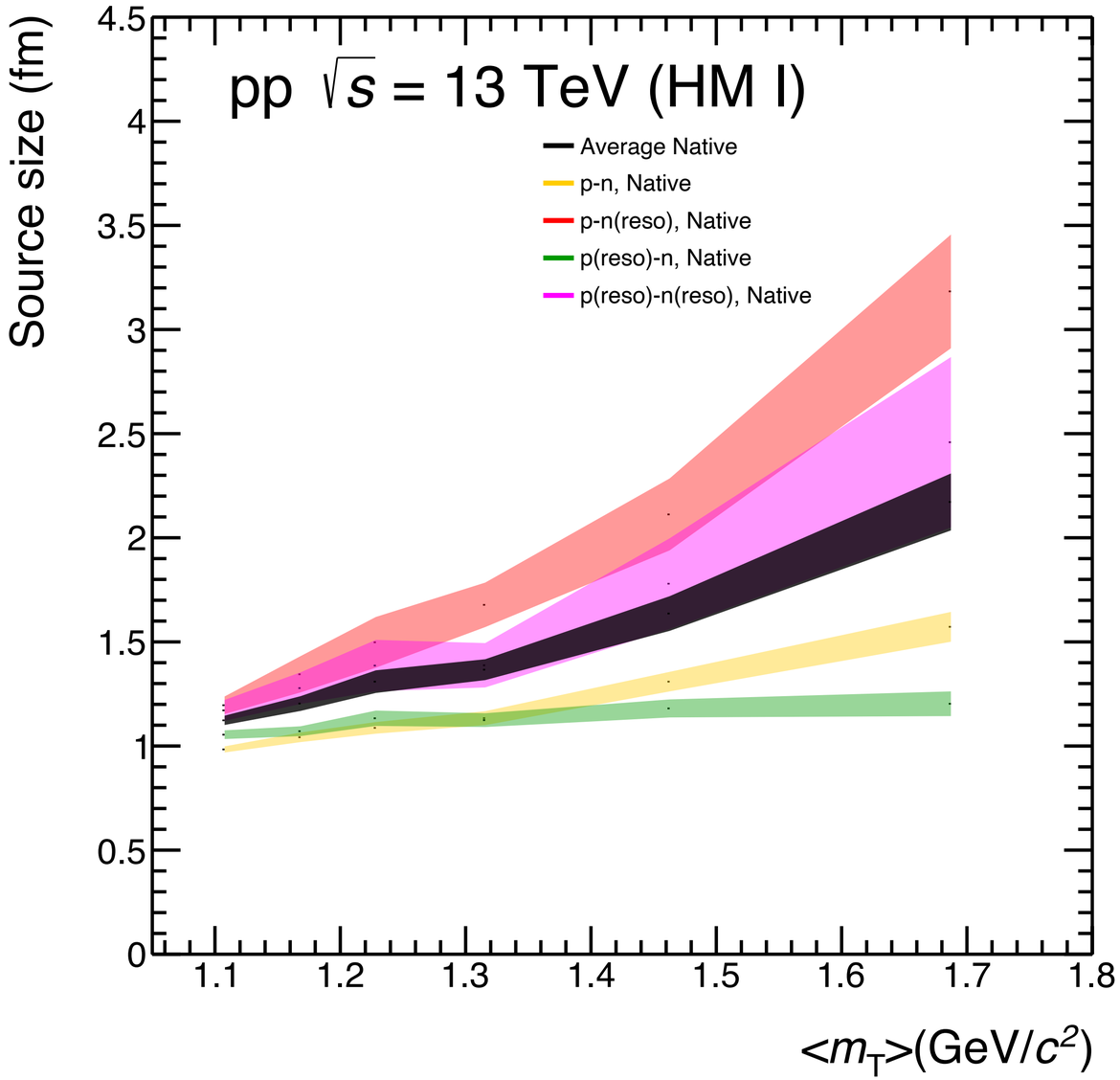
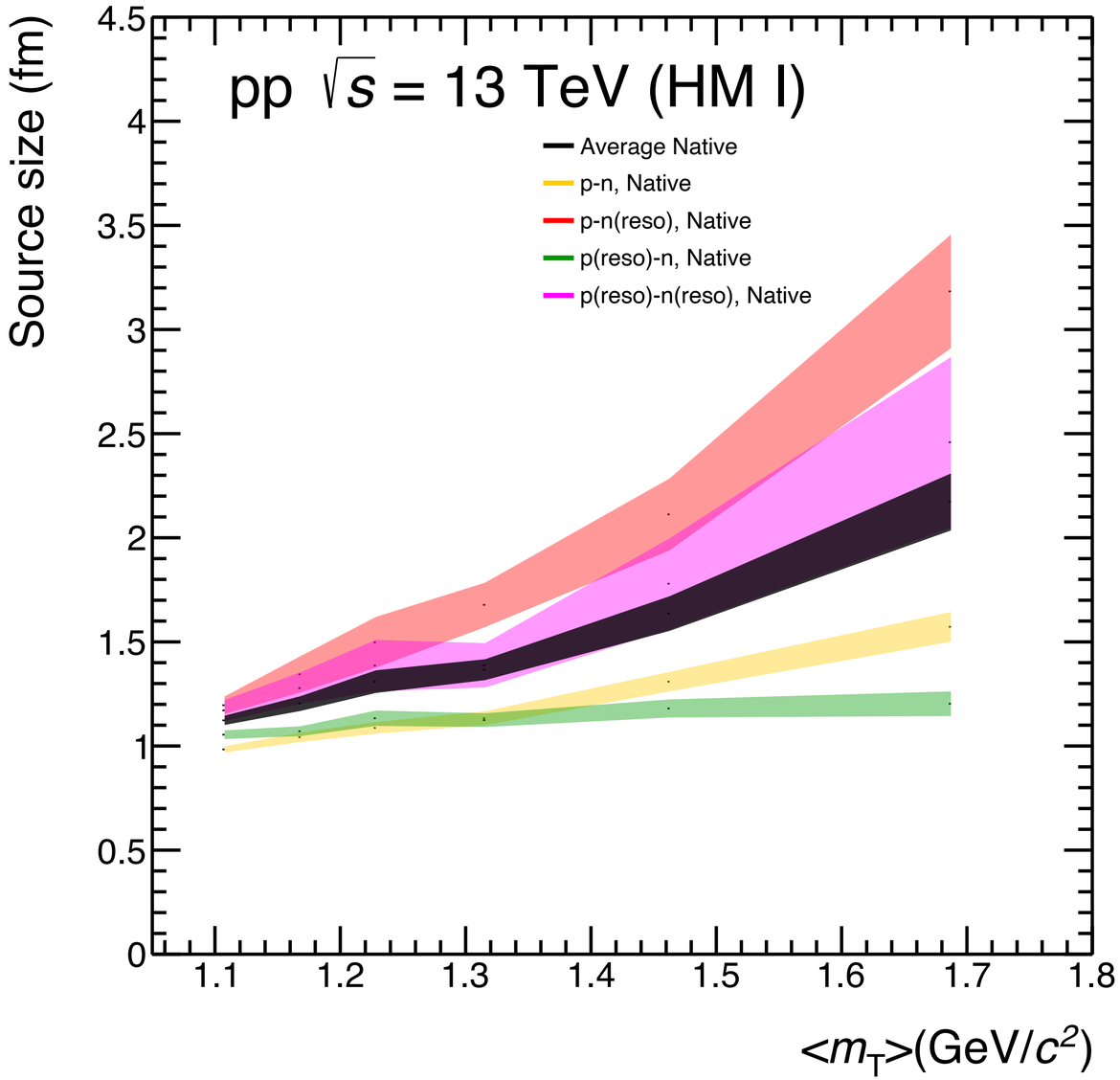
A closer look at source size

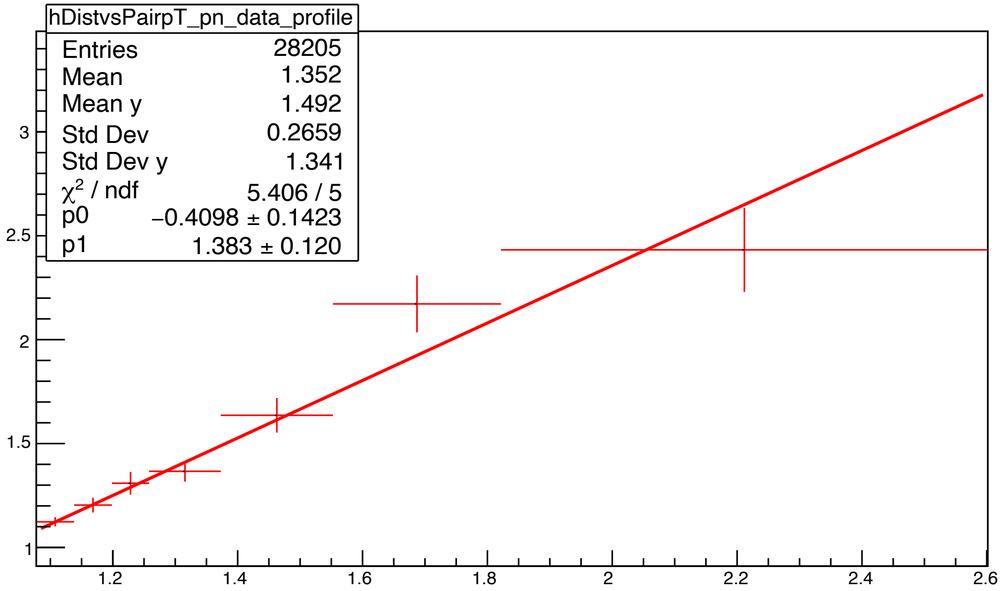


Native Pythia

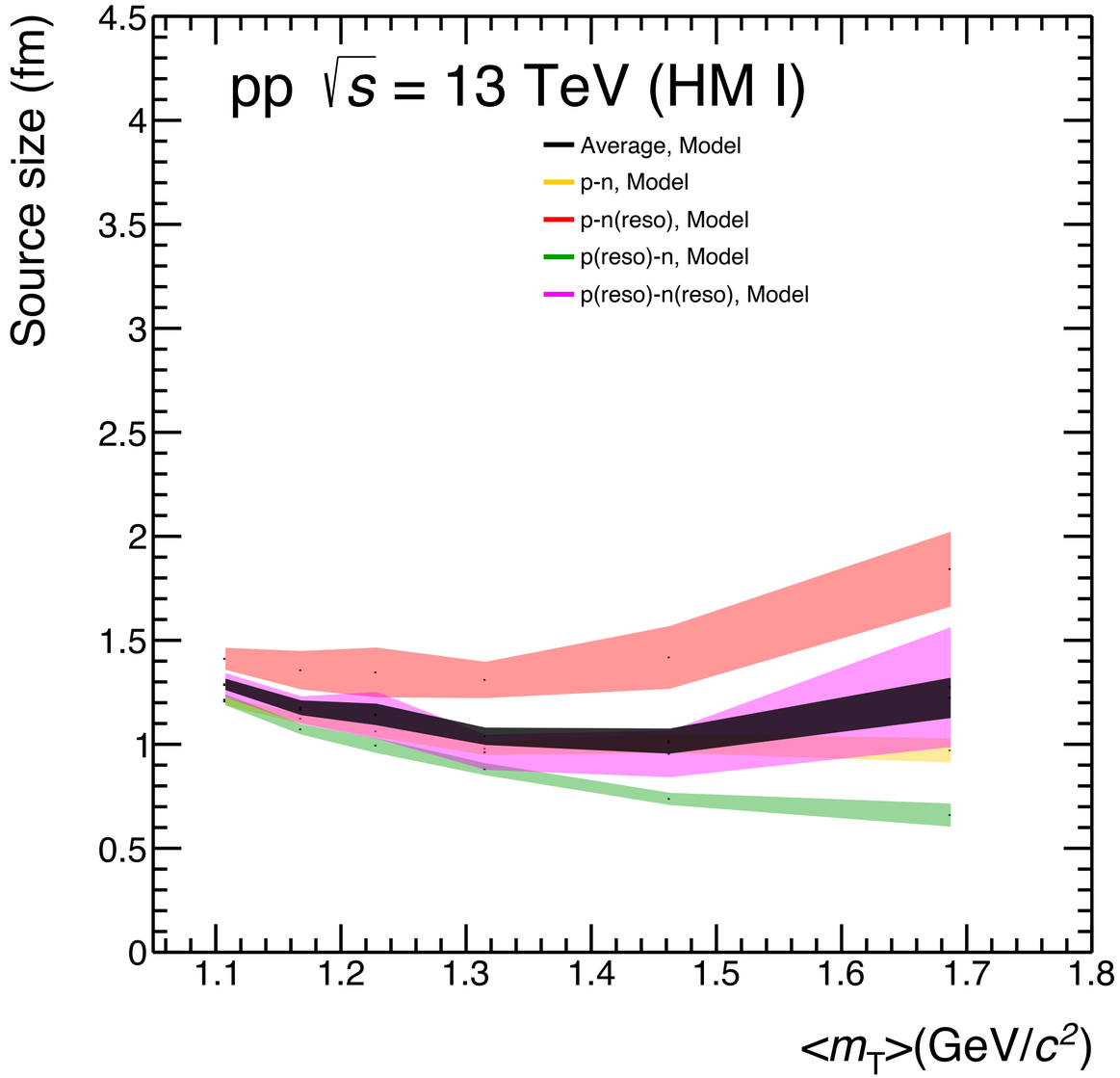
(after modified resonance weight)

A closer look at source size





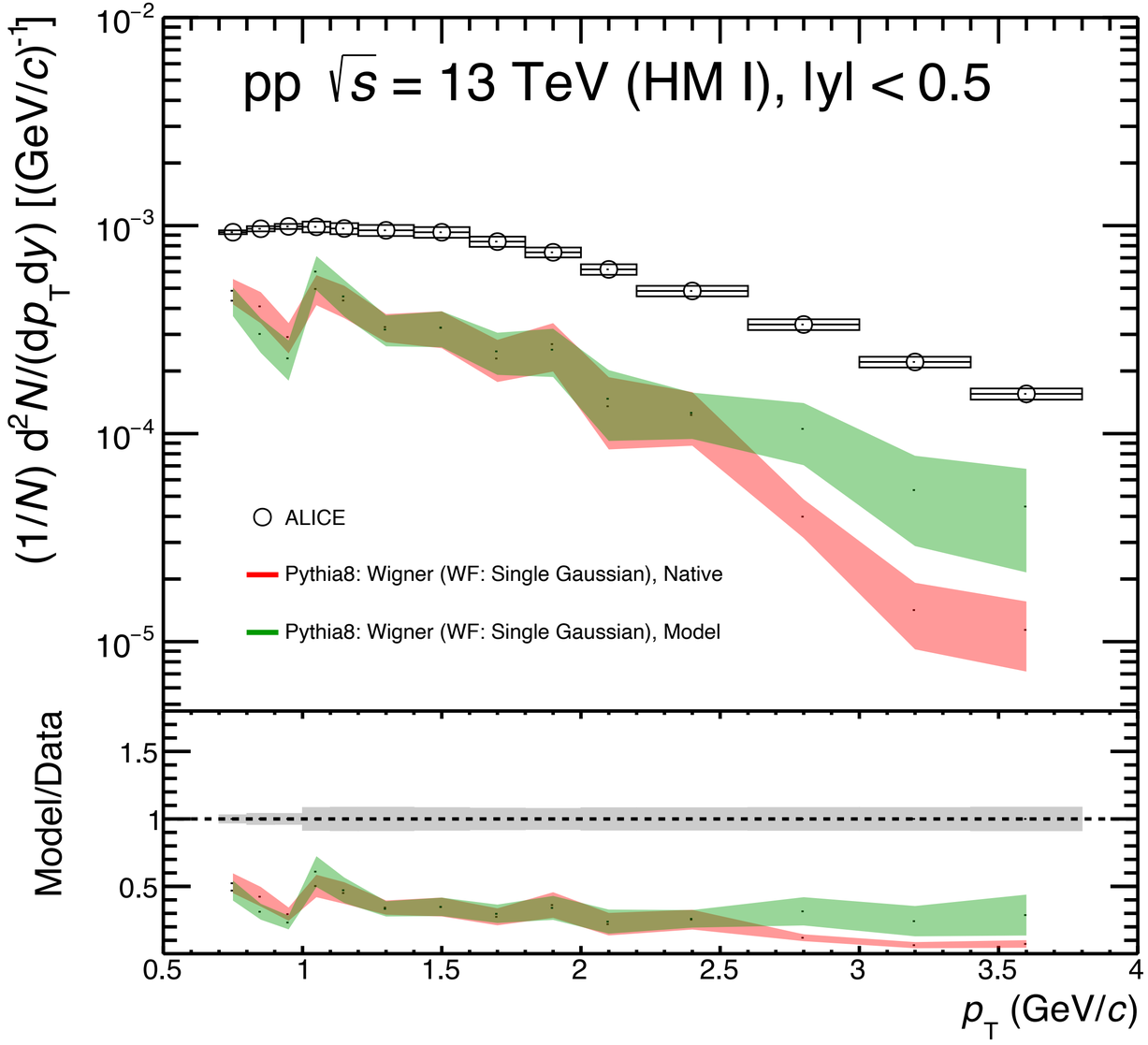
A closer look at source size



From Source model

Deuteron spectra

pp, 13 TeV (HM)



