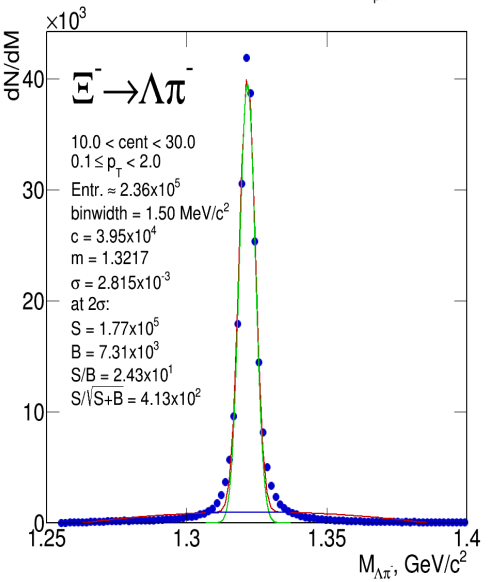


arXiv:1901.03125v1 [hep-ex] 10 Jan 2019

Reconstructed Decays

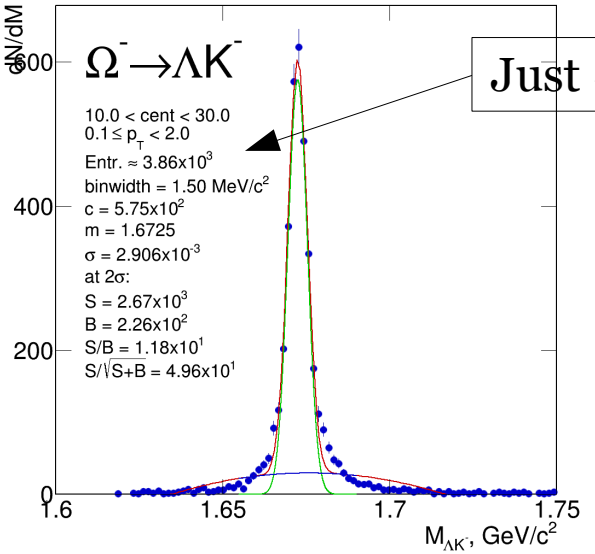






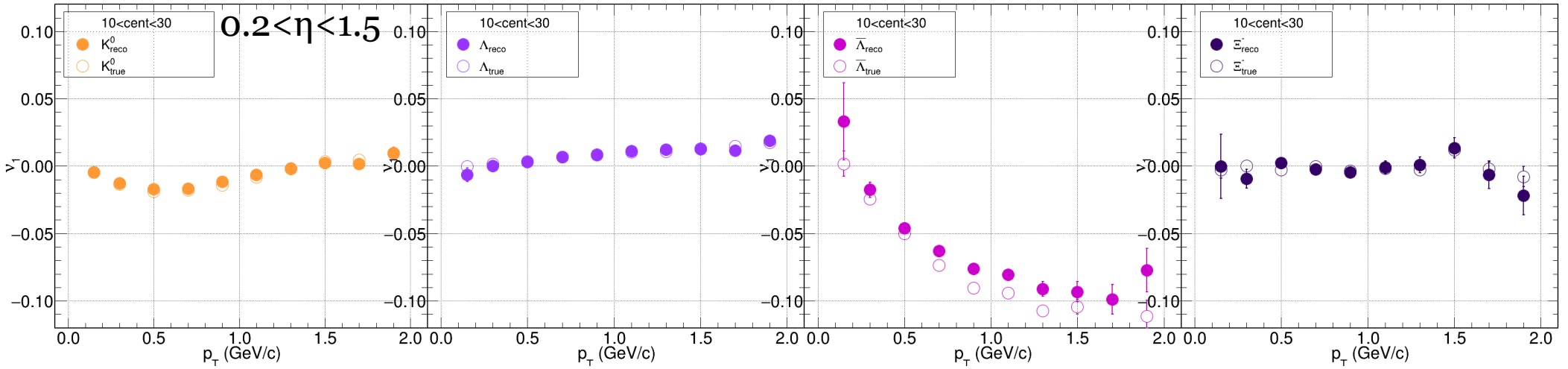
Fully reconstructed particles,
but true MC ID and MC PID used.
(please disregard S, B, etc.)
$0.1<p_T<2.0$