10B MB events

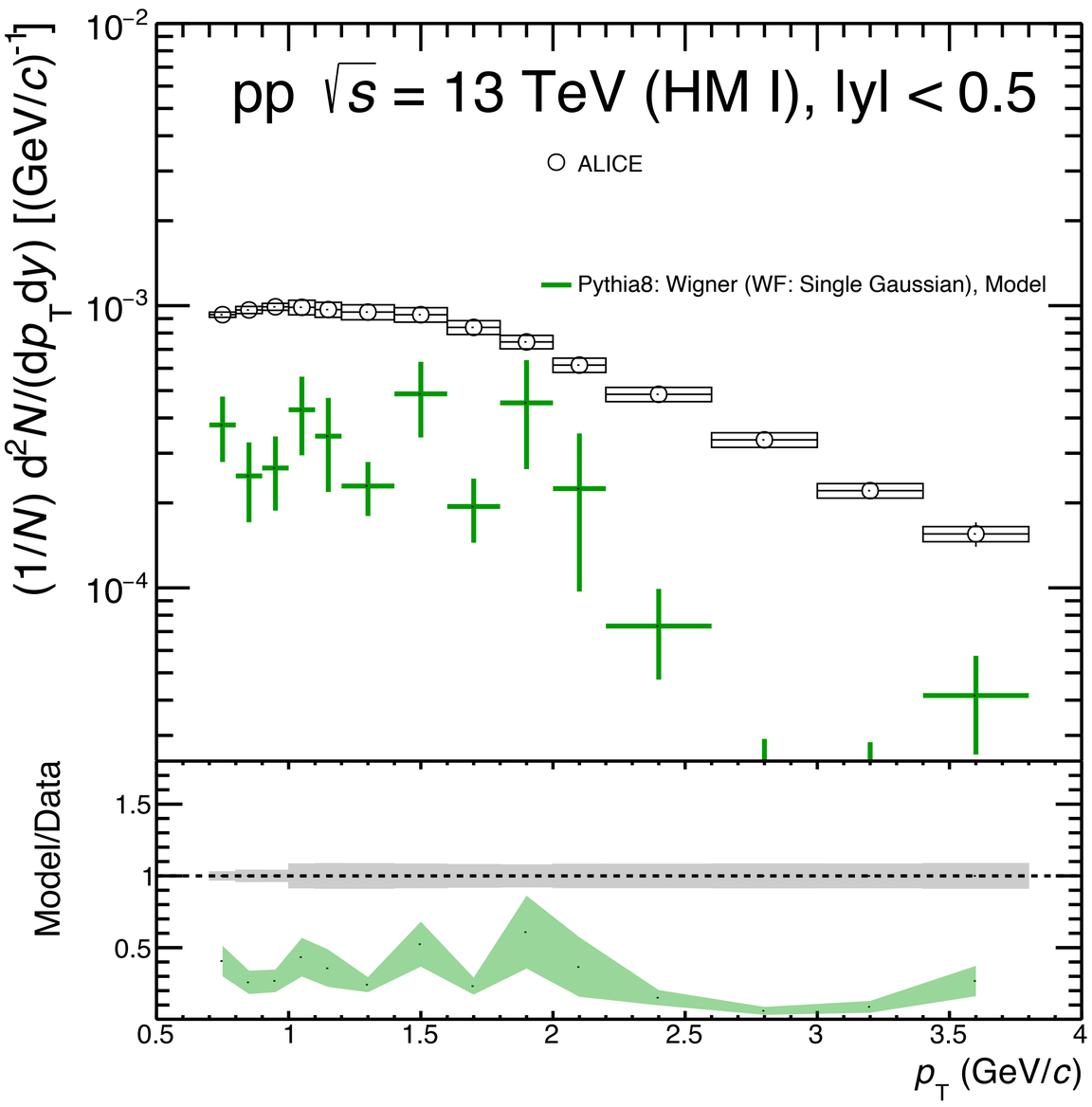
~ 500K HM events

- A criterion is implemented to ensure that nucleons are only used once for coalescence (removal of possible double counting), not a major effect!
  p + n -> p + n(reso) -> p(reso) + n -> p(reso) + n(reso)

- In Pythia, protons and neutrons have different weights of primordials (although they have similar inclusive numbers, Pythia generates more primordial neutrons compared to primordial protons).
  Primordial fraction p: 66.12%
  Resonance fraction p: 33.88%
  Primordial fraction n: 83.06%
  Resonance fraction n: 16.94%

Backup

Deuteron spectra



- A criterion is implemented to ensure that nucleons are only used once for coalescence (removal of possible double counting), not a major effect!
  p + n -> p + n(reso) -> p(reso) + n -> p(reso) + n(reso)

- In Pythia, protons and neutrons have different weights of primordials (although they have similar inclusive numbers, Pythia generates more primordial neutrons compared to primordial protons).
  Primordial fraction p: 66.12%
  Resonance fraction p: 33.88%
  Primordial fraction n: 83.06%
  Resonance fraction n: 16.94%

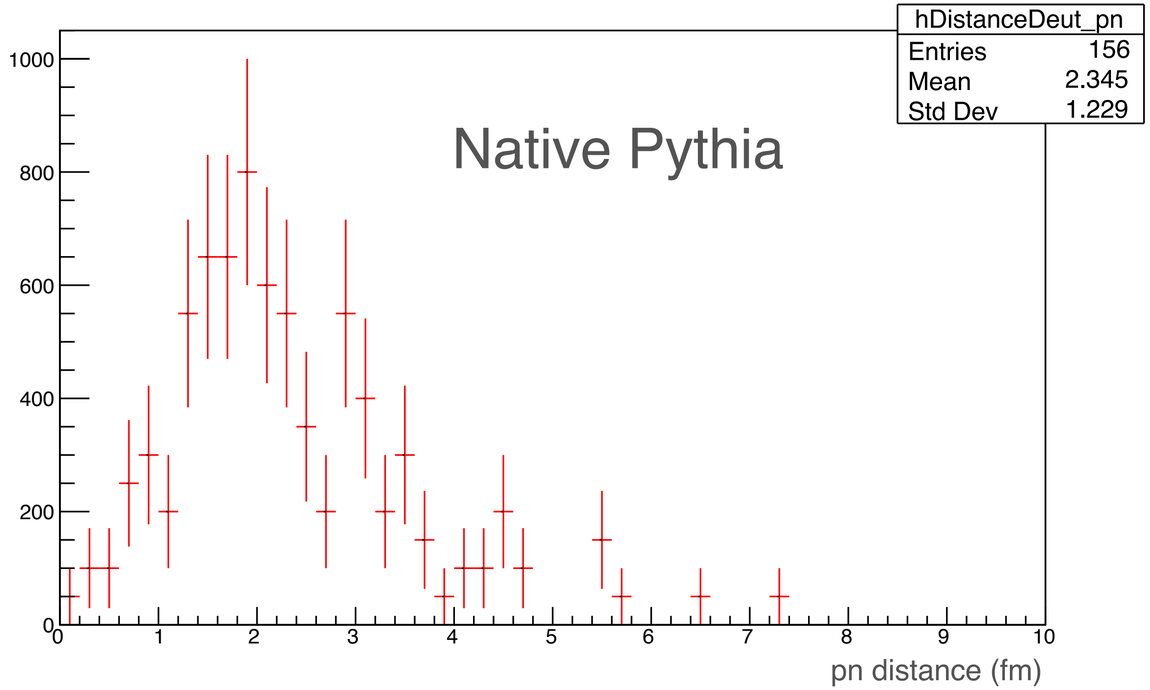
- Tested with limited statistics

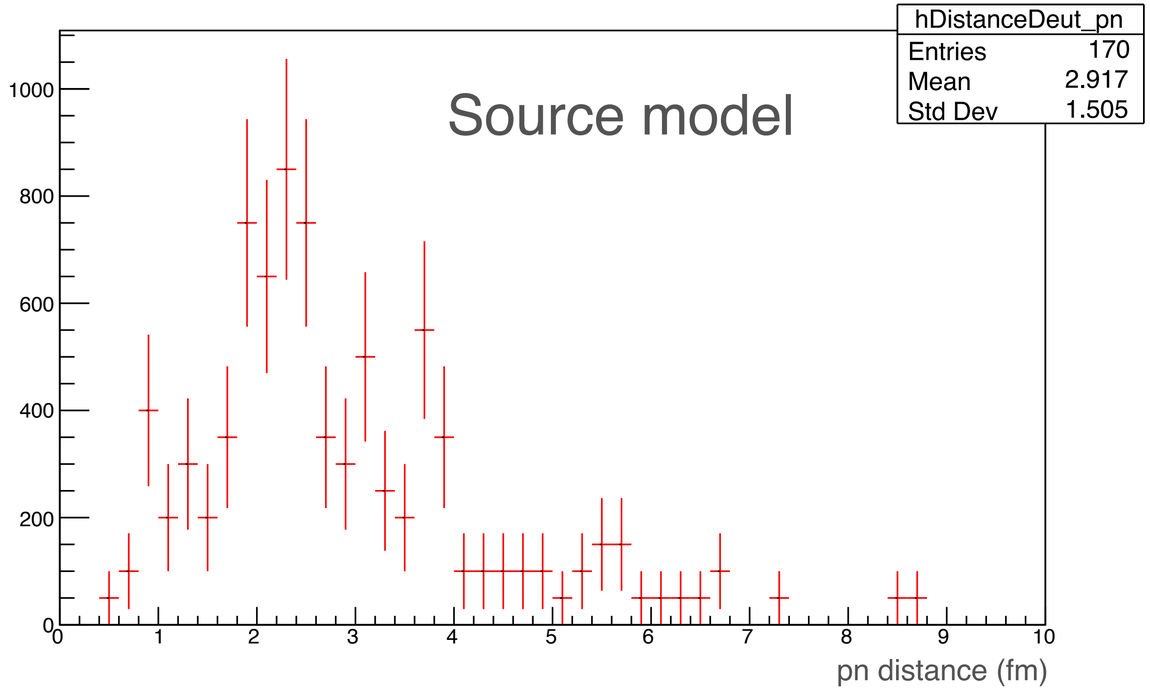
- Possible source of systematics?

pn distance distributions

pp, 13 TeV (HM)

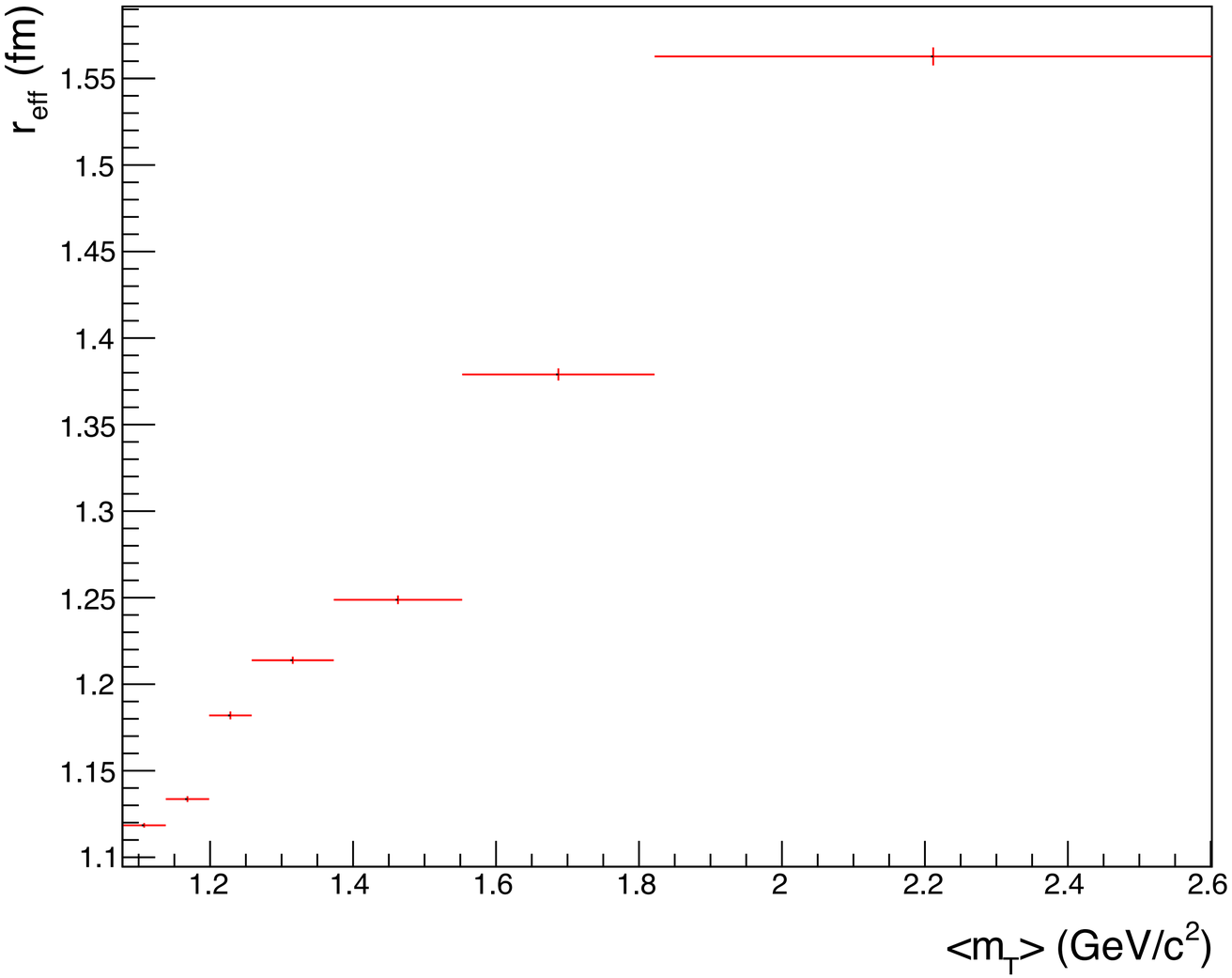
First m_T bin



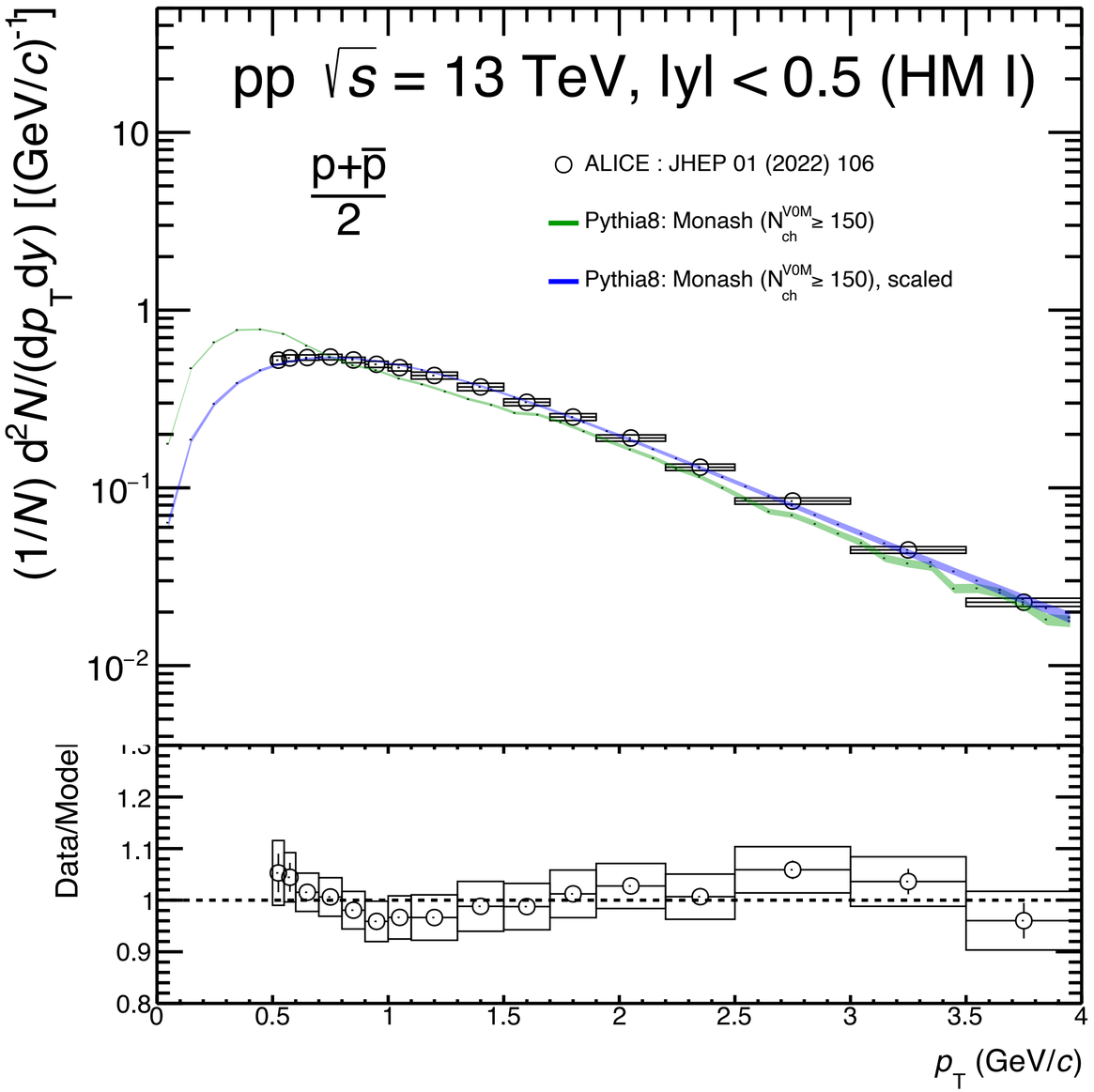


Source size (Pythia)

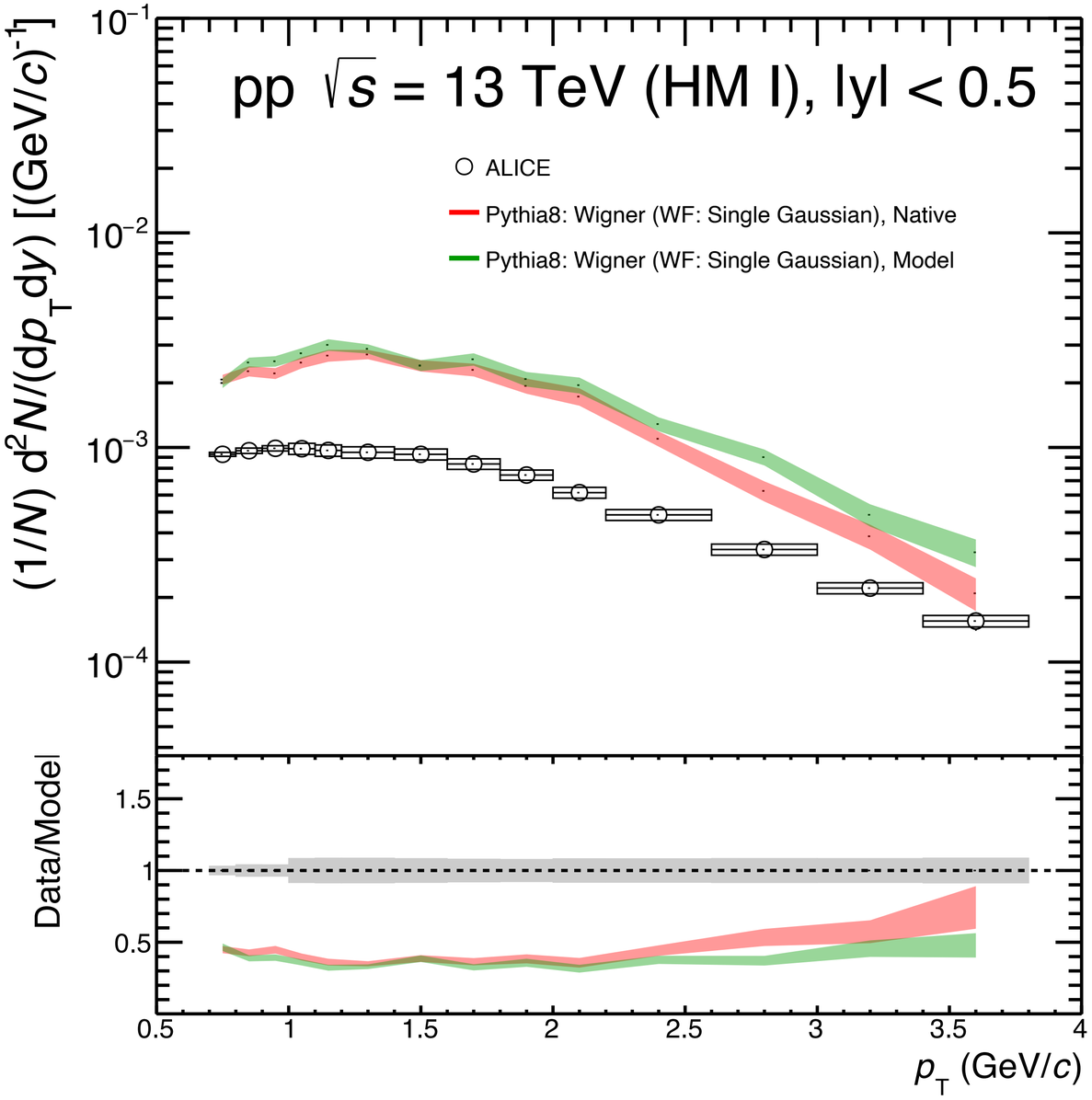
pp, 13 TeV (HM)