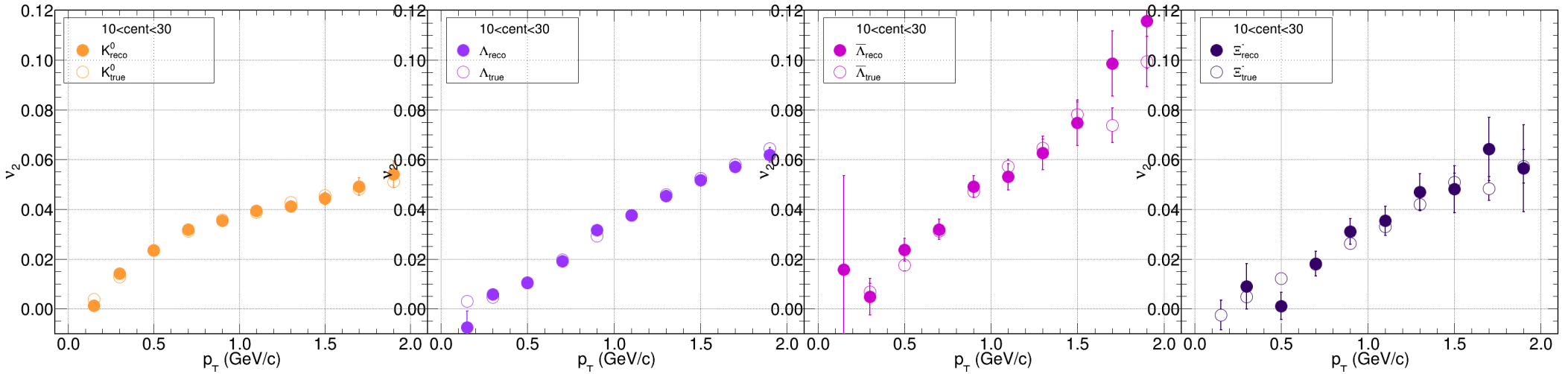
Q: Why only TRUE?
A: Establishing a baseline,
no systematics due to cuts,
highest possible efficiency/statistics



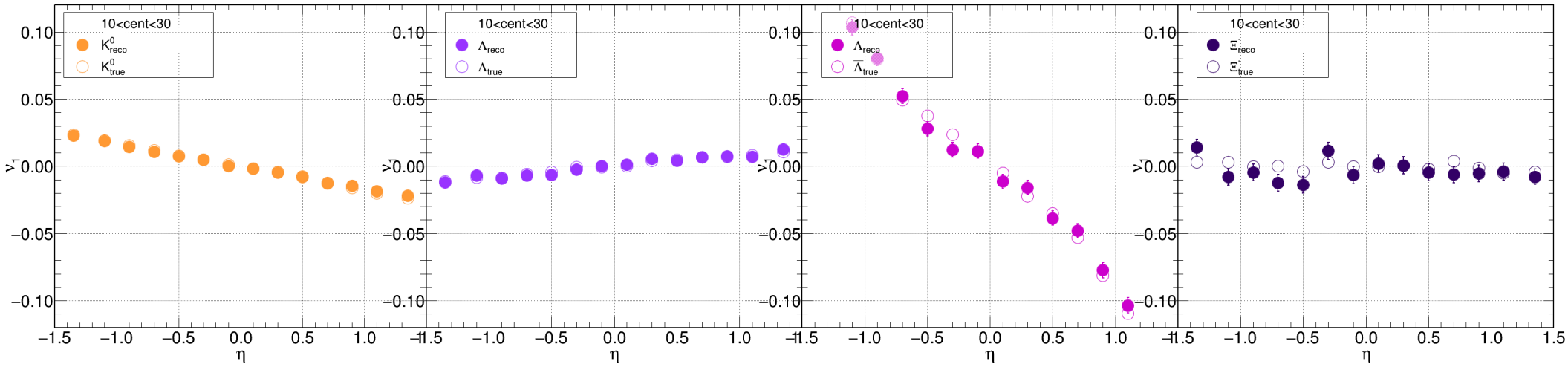
Just ~4k Omegas :(

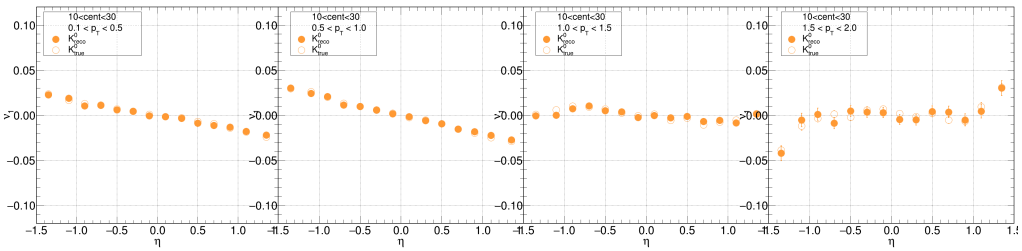
Flow Results $v_{1,2}$ vs p_T

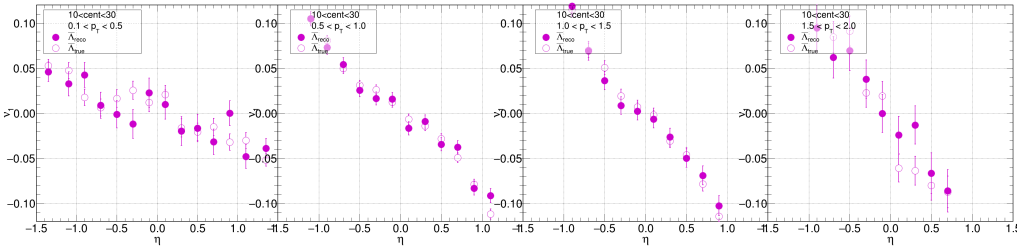


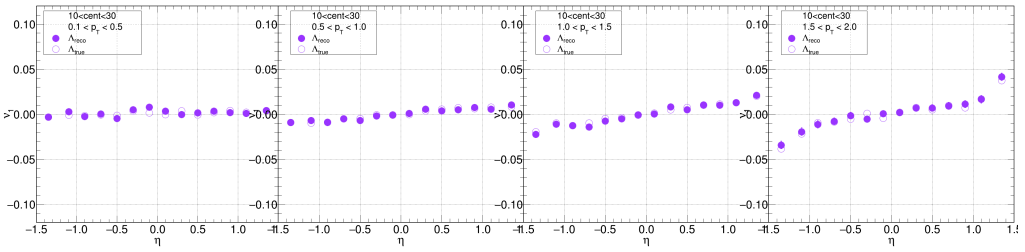


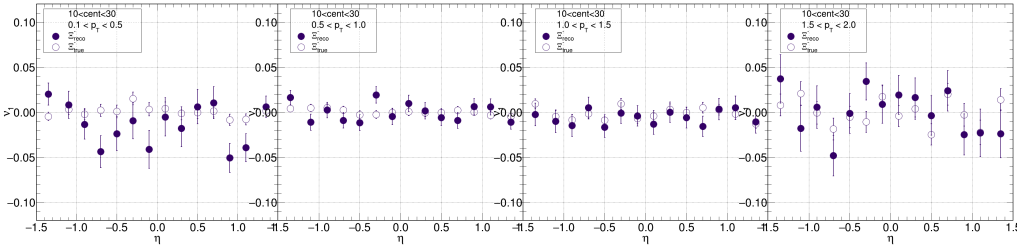
Flow Results v_1 vs η (p_T bins)











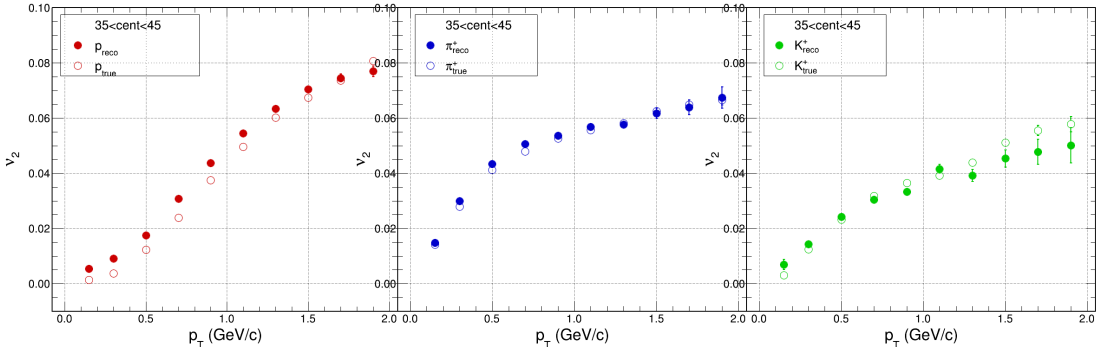
Computing and Plans

- Analysis of large data sets is slow on my 2 core i3 from 2011.
  Plan to upgrade in the middle of this year.
- Currently using nc cluster. Processing speed and storage are a concern.
  Recent upgrade and user_max_task increase 50->200 was a huge improvement.
  Also, more space seems to be available
- What about HybriLIT, GOVORUN, lxpub?
  (forum post: "Как работать на ферме lxpub" is it still relevant?)
- Data set: 15k files * 1k ev I would like to generate much more
- Continue studying anisotropic flow at MPD.
- K_s^0 and Λ flow with background and realistic cuts, BG-subtraction method
- MpdKinematicFitter for cascades?
  Implement rave to MPD (framework for kinfit)
- Implement latest Kalman Filter improvement for low p_T
- Migrate to root6: RDataFrame, TMVA for particle cuts, etc. (some testing done)