Proton spectra

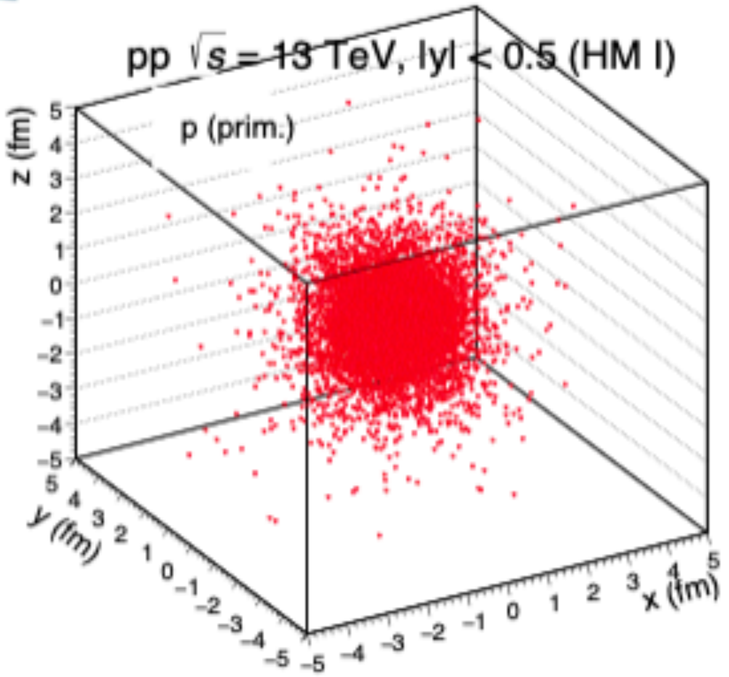


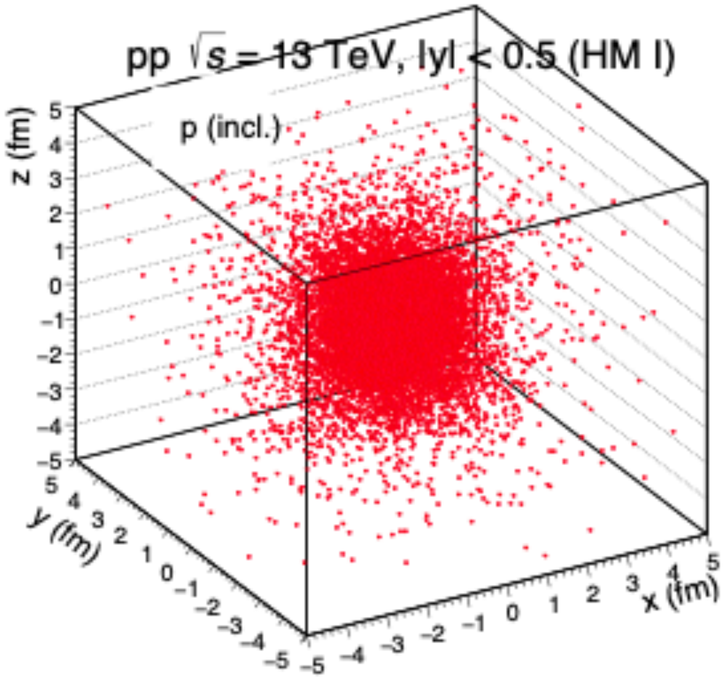
Deuteron spectra

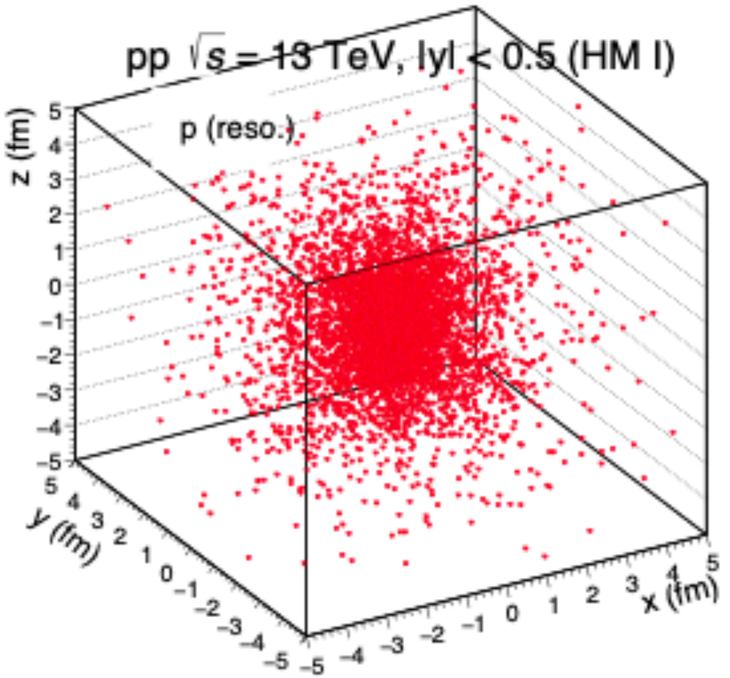


Spatial info from Pythia8 (protons)

pp, 13 TeV (HM)

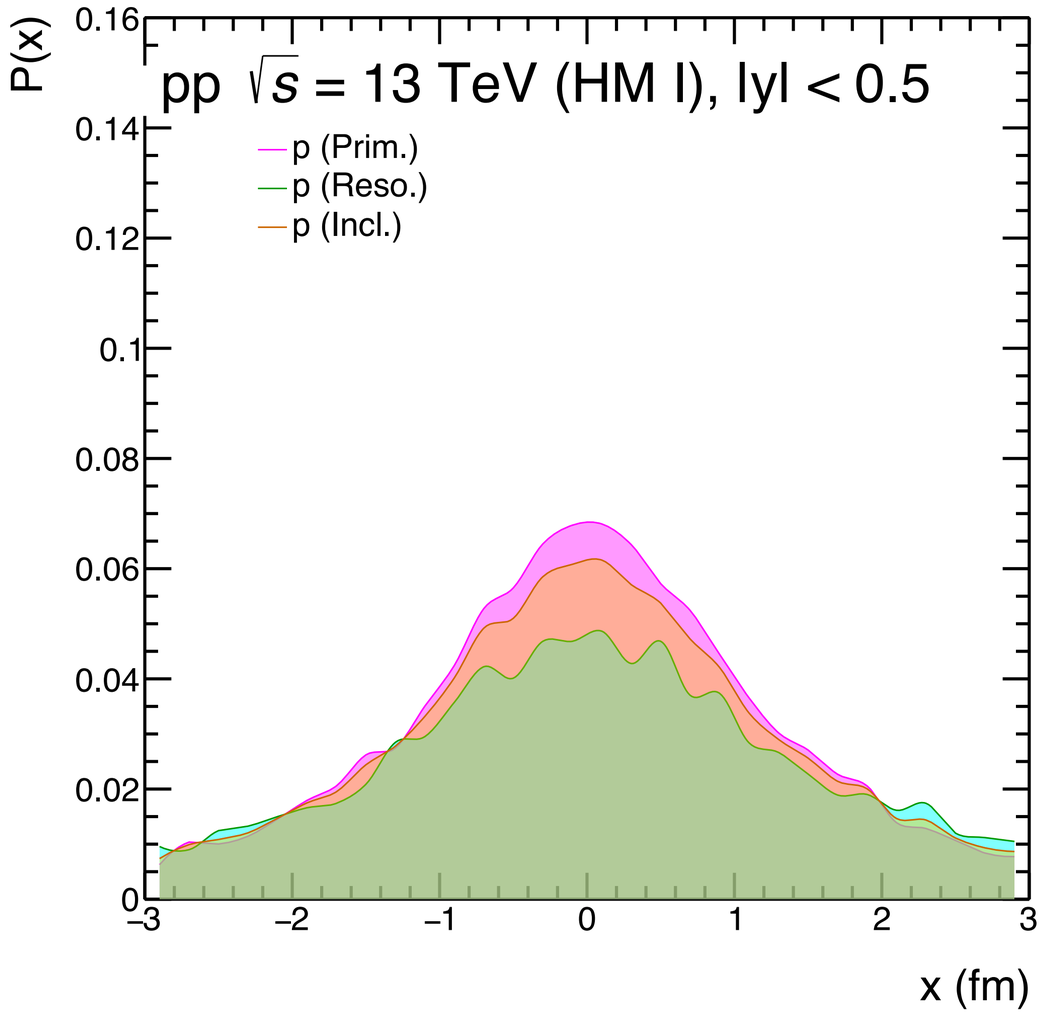


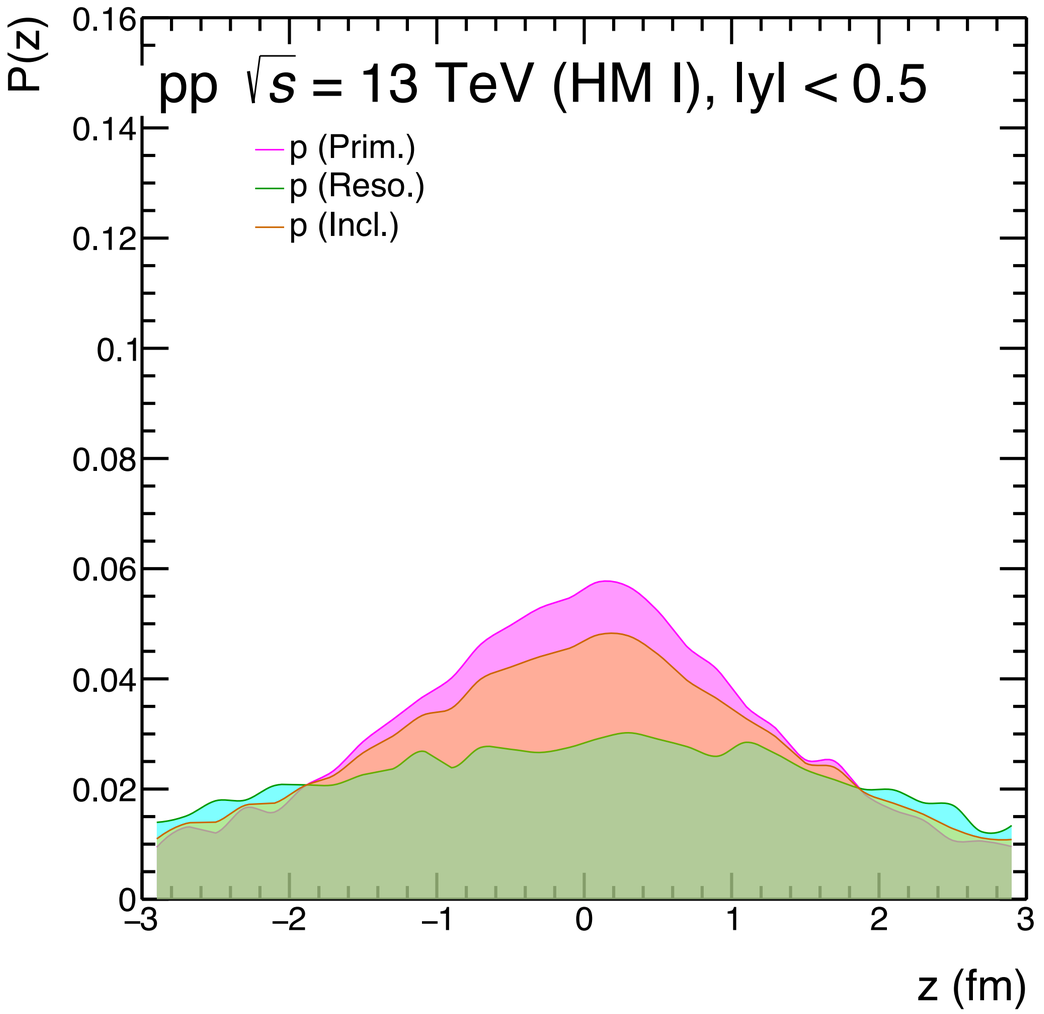




- The plots are in lab frame and coordinates represent the production coordinates of protons