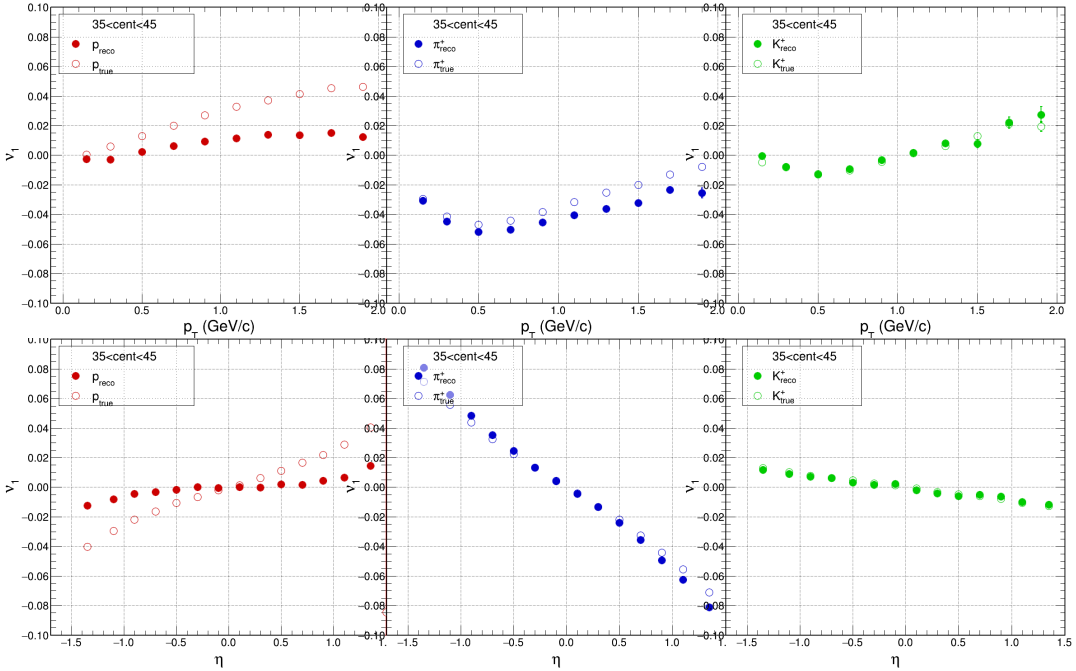
Thank you!

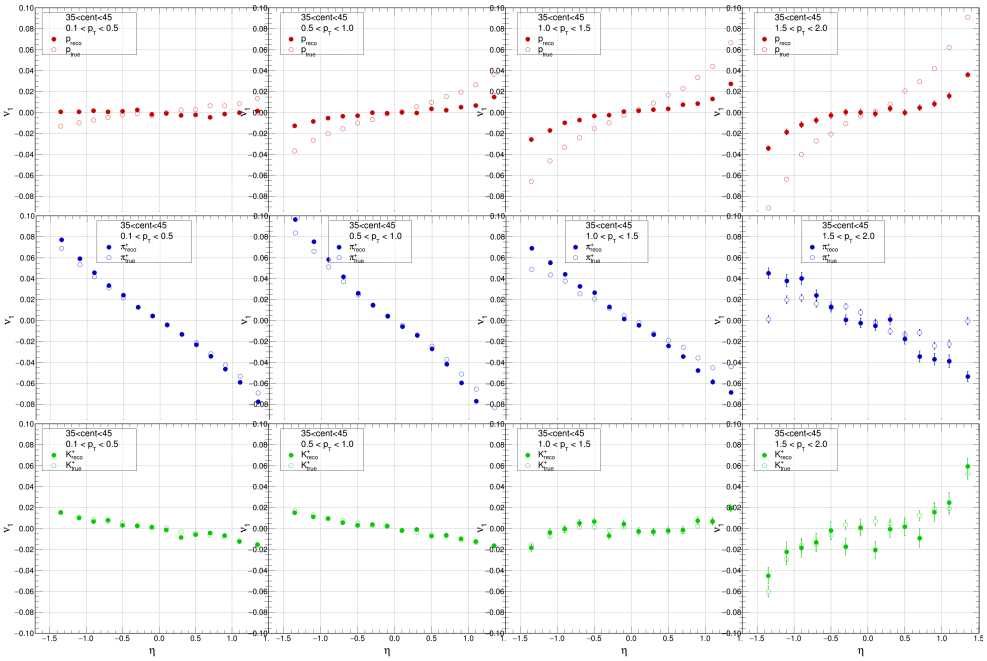
extra

What abot 35..45 cent and above?