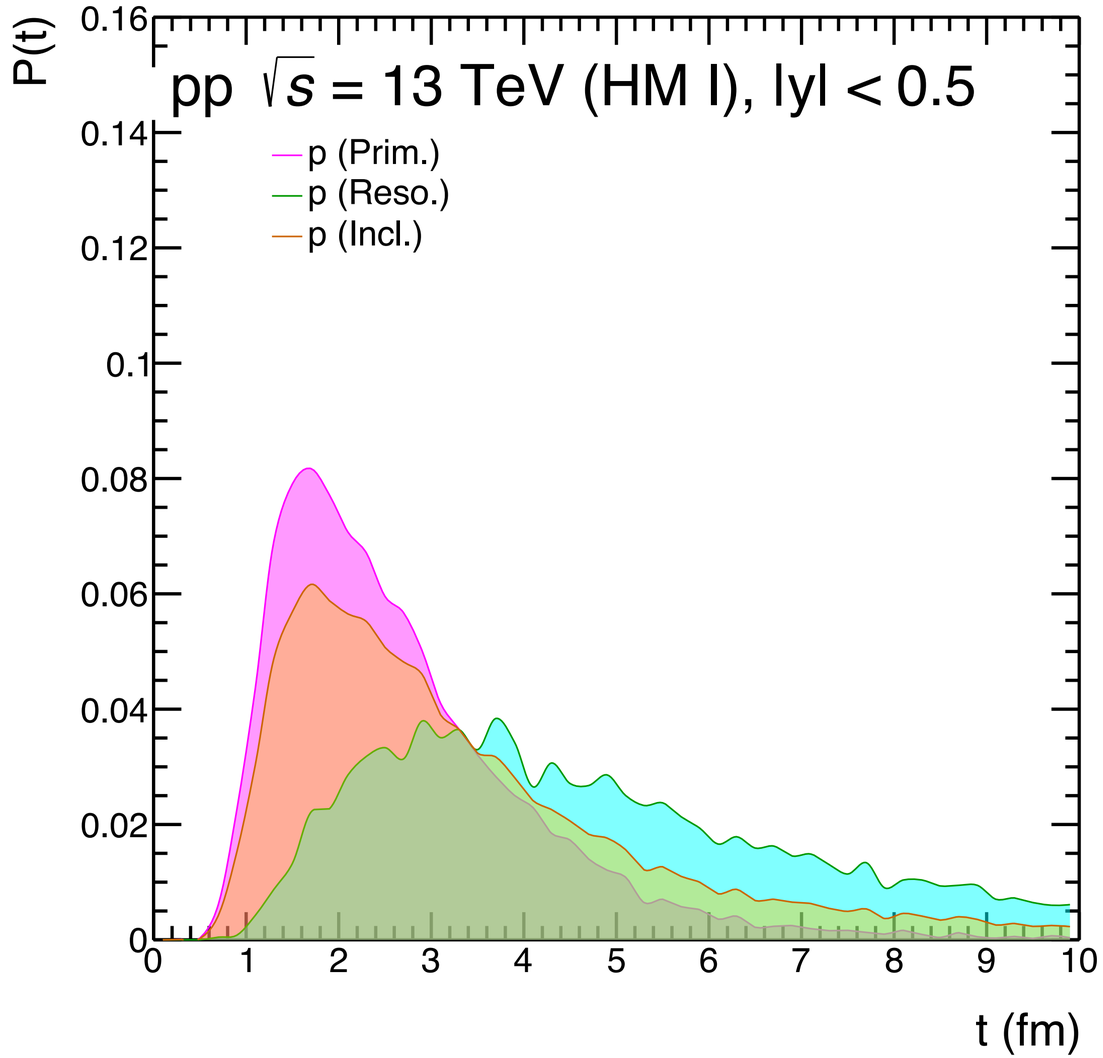
Spatial info from Pythia8



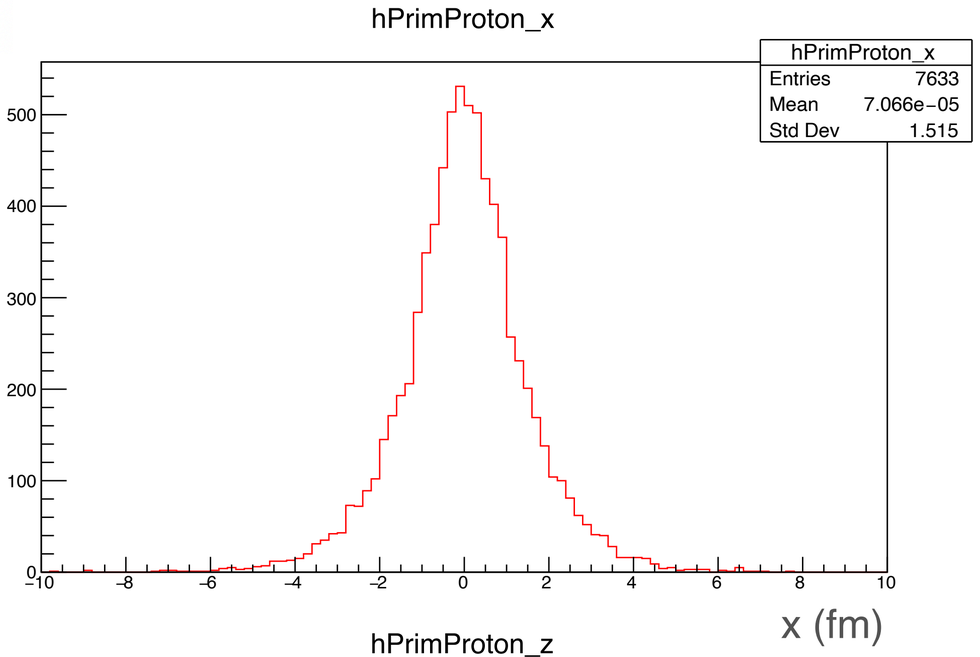


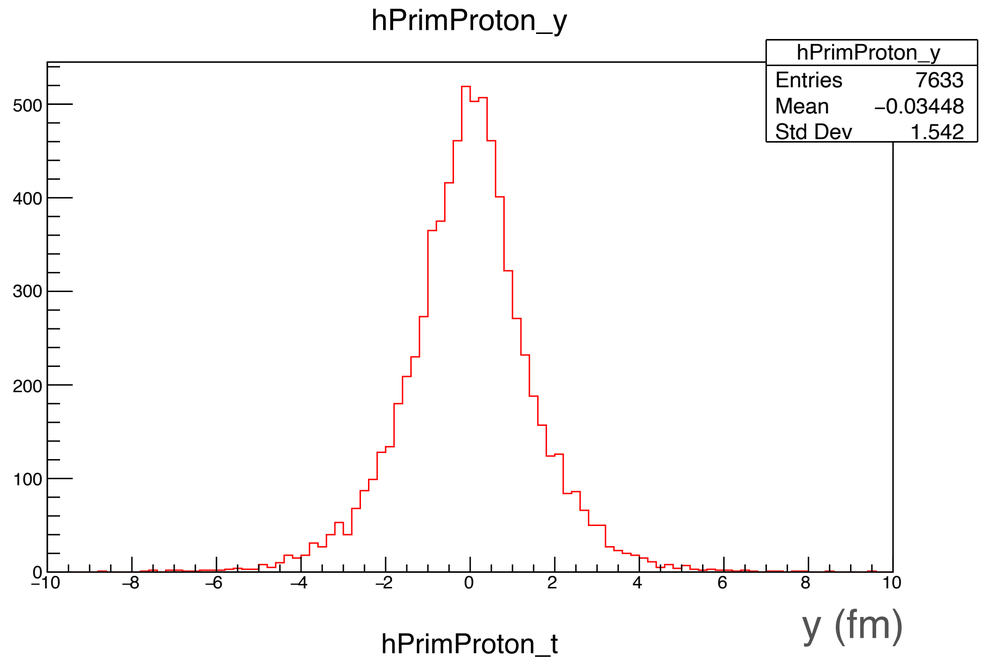
Formation time info from Pythia8

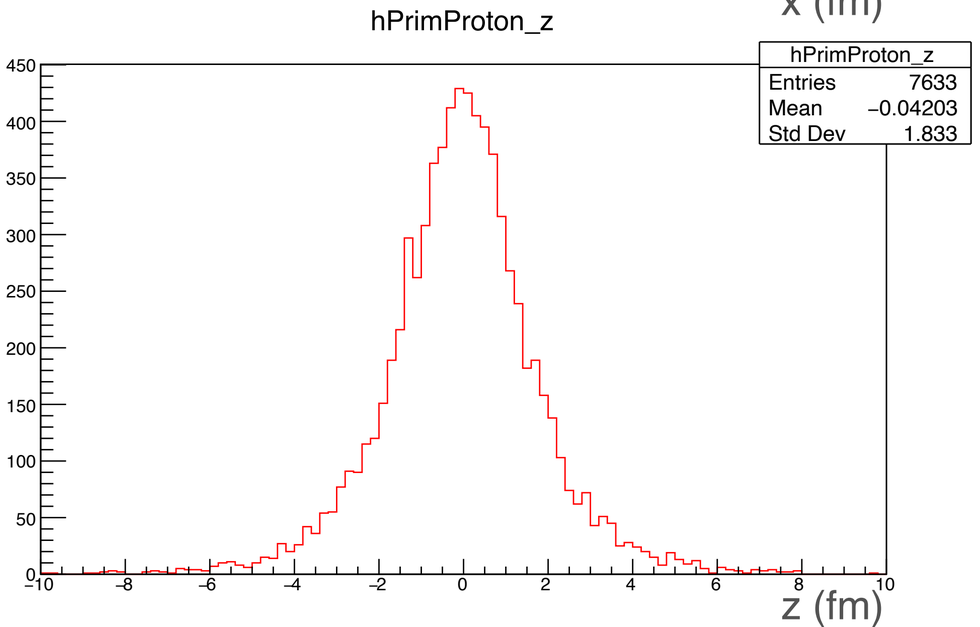
pp, 13 TeV (HM)

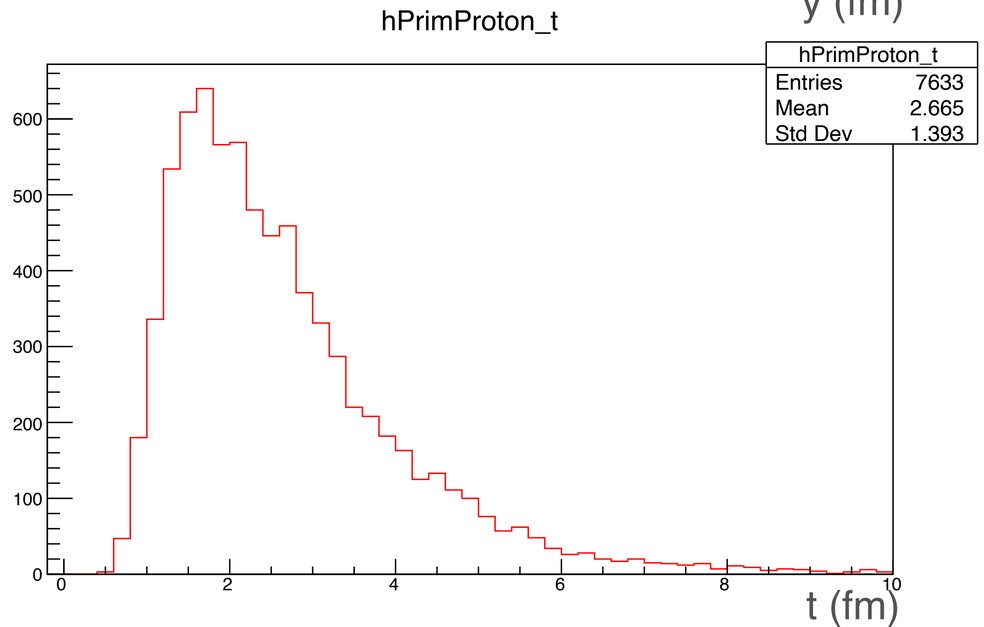


Spatial info from Pythia8 (primordials) pp, 13 TeV (HM)

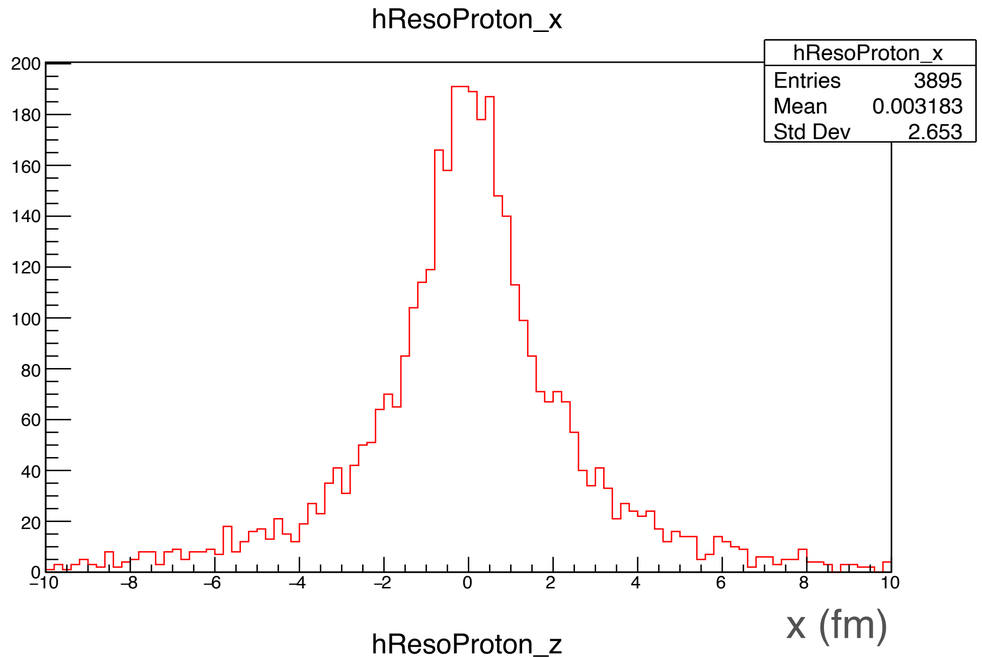


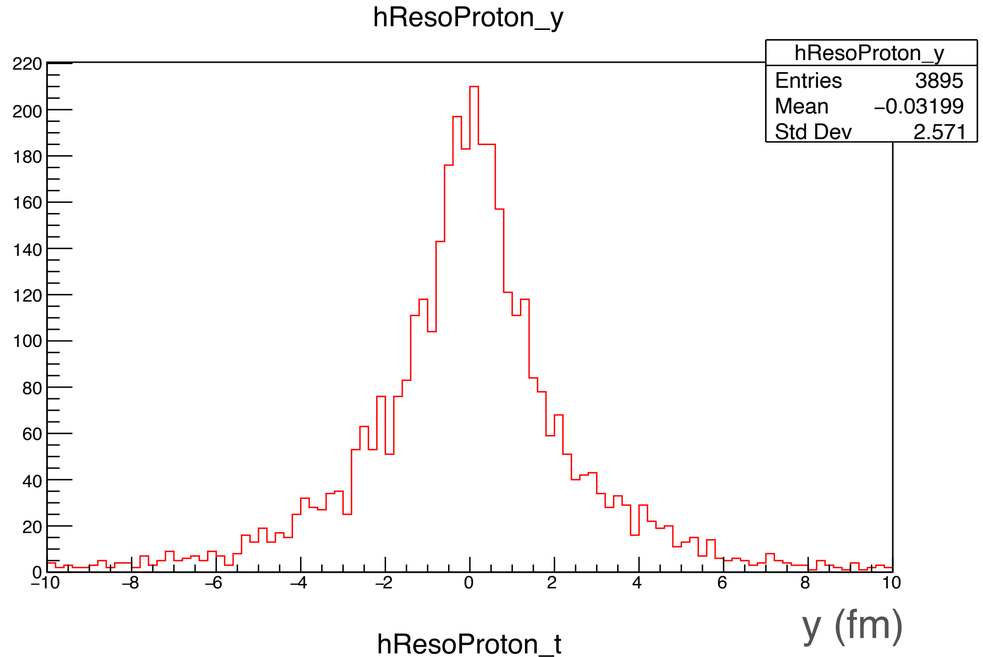


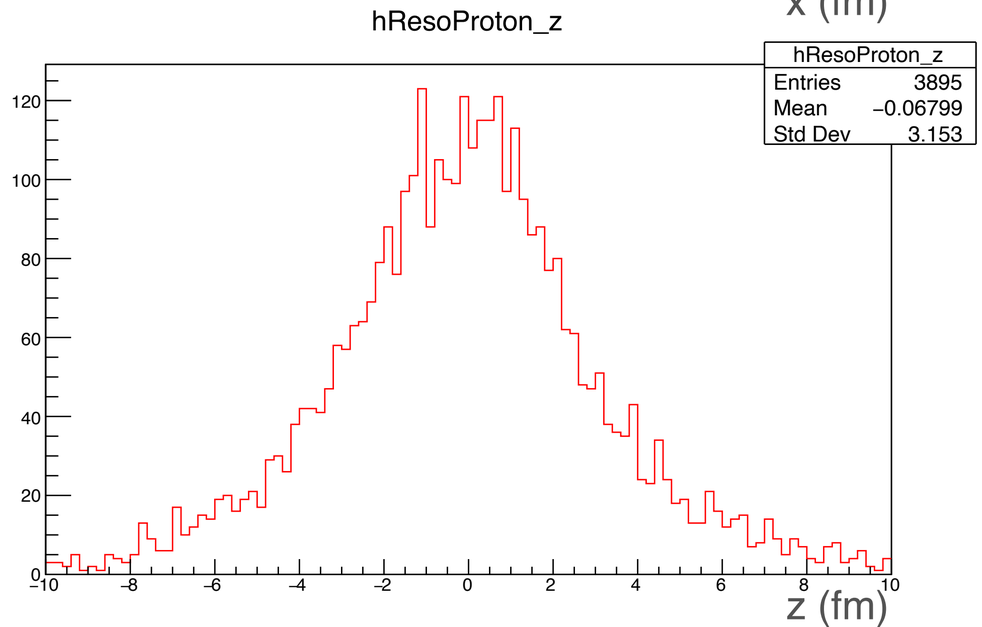


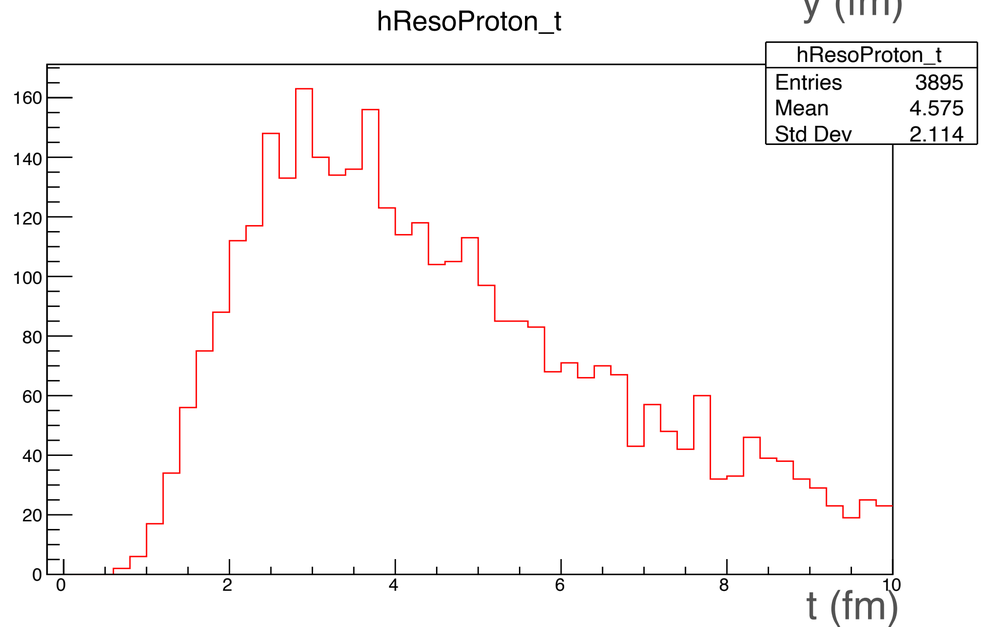


Spatial info from Pythia8 (resonances) pp, 13 TeV (HM)



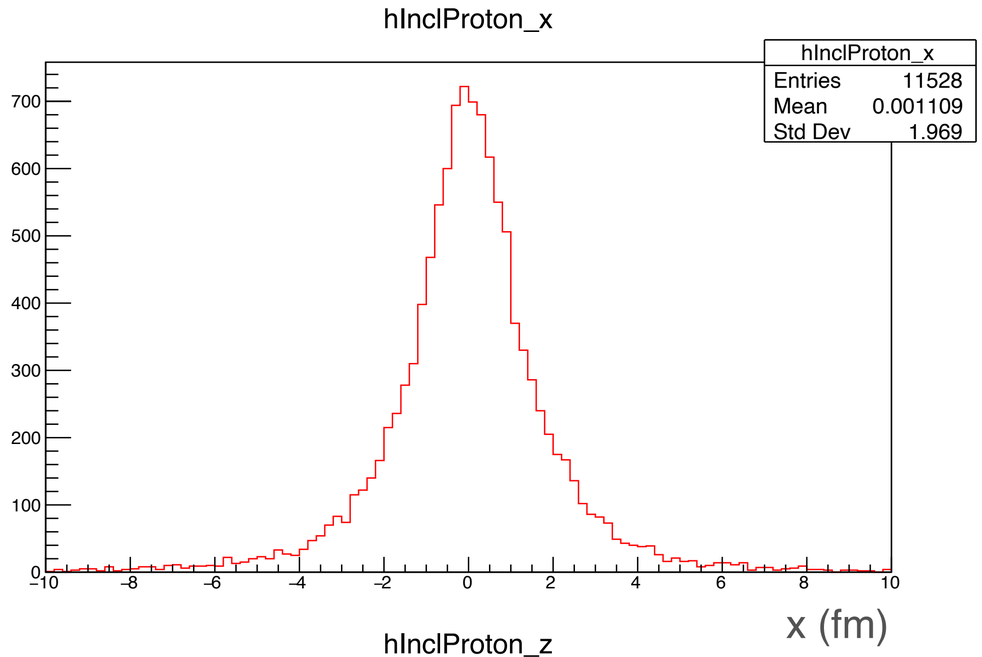


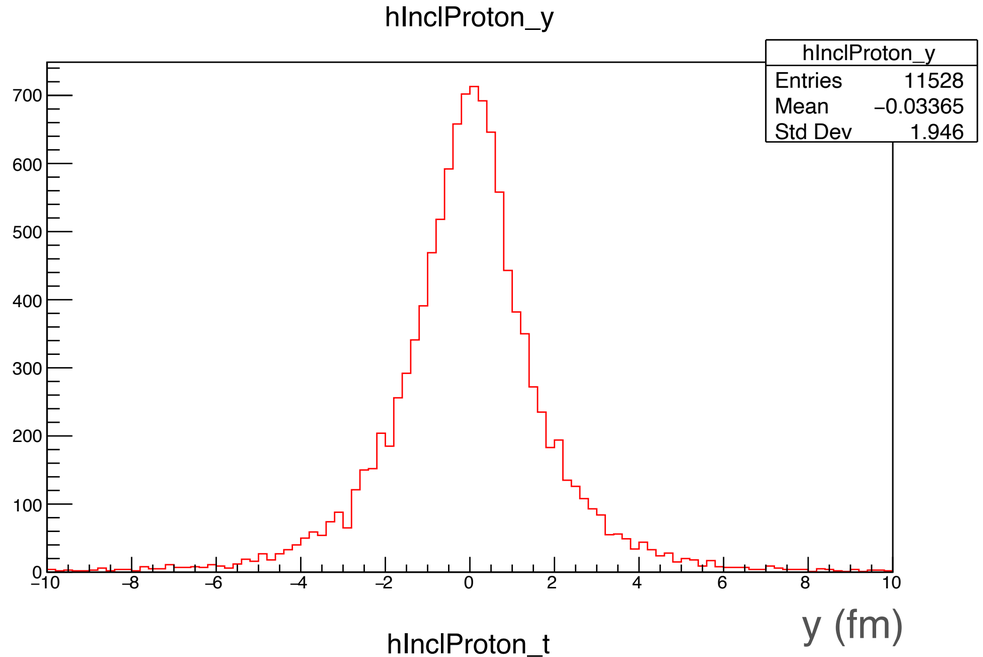


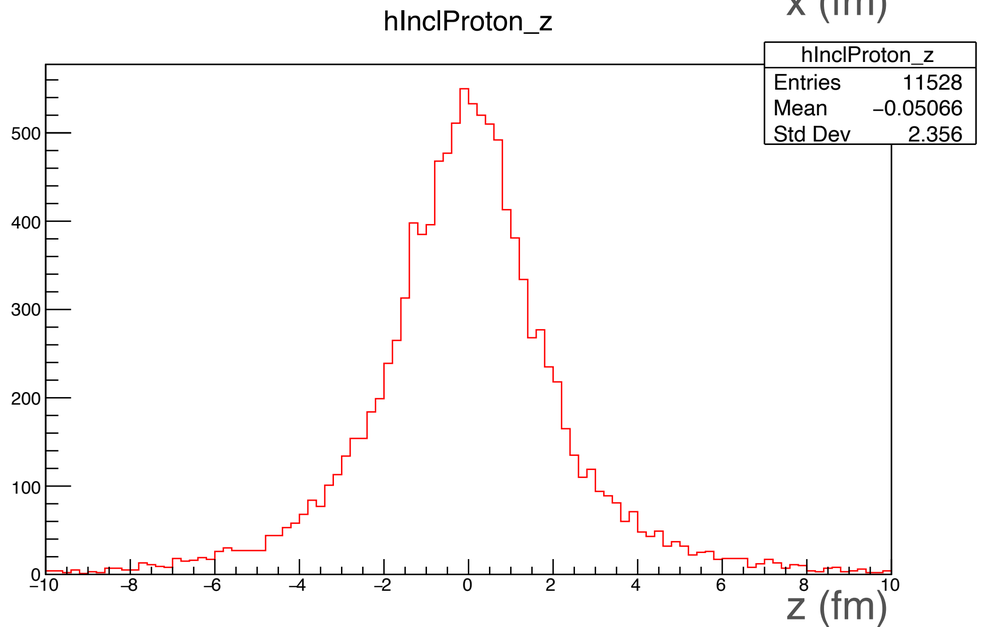


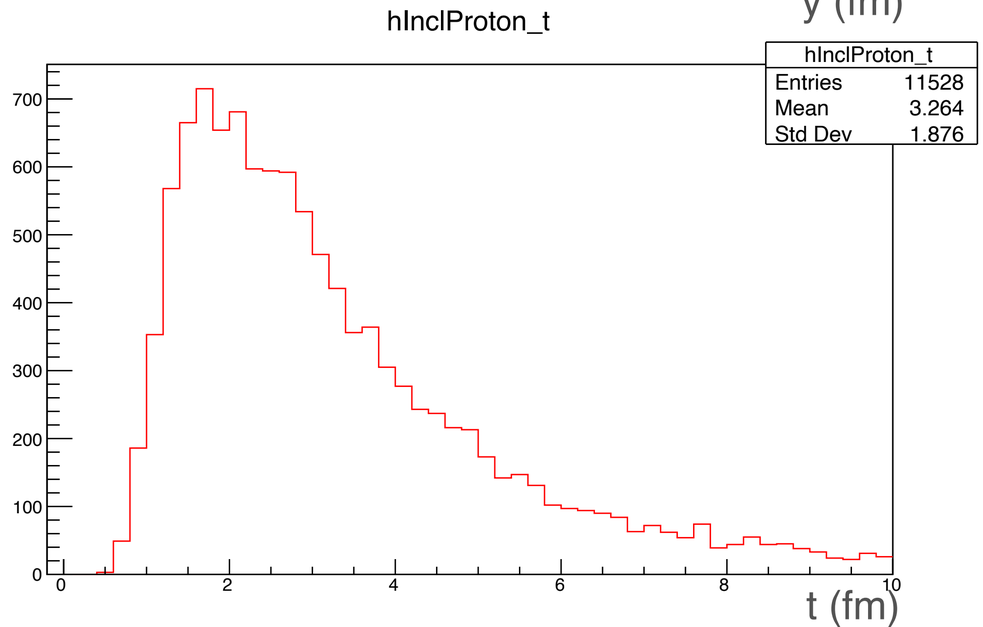
Spatial info from Pythia8 (inclusive)

pp, 13 TeV (HM)

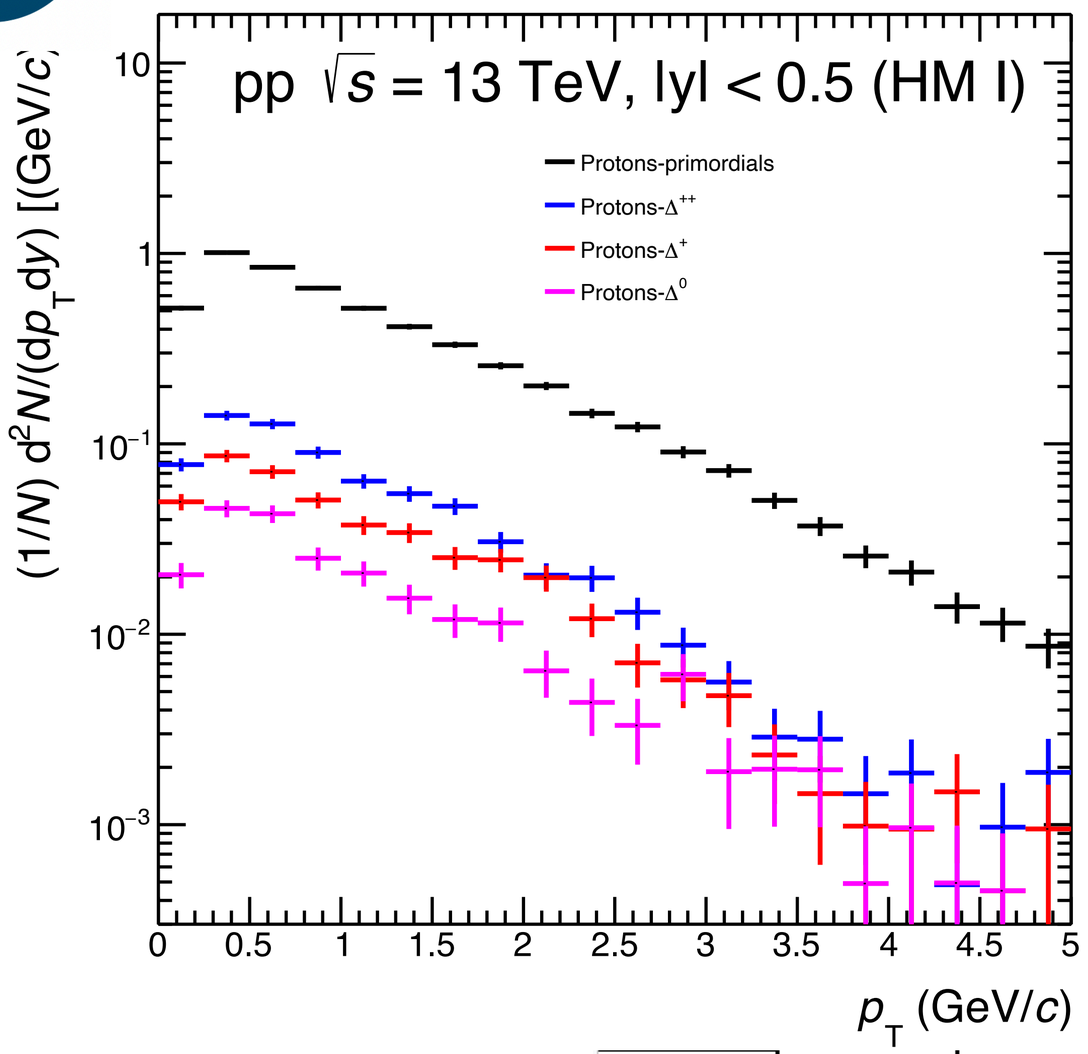


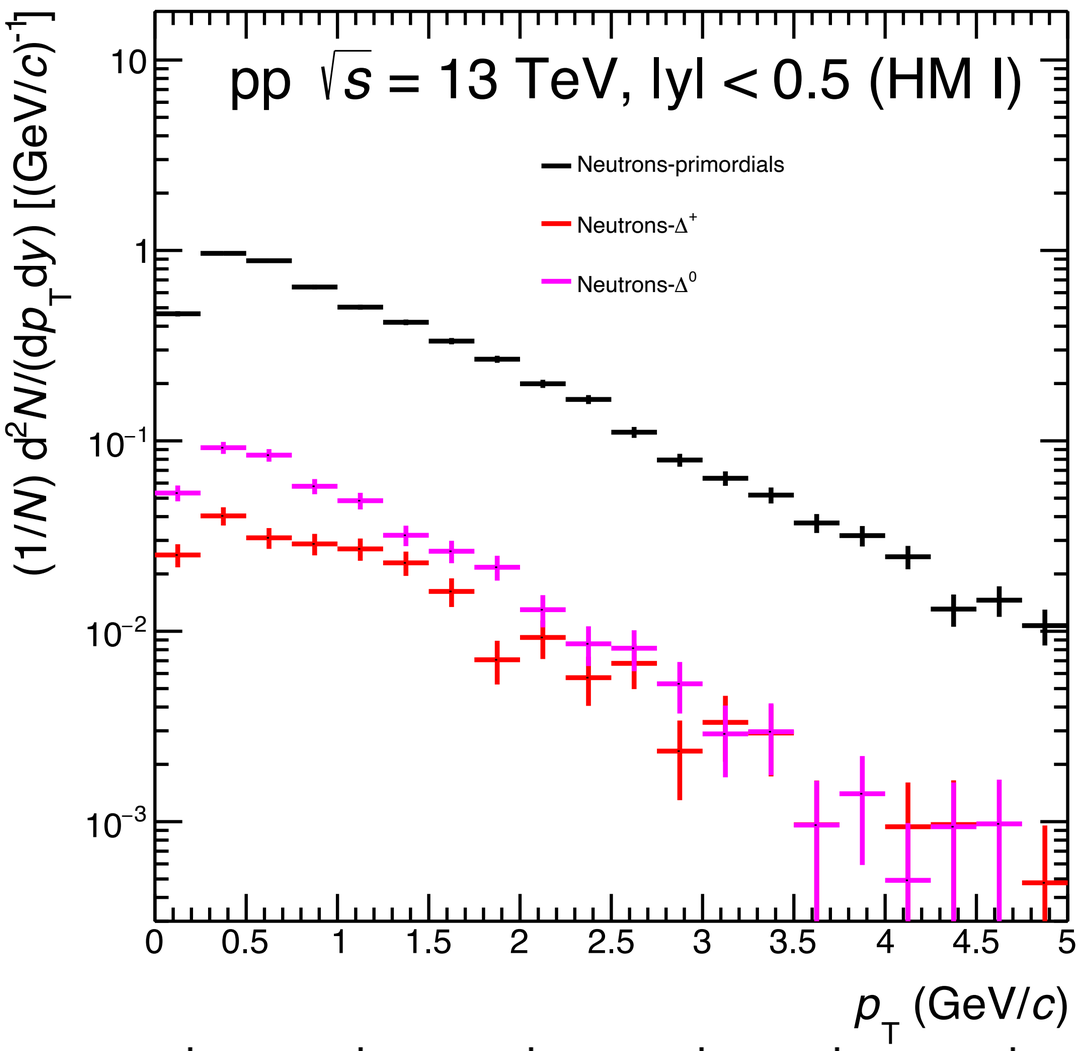






Resonance cocktail





- Primordial fraction: 83.3%

FIST States	PDG IDs	Fraction EPOS (HM)	Fraction PYTHIA (HM)	Fraction FIST	Fist combined	correction	Width	Lifetime[s]	cT[fm]
Δ++(1232)	2224	16.47090041	8.75	11.47830	11.47830	0.69688	117	5.63E-24	1.69
Δ+(1232)	2214	8.089509995	5.39	7.99444	7.99444	0.98825	117	5.63E-24	1.69
Δ0(1232)	2114	4.358747568	2.74	3.99245	3.99245	0.91596	117	5.63E-24	1.69

Resonance cocktail

A	B	C	D	E	F	G	H	I	J	K	L	M
Δ++(1232)	2224	16.47090041	8.75	11.47830	11.47830	0.69688	117	5.63E-24	1.69	57.742365	<1fm	9311
Δ+(1232)	2214	8.089509995	5.39	7.99444	7.99444	0.98825	117	5.63E-24	1.69	Primordial	1-2fm	4573
Δ0(1232)	2114	4.358747568	2.74	3.99245	3.99245	0.91596	117	5.63E-24	1.69	35.4234	>2fm	2464
Δ++(1600)	32224	4.054484345		2.14039	3.05908	0.75449	250	2.63E-24	0.79	Total account		2292
Δ++(1620)	2222			0.91869			130	5.06E-24	1.52	93.165765		
Δ+(1600)	32214	1.827348311		1.60939	2.29064	1.25353	250	2.63E-24	0.79	totalProtonsEPOS		1033
Δ+(1620)	2122			0.68125			130	5.06E-24	1.52	56530		
D0(1600)	32114	1.46117106		0.99317	1.40203	0.95952	250	2.63E-24	0.79	EPOS Res		826
D0(1620)	1212			0.40886			130	5.06E-24	1.52	66.89014682		
Δ-(1600)	31114			0.36348	0.49502		250	2.63E-24	0.79	Prim EPOS		
Δ-(1620)	1112			0.13154			130	5.06E-24	1.52	28.70157439		
Δ++(1700)	12224	1.954714311		1.33647	1.33647	0.68372	300	2.19E-24	0.66	EPOS tot		1105
Δ+(1700)	12214	0.5943746683		0.95444	0.95444	1.60579	300	2.19E-24	0.66	95.59172121		336
Δ0(1700)	12114	0.4917742791		0.52138	0.52138	1.06020	300	2.19E-24	0.66			278
N+(1440)	12212	2.085618256		1.17910	1.17910	0.56535	350	1.88E-24	0.56	PrimCorr		1179
N0(1440)	12112	4.287988679		0.97805	0.97805	0.22809	350	1.88E-24	0.56	1.234197104		2424
N+(1520)	2124	2.306739784		1.73877	2.88020	1.24860	110	5.98E-24	1.80			1304
N+(1535)	22212			1.14143			150	4.39E-24	1.32			
N0(1520)	1214	2.457102423		2.04106	2.57755	1.04902	110	5.98E-24	1.80			1389
N0(1535)	22112			0.53649			150	4.39E-24	1.32			
N+(1650)	32212	1.505395365		0.53649	3.08116	2.04674	125	5.27E-24	1.58			851
N+(1675)	2216			1.38066			145	4.54E-24	1.36			
N+(1680)	12216			1.16401			120	5.49E-24	1.65			
N0(1650)	32112	1.692906421		0.47099	2.46515	1.45616	125	5.27E-24	1.58			957
N0(1675)	2116			0.92028			145	4.54E-24	1.36			
N0(1680)	12116			1.07388			120	5.49E-24	1.65			
N+(1700)	22124	2.032549089		1.09345	2.47763	1.21897	200	3.29E-24	0.99			1149
N+(1710)	42212			0.38374			140	4.70E-24	1.41			
N+(1720)	32124			1.00044			250	2.63E-24	0.79			
N0(1700)	21214	1.975941978		0.32142	0.78378	0.39666	200	3.29E-24	0.99			1117
N0(1710)	42112			0.19967			140	4.70E-24	1.41	dominates		
N0(1720)	31214			0.26269			250	2.63E-24	0.79			

From Maxi

Resonance cocktail

particle: id="112212" name="Delta(1620)+" antiName="Delta(1620)bar-" spinType="2" chargeType="3" colType="0" m0="1.630" mWidth="0.140" mMin="1.25" mMax="2.31" varWidth="on"
channel: onMode="1" bRatio="0.102041" meMode="3" products="2112 211"
channel: onMode="1" bRatio="0.204082" meMode="3" products="2212 111"
channel: onMode="1" bRatio="0.337415" meMode="5" products="2114 211"
channel: onMode="1" bRatio="0.042177" meMode="5" products="2214 111"
channel: onMode="1" bRatio="0.253061" meMode="5" products="2224 -211"
channel: onMode="1" bRatio="0.020408" meMode="3" products="202112 211"
channel: onMode="1" bRatio="0.040816" meMode="3" products="202212 111"

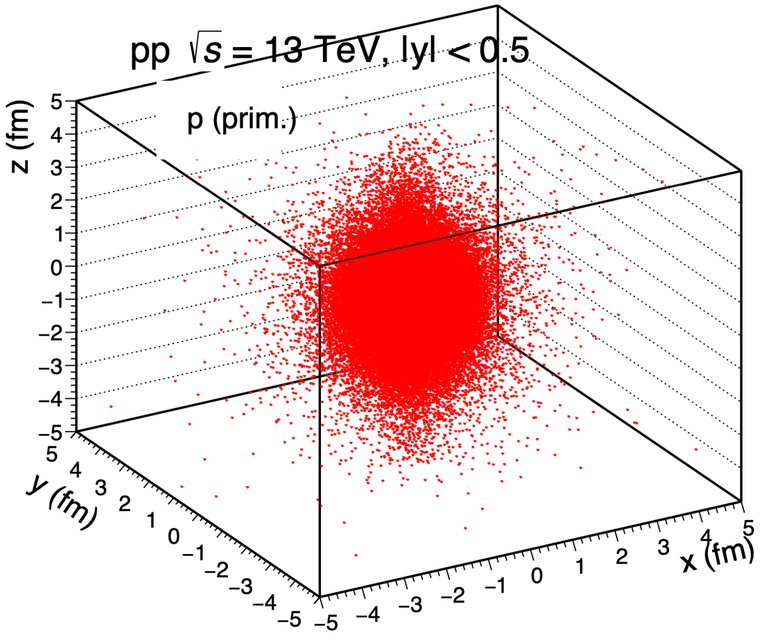
particle: id="112214" name="p(1700)+" antiName="pbar(1700)-" spinType="4" chargeType="3" colType="0" m0="1.720" mWidth="0.200" mMin="1.40" mMax="2.70" varWidth="on"
channel: onMode="1" bRatio="0.070796" meMode="5" products="2112 211"
channel: onMode="1" bRatio="0.035398" meMode="5" products="2212 111"
channel: onMode="1" bRatio="0.194690" meMode="4" products="223 2212"
channel: onMode="1" bRatio="0.103245" meMode="4" products="2114 211"
channel: onMode="1" bRatio="0.206490" meMode="4" products="2214 111"
channel: onMode="1" bRatio="0.309735" meMode="4" products="2224 -211"
channel: onMode="1" bRatio="0.041298" meMode="5" products="202112 211"
channel: onMode="1" bRatio="0.020649" meMode="5" products="202212 111"
channel: onMode="1" bRatio="0.011799" meMode="3" products="102114 211"
channel: onMode="1" bRatio="0.005900" meMode="3" products="102214 111"

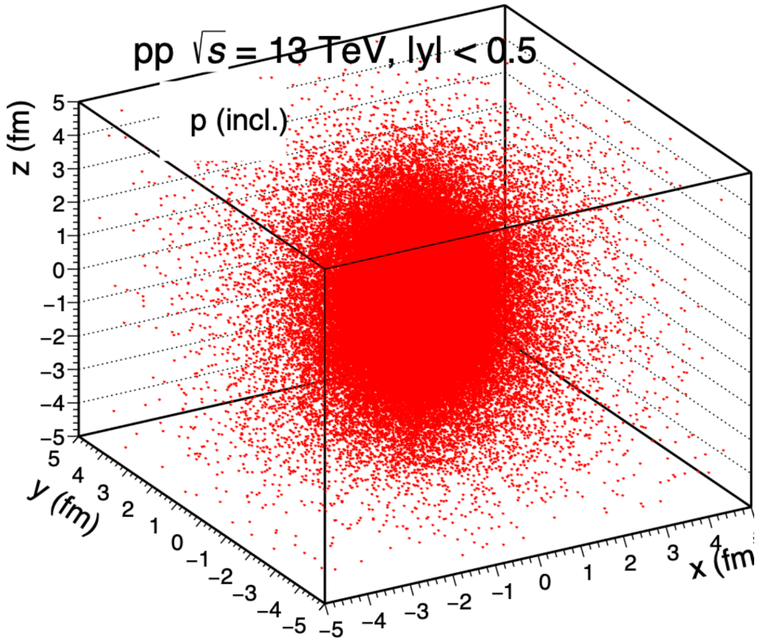
Comments on the data

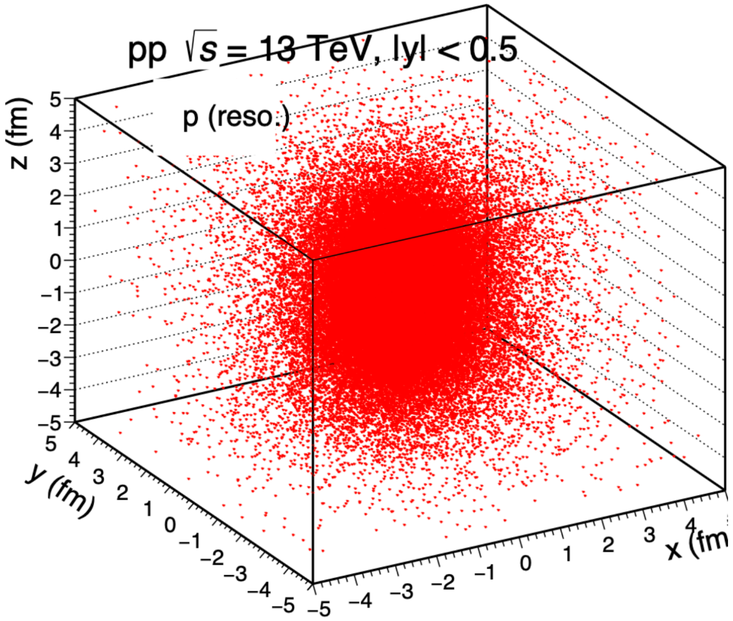
Much of the current data has been updated based on the 2012 Review of Particle Physics [Ber12], while some is still based on the 2006 RPP [Yao06]. All known particle masses, widths and lifetimes have been set accordingly, while most not-yet-measured particles are kept at their values from PYTHIA 6. Decay channels and their branching ratios remain a major worry: many particles do not have one single solidly measured branching ratio, and many further do not have known branching ratios that add up to (the neighbourhood of) unity.