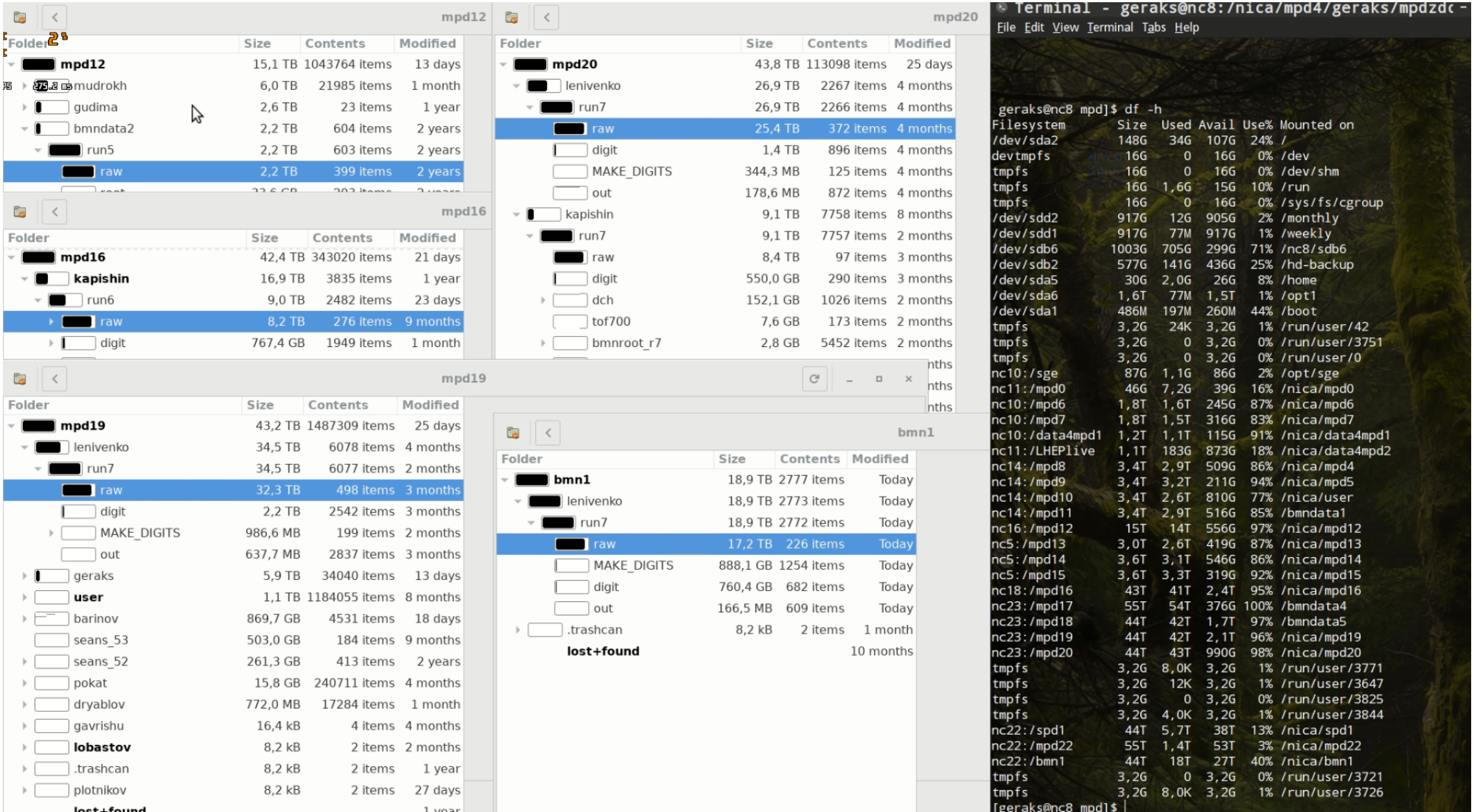
At centrality > 30 %
Elliptic flow seems to be ok.
What is wrong with directed flow?
Mismatch between TRUE and RECO seems to be increasing with p_T for protons and pions (less).
Kaons not affected.
Why? Acceptance? Resolution?
Cuts (Nhits, eta)? Physics?