Spatial info from Pythia8 (protons)

pp, 13 TeV (MB)



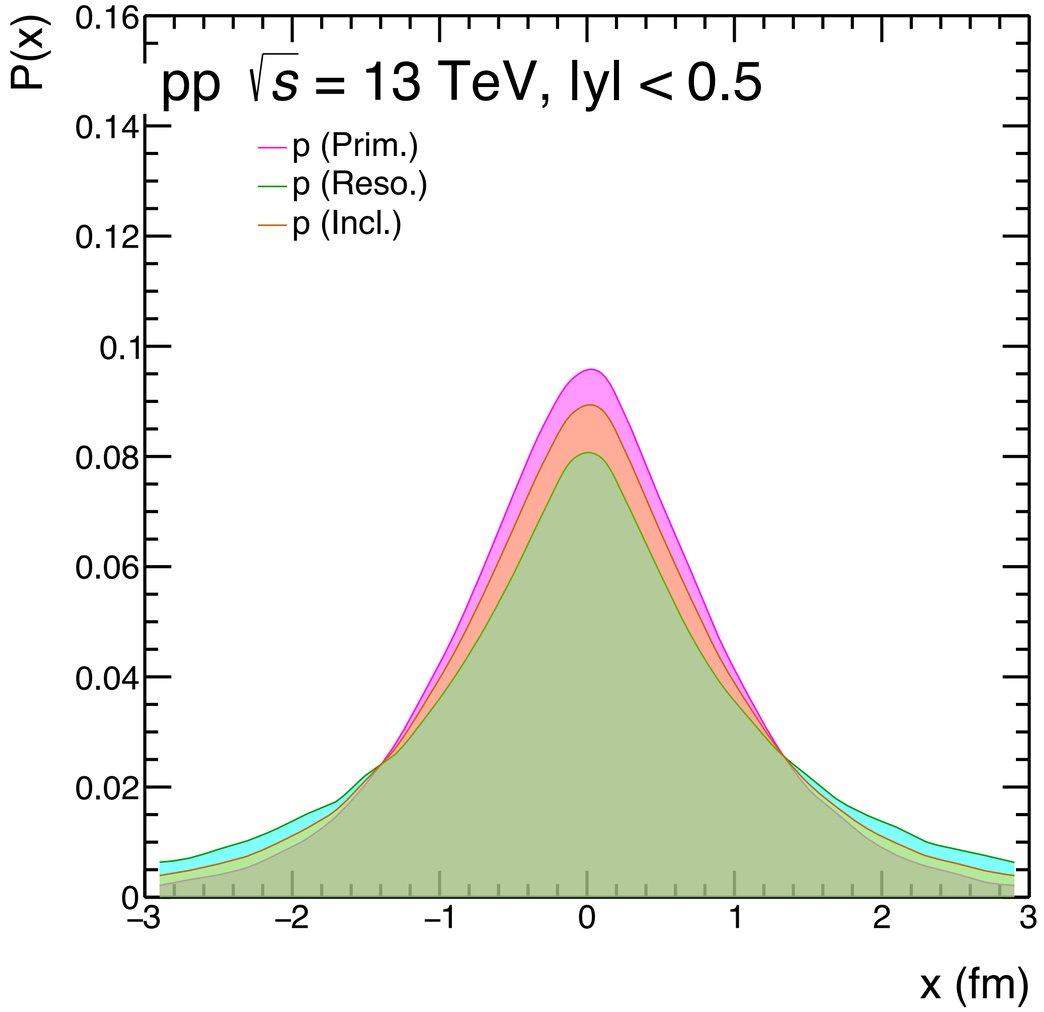


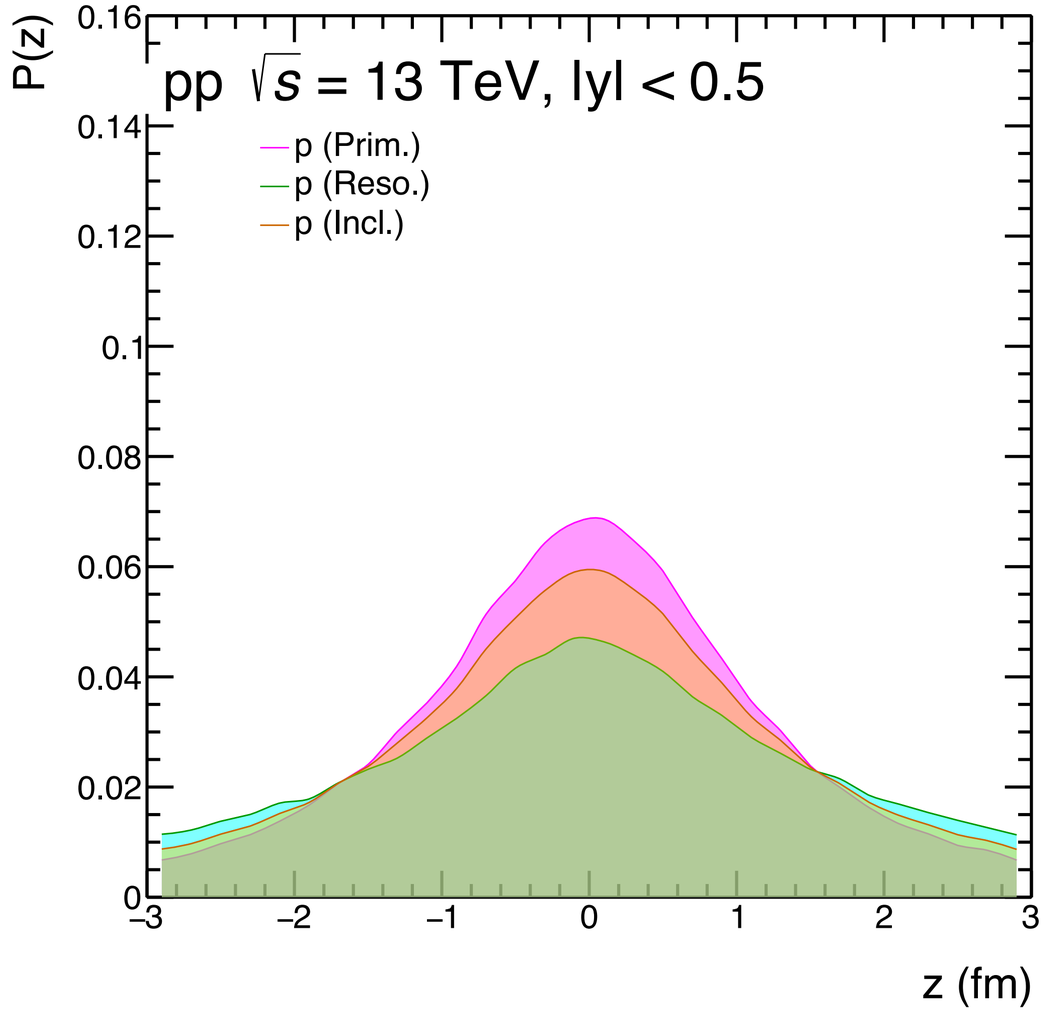


- The plots are in lab frame and coordinates represent the production coordinates of protons

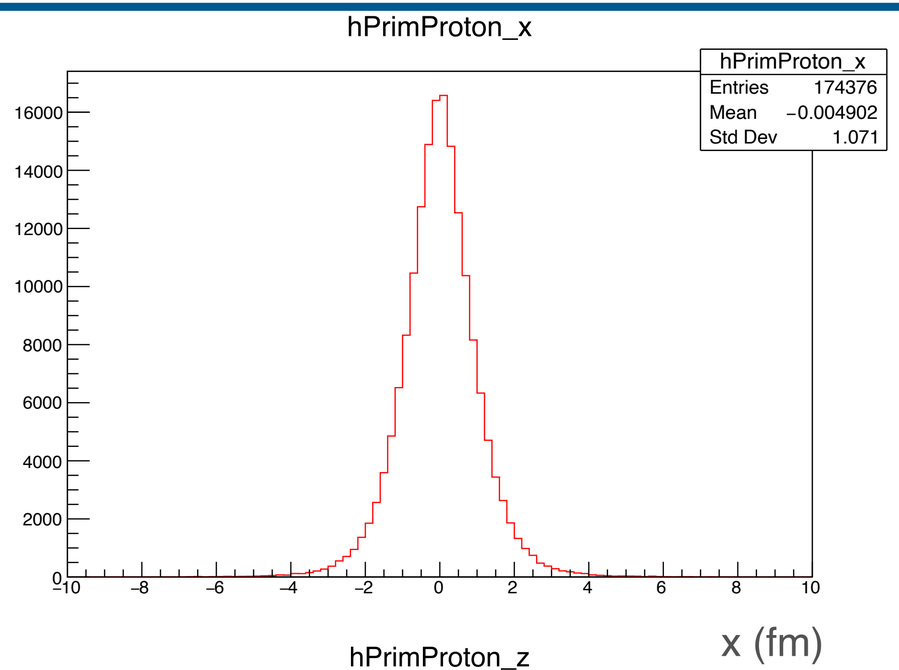
Spatial info from Pythia8

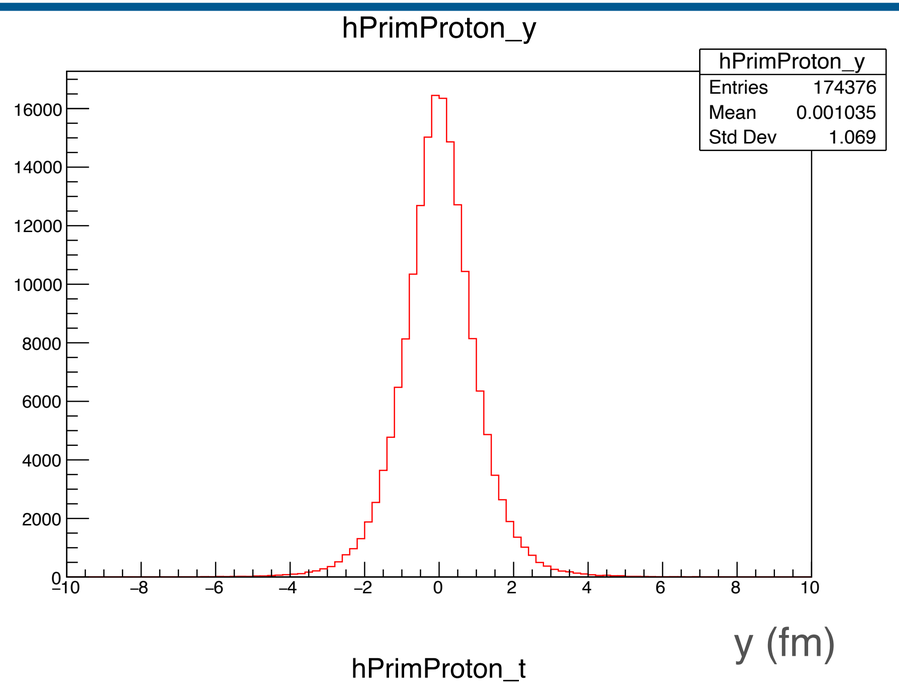
pp, 13 TeV (MB)

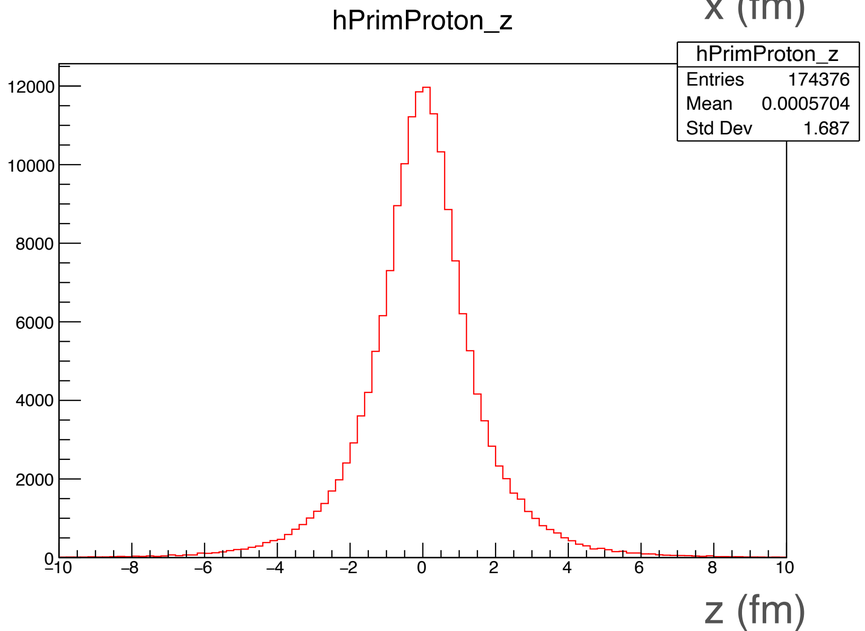


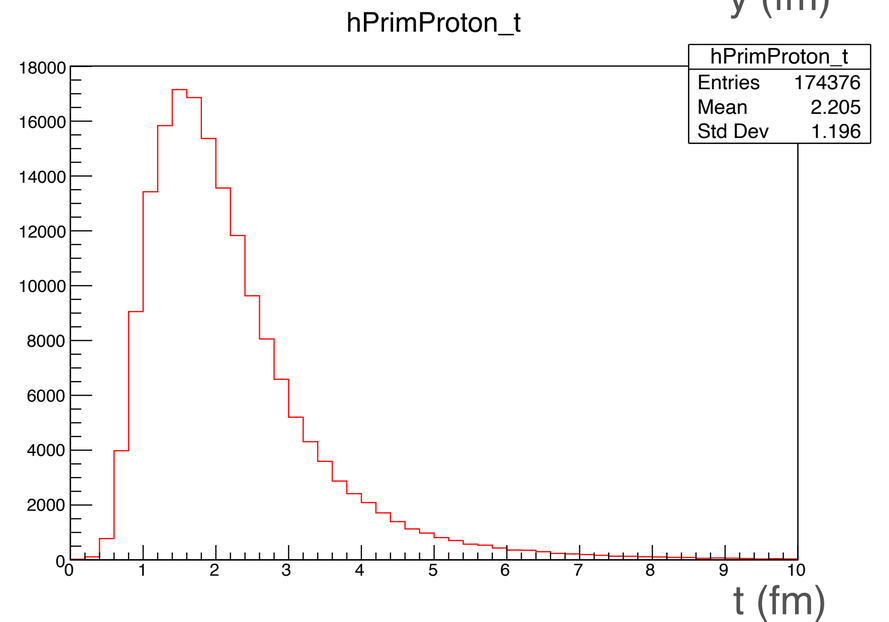


Spatial info from Pythia8 (primordials) pp, 13 TeV (MB)

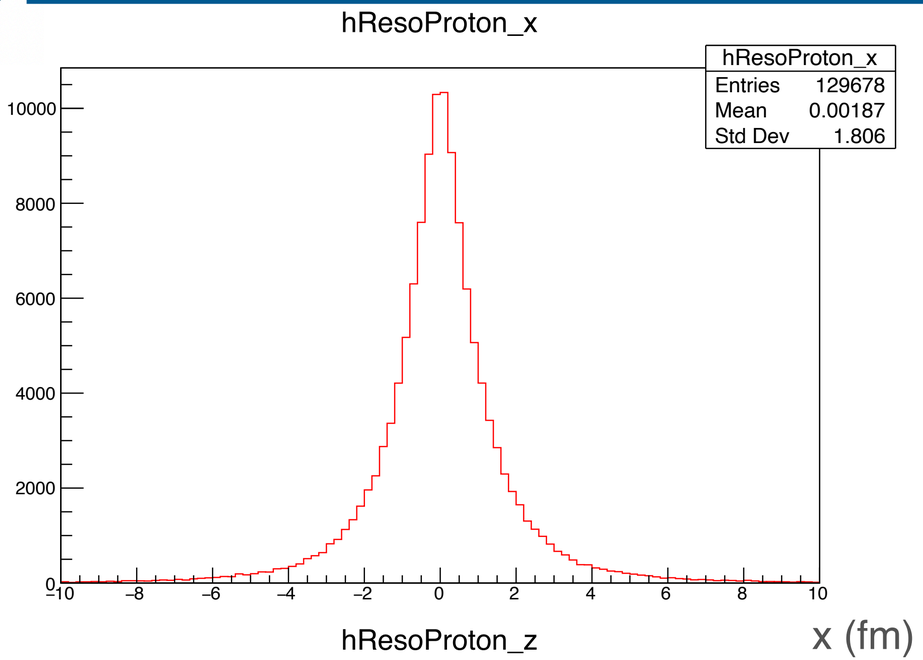


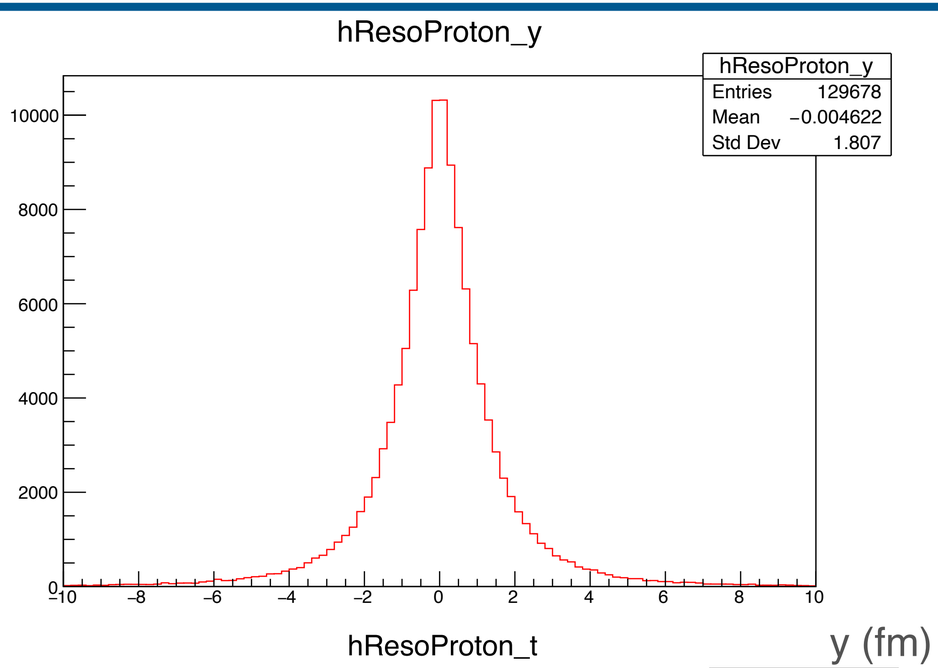


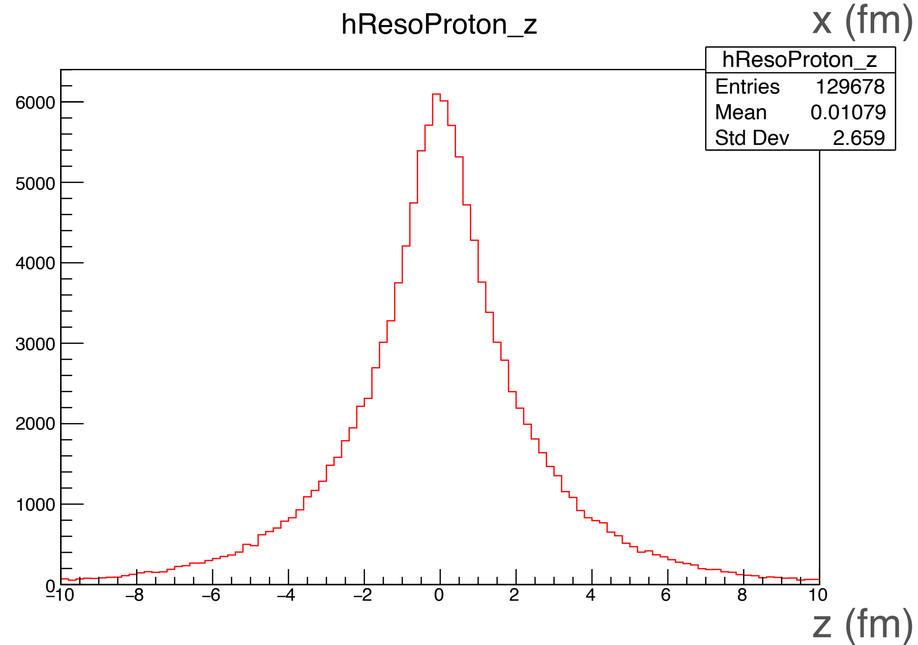


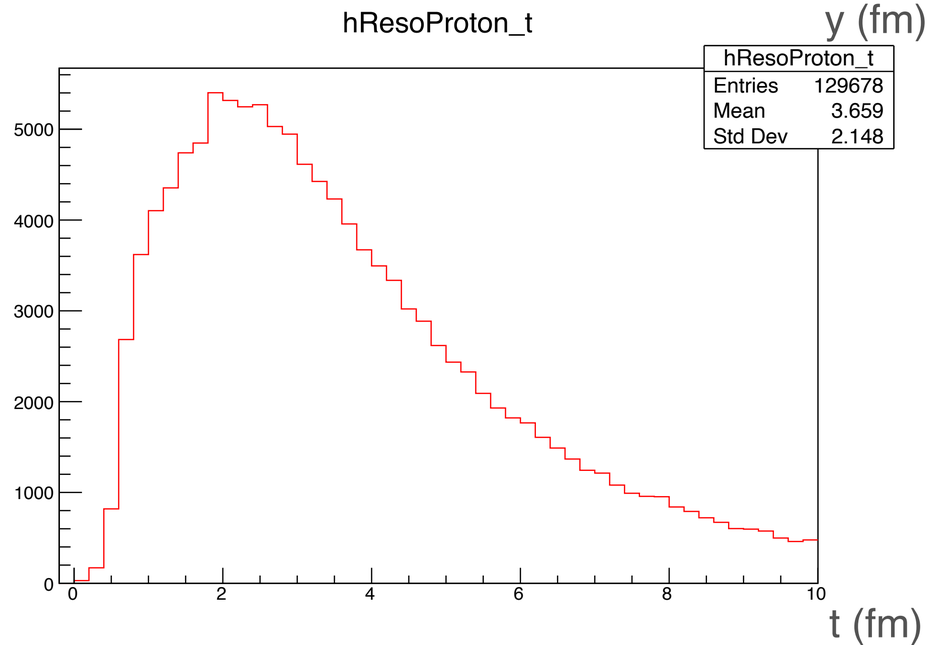


Spatial info from Pythia8 (resonances) pp, 13 TeV (MB)



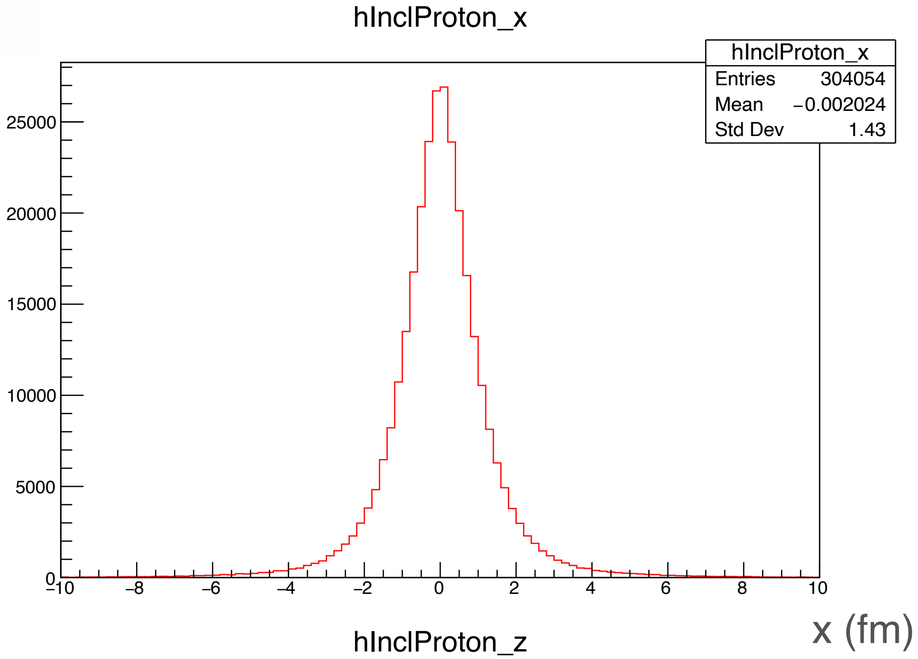


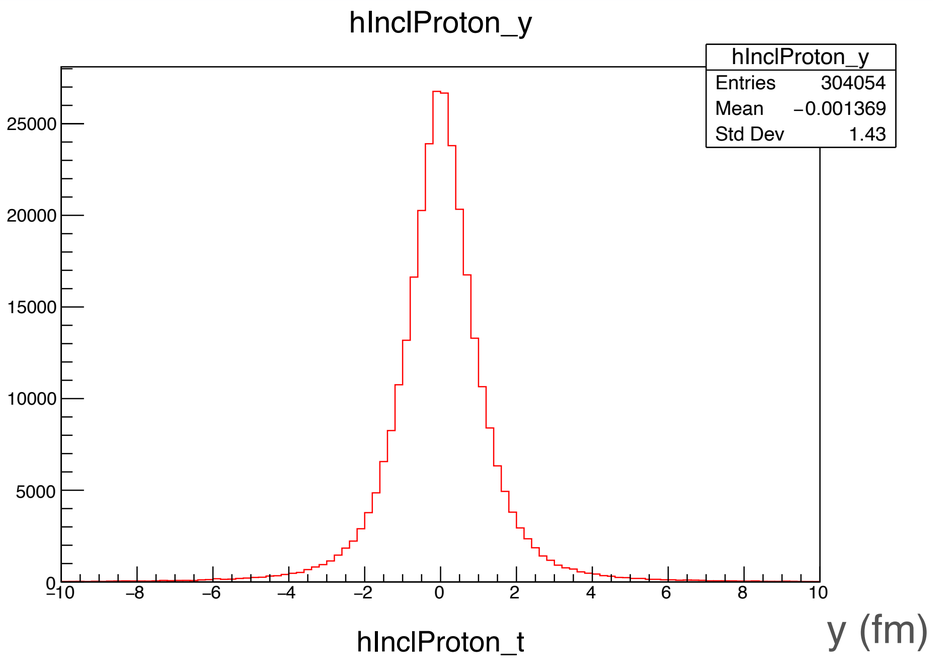


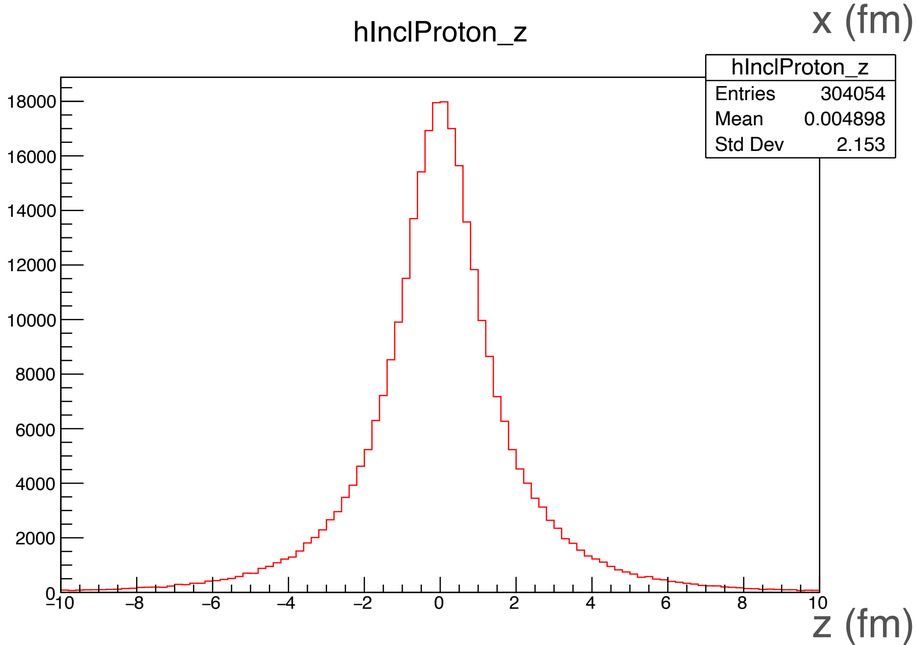


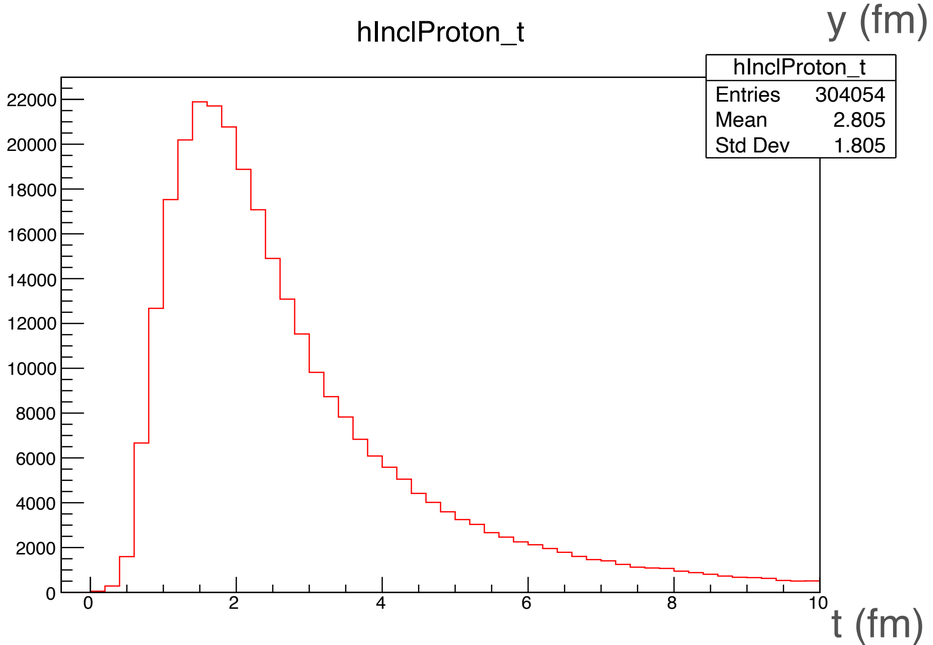
Spatial info from Pythia8 (inclusive)

pp, 13 TeV (MB)

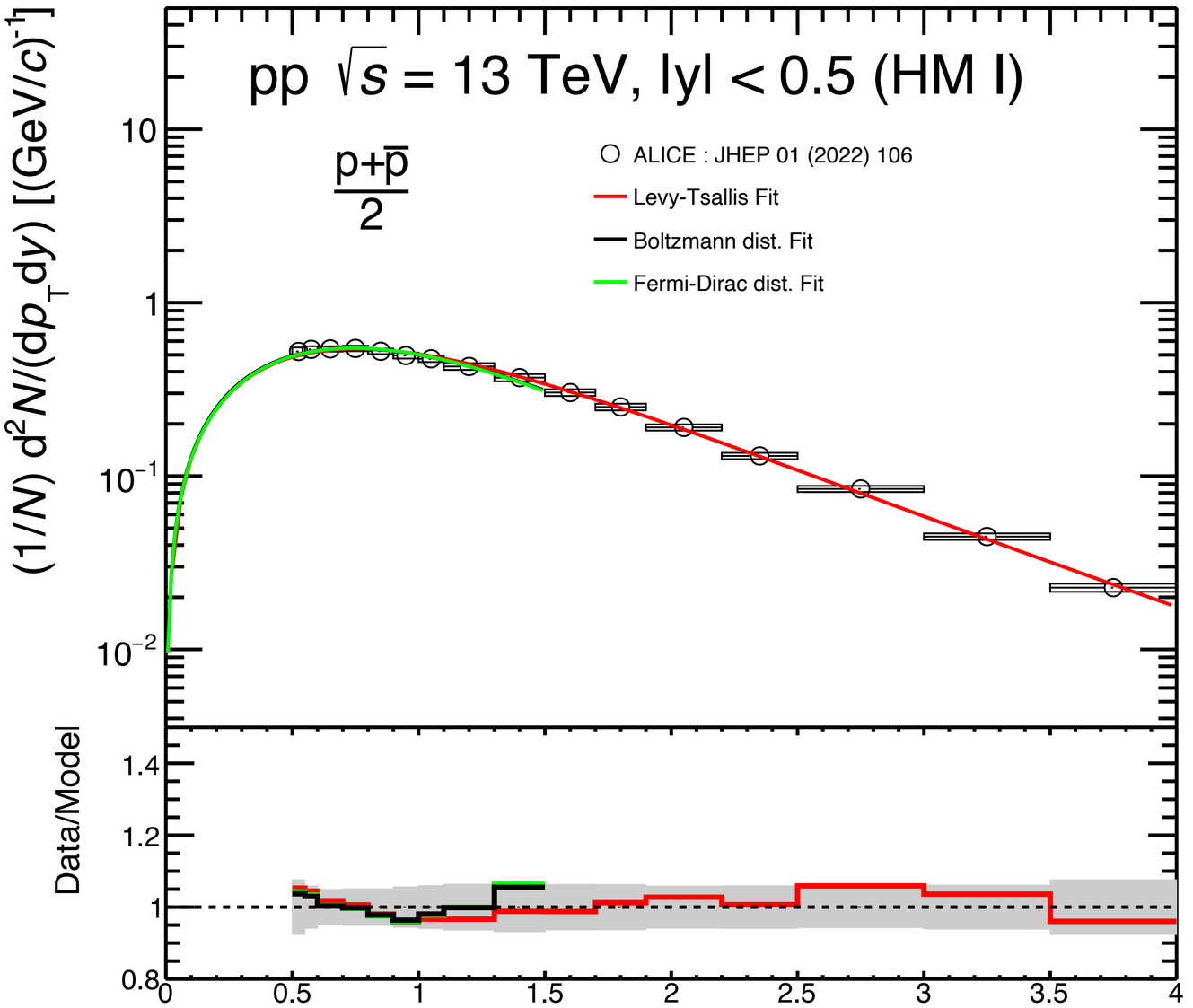






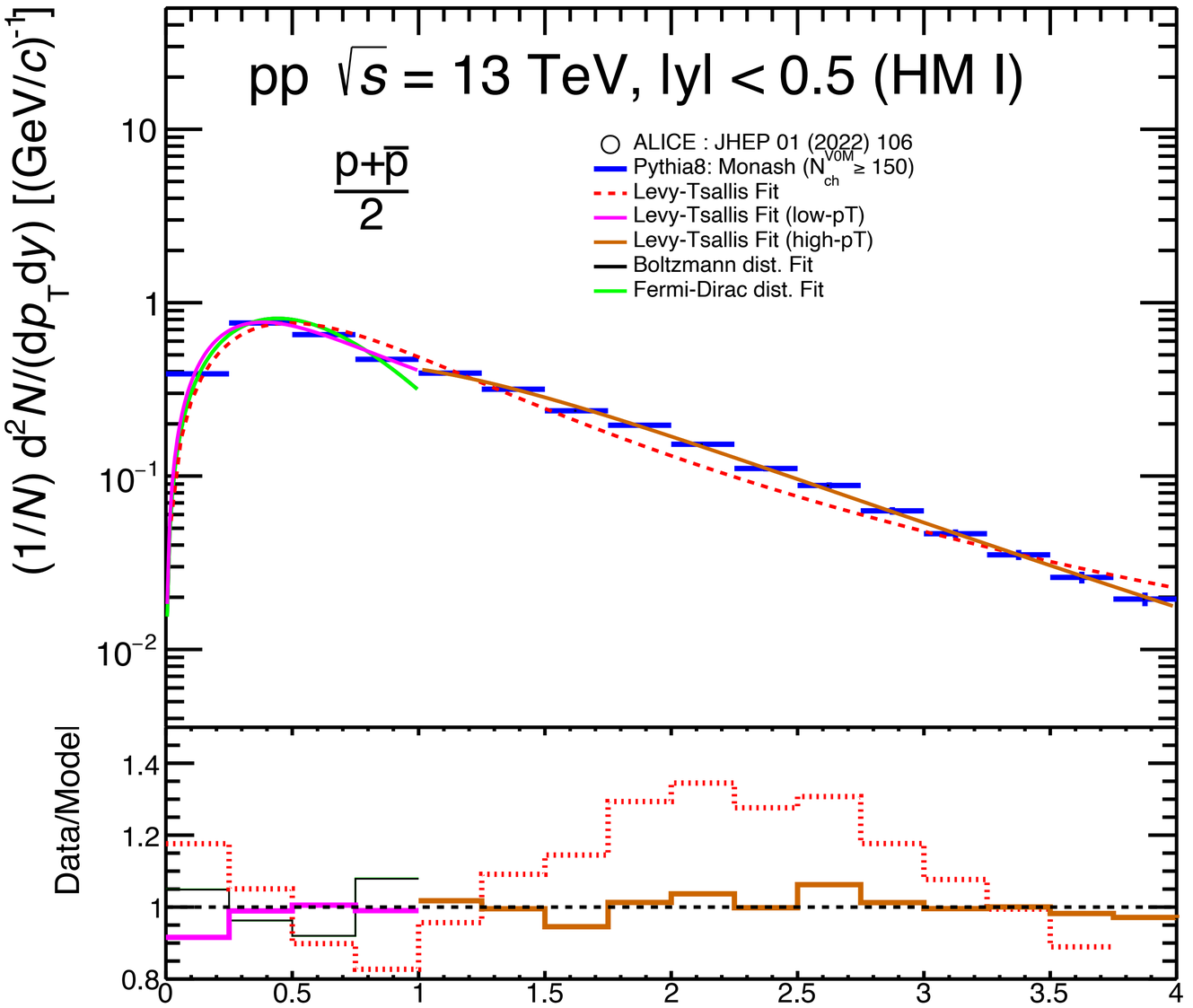


Fit to proton spectrum (Data)