Disk space @nc

I understand the need for disk space but what about data duplication?
What are the bmndata disks used for?



mpd12

Folder	Size	Contents	Modified
mpd12	15,1 TB	1043764 items	13 days
mudrokh	6,0 TB	21985 items	1 month
gudima	2,6 TB	23 items	1 year
bmndata2	2,2 TB	604 items	2 years
run5	2,2 TB	603 items	2 years
raw	2,2 TB	399 items	2 years

mpd20

Folder	Size	Contents	Modified
mpd20	43,8 TB	113098 items	25 days
lenivenko	26,9 TB	2267 items	4 months
run7	26,9 TB	2266 items	4 months
raw	25,4 TB	372 items	4 months
digit	1,4 TB	896 items	4 months
MAKE_DIGITS	344,3 MB	125 items	4 months
out	178,6 MB	872 items	4 months
kapishin	9,1 TB	7758 items	8 months
run7	9,1 TB	7757 items	2 months
raw	8,4 TB	97 items	3 months
digit	550,0 GB	290 items	3 months
dch	152,1 GB	1026 items	2 months
tof700	7,6 GB	173 items	2 months
bmnroot_r7	2,8 GB	5452 items	2 months

mpd16

Folder	Size	Contents	Modified
mpd16	42,4 TB	343020 items	21 days
kapishin	16,9 TB	3835 items	1 year
run6	9,0 TB	2482 items	23 days
raw	8,2 TB	276 items	9 months
digit	767,4 GB	1949 items	1 month

mpd19

Folder	Size	Contents	Modified
mpd19	43,2 TB	1487309 items	25 days
lenivenko	34,5 TB	6078 items	4 months
run7	34,5 TB	6077 items	2 months
raw	32,3 TB	498 items	3 months
digit	2,2 TB	2542 items	3 months
MAKE_DIGITS	986,6 MB	199 items	2 months
out	637,7 MB	2837 items	3 months
geraks	5,9 TB	34040 items	13 days
user	1,1 TB	1184055 items	8 months
barinov	869,7 GB	4531 items	18 days
seans_53	503,0 GB	184 items	9 months
seans_52	261,3 GB	413 items	2 years
pokat	15,8 GB	240711 items	4 months
dryablov	772,0 MB	17284 items	1 month
gavrishu	16,4 kB	4 items	4 months
lobastov	8,2 kB	2 items	2 months
.trashcan	8,2 kB	2 items	1 year
plotnikov	8,2 kB	2 items	27 days

bmn1

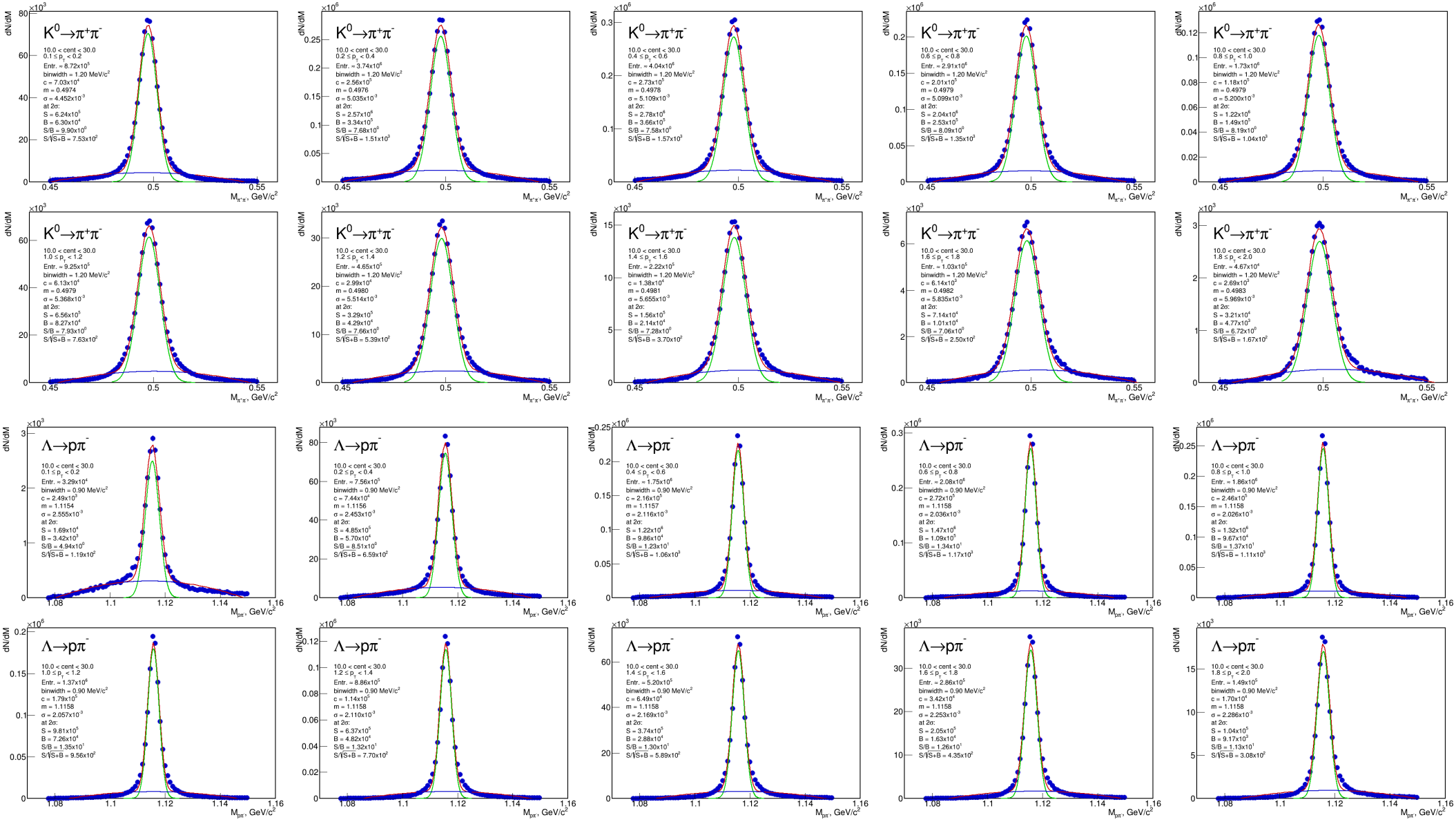
Folder	Size	Contents	Modified
bmn1	18,9 TB	2777 items	Today
lenivenko	18,9 TB	2773 items	Today
run7	18,9 TB	2772 items	Today
raw	17,2 TB	226 items	Today
MAKE_DIGITS	888,1 GB	1254 items	Today
digit	760,4 GB	682 items	Today
out	166,5 MB	609 items	Today
.trashcan	8,2 kB	2 items	1 month
lost+found			10 months