- Data to fit ratio look good for Levy-Tsallis fit and no significant spread in extrapolated region

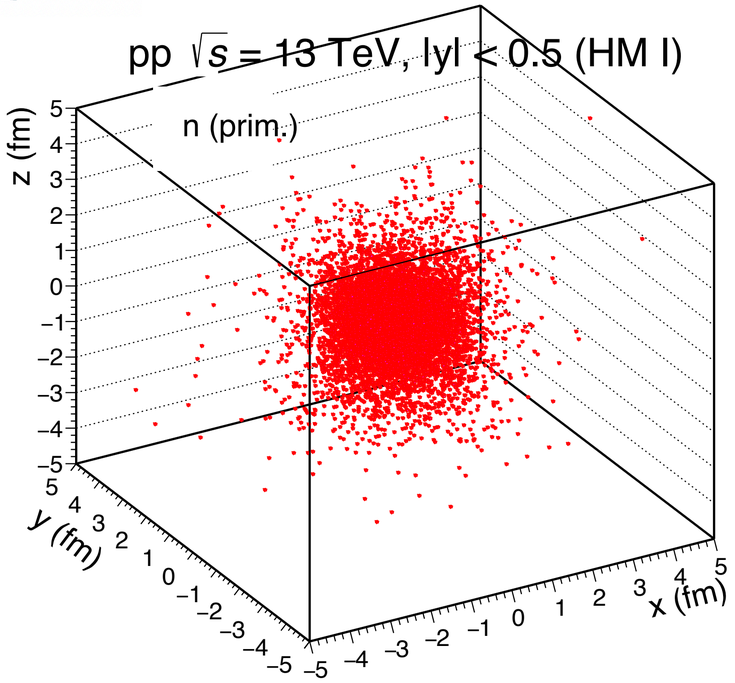
Fits to proton spectrum (Pythia8)

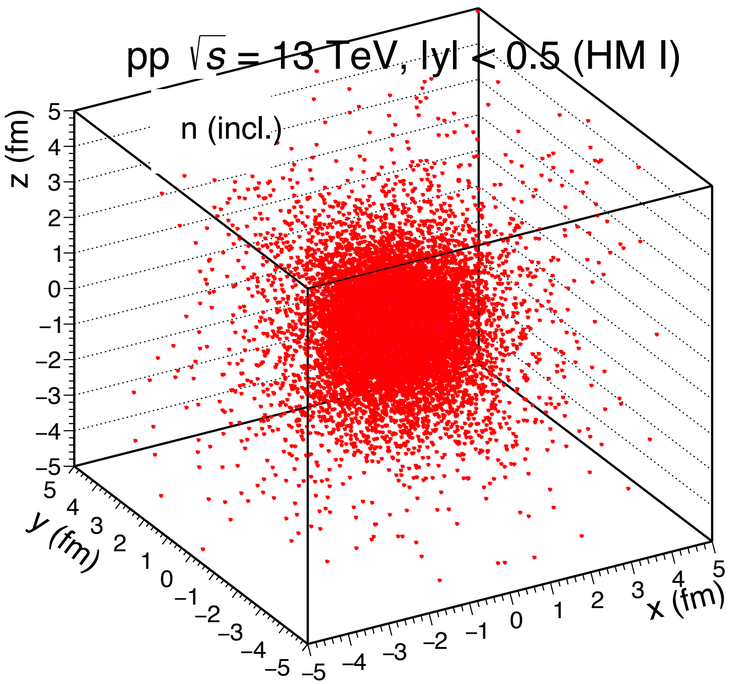


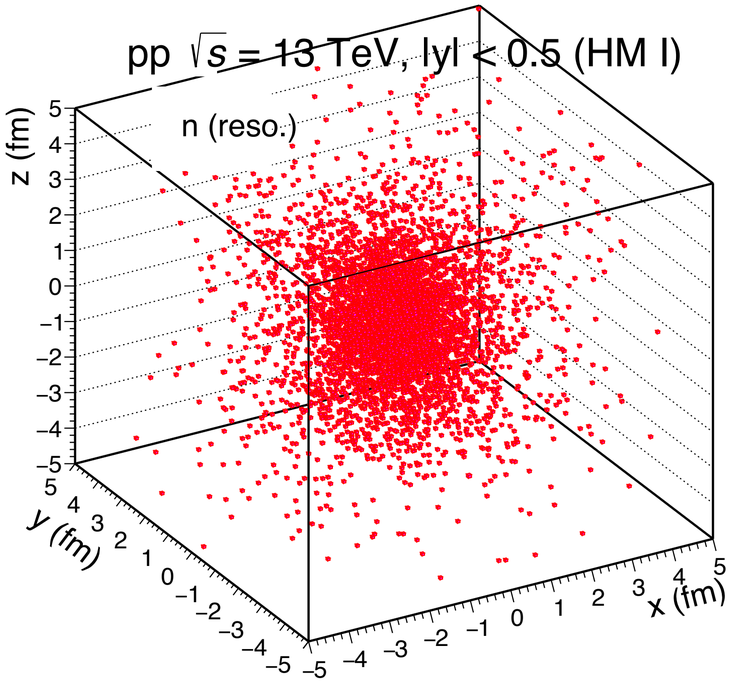
- Data to fit ratio look good for Levy-Tsallis fit if one separates low and high pT region

Spatial info from Pythia8 (neutrons)

Events: 200M MB (~10K HM) events

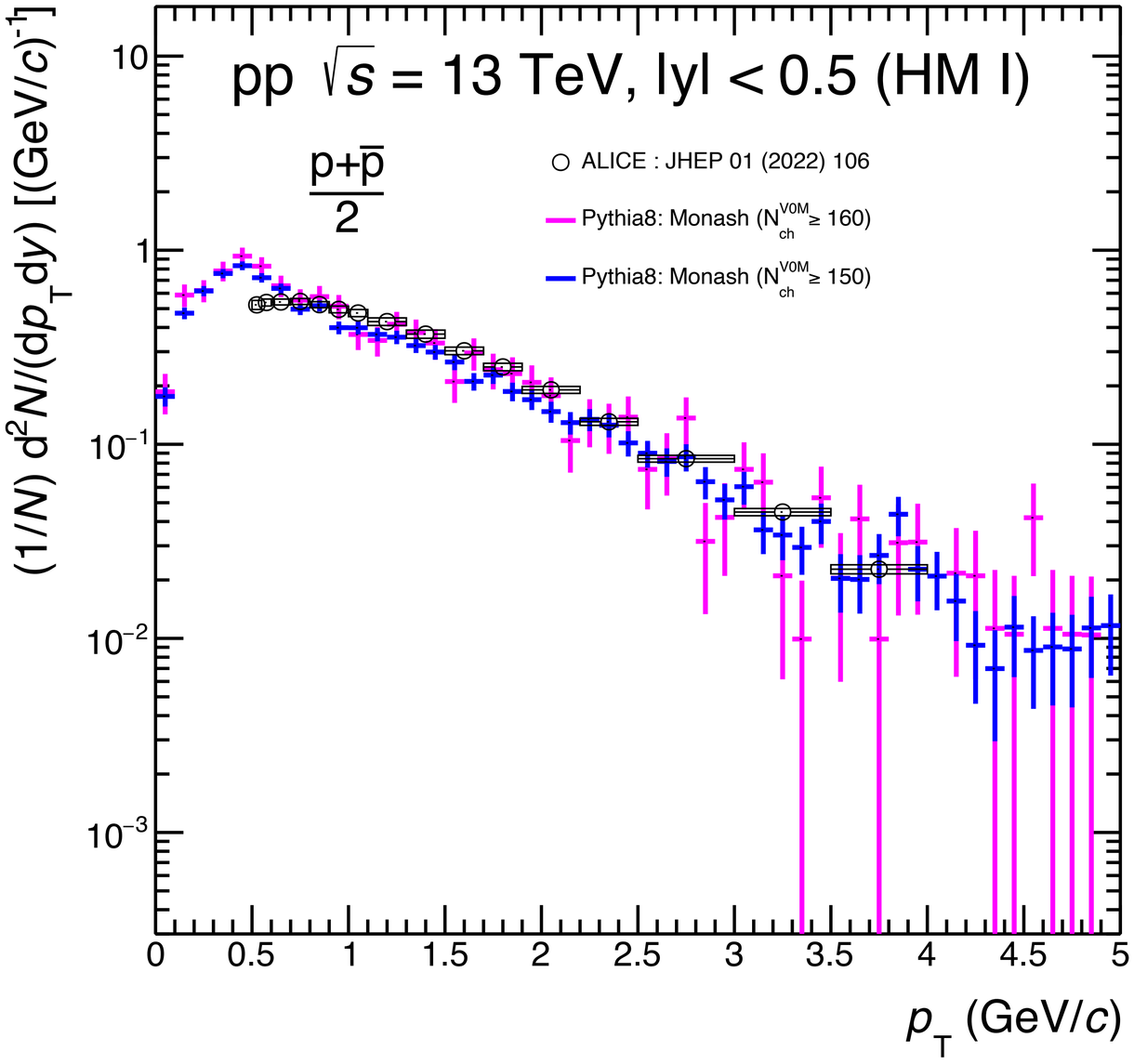




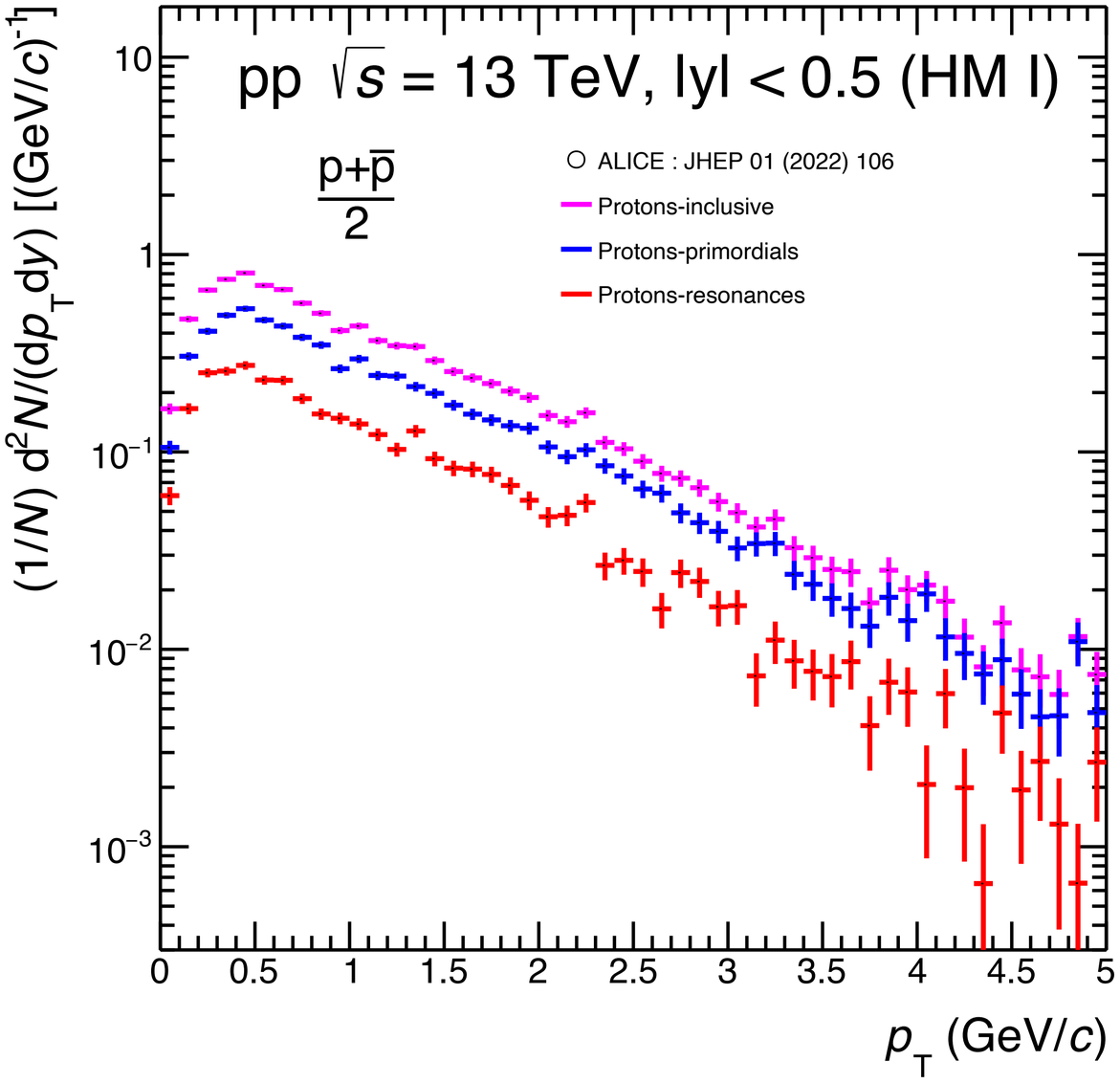


- The plots are in lab frame and coordinates represent the production coordinates of protons

Proton Comparison (HM I)

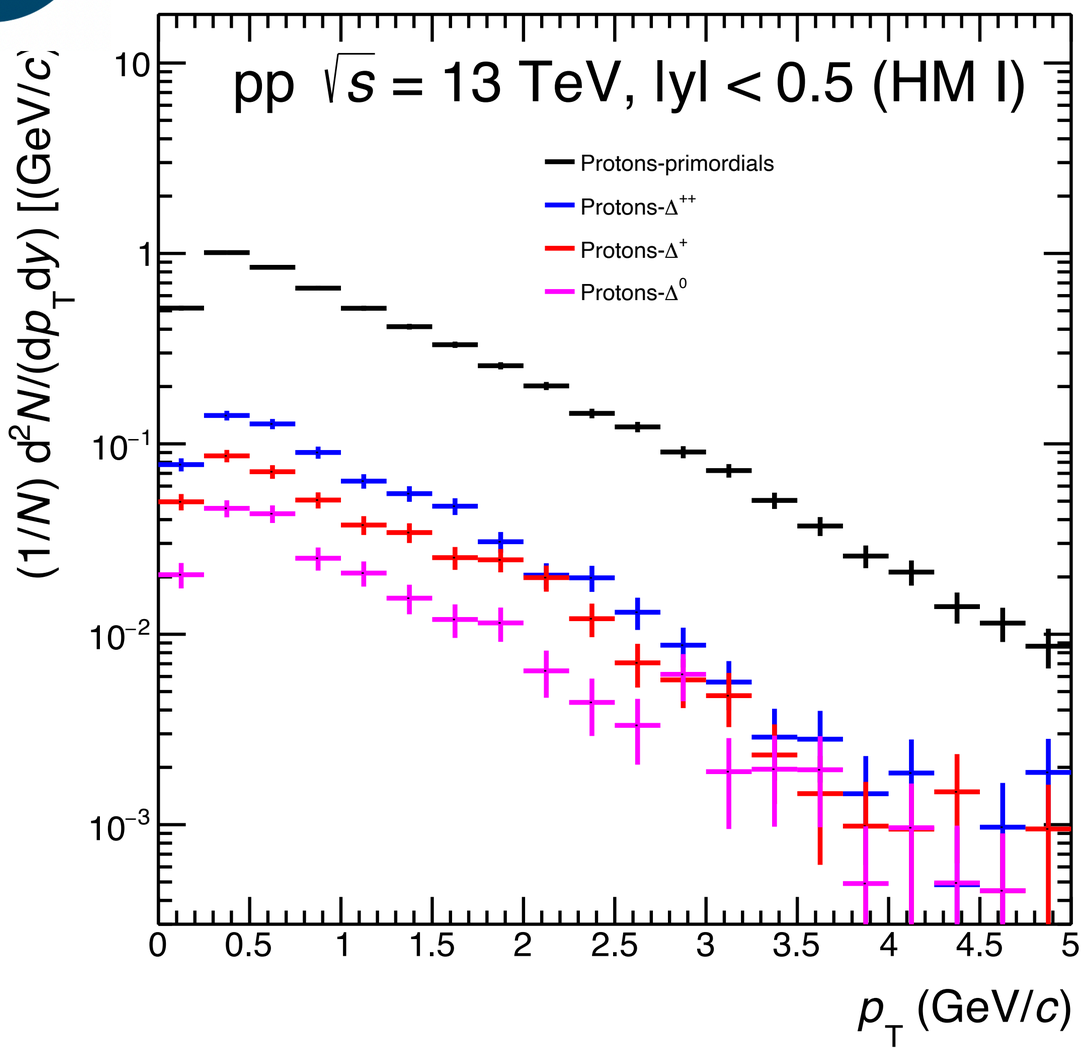