Terminal - geraks@nc8:/nica/mpd4/geraks/mpdzdc

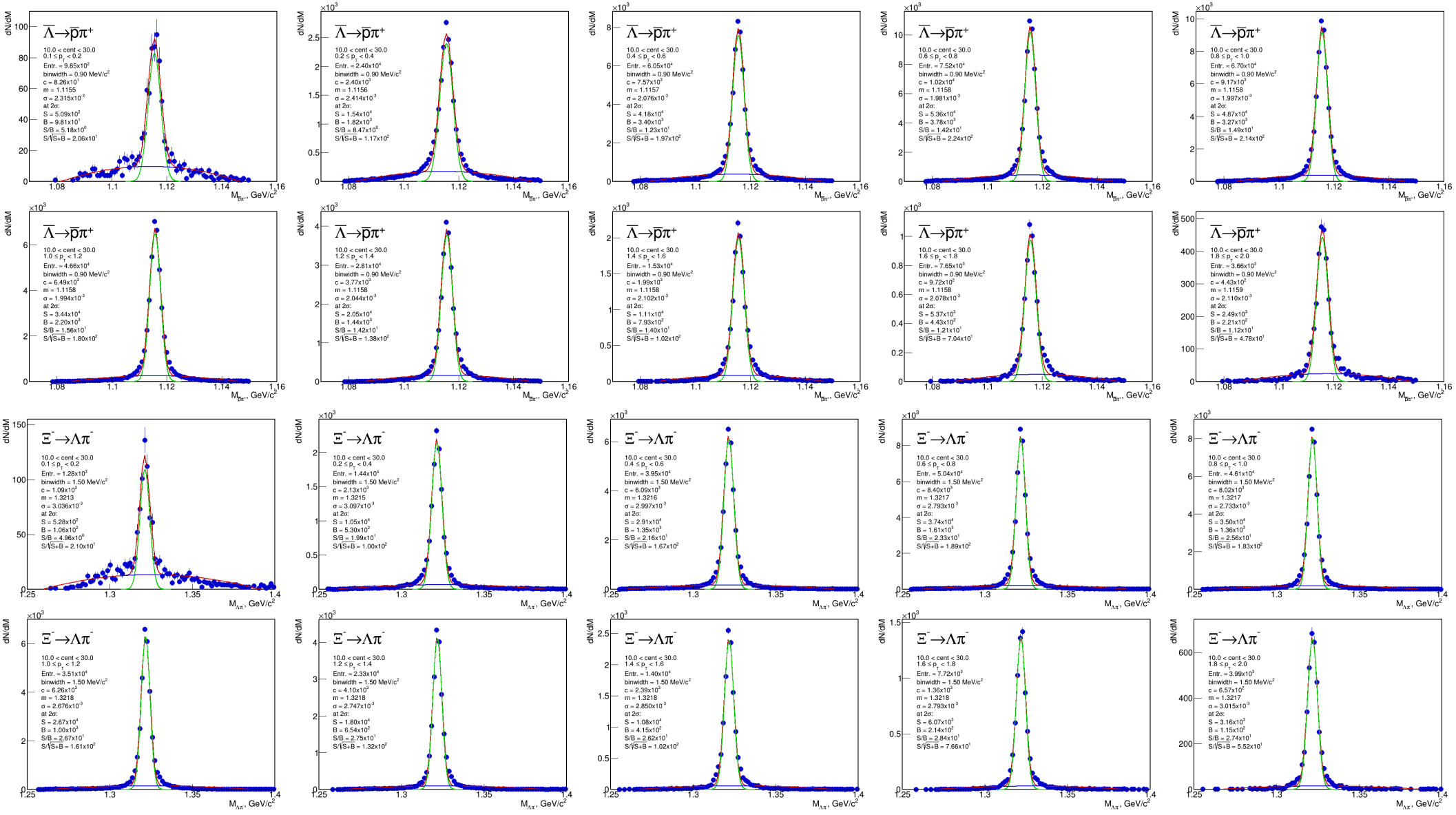
File Edit View Terminal Tabs Help

```
geraks@nc8 mpd]$ df -h
Filesystem      Size  Used Avail Use% Mounted on
/dev/sda2       148G   34G  107G  24% /
devtmpfs         16G     0   16G   0% /dev
tmpfs            16G     0   16G   0% /dev/shm
tmpfs            16G  1,6G   15G  10% /run
tmpfs            16G     0   16G   0% /sys/fs/cgroup
/dev/sdd2       917G   12G  905G   2% /monthly
/dev/sdd1       917G   77M  917G   1% /weekly
/dev/sdb6      1003G  705G  299G  71% /nc8/sdb6
/dev/sdb2       577G  141G  436G  25% /hd-backup
/dev/sda5        30G  2,0G   26G   8% /home
/dev/sda6       1,6T   77M  1,5T   1% /opt1
/dev/sda1       486M  197M  260M  44% /boot
tmpfs           3,2G   24K  3,2G   1% /run/user/42
tmpfs           3,2G     0  3,2G   0% /run/user/3751
tmpfs           3,2G     0  3,2G   0% /run/user/0
nc10:/sge        87G  1,1G   86G   2% /opt/sge
nc11:/mpd0       46G  7,2G   39G  16% /nica/mpd0
nc10:/mpd6      1,8T  1,6T  245G  87% /nica/mpd6
nc10:/mpd7      1,8T  1,5T  316G  83% /nica/mpd7
nc10:/data4mpd1 1,2T  1,1T  115G  91% /nica/data4mpd1
nc11:/LHEPlive  1,1T  183G  873G  18% /nica/data4mpd2
nc14:/mpd8      3,4T  2,9T  509G  86% /nica/mpd4
nc14:/mpd9      3,4T  3,2T  211G  94% /nica/mpd5
nc14:/mpd10     3,4T  2,6T  810G  77% /nica/user
nc14:/mpd11     3,4T  2,9T  516G  85% /bmndata1
nc16:/mpd12      15T   14T  556G  97% /nica/mpd12
nc5:/mpd13      3,0T  2,6T  419G  87% /nica/mpd13
nc5:/mpd14      3,6T  3,1T  546G  86% /nica/mpd14
nc5:/mpd15      3,6T  3,3T  319G  92% /nica/mpd15
nc18:/mpd16      43T   41T  2,4T  95% /nica/mpd16
nc23:/mpd17      55T   54T  376G 100% /bmndata4
nc23:/mpd18      44T   42T  1,7T  97% /bmndata5
nc23:/mpd19      44T   42T  2,1T  96% /nica/mpd19
nc23:/mpd20      44T   43T  990G  98% /nica/mpd20
tmpfs           3,2G  8,0K  3,2G   1% /run/user/3771
tmpfs           3,2G   12K  3,2G   1% /run/user/3647
tmpfs           3,2G     0  3,2G   0% /run/user/3825
tmpfs           3,2G  4,0K  3,2G   1% /run/user/3844
nc22:/spd1       44T  5,7T   38T  13% /nica/spd1
nc22:/mpd22      55T  1,4T   53T   3% /nica/mpd22
nc22:/bmn1       44T   18T   27T  40% /nica/bmn1
tmpfs           3,2G     0  3,2G   0% /run/user/3721
tmpfs           3,2G  8,0K  3,2G   1% /run/user/3726
[geraks@nc8 mpd]$
```

Reconstructed Decays in 10 p_T bins



Reconstructed Decays in 10 p_T bins



Reconstructed Decays in 10 p_T bins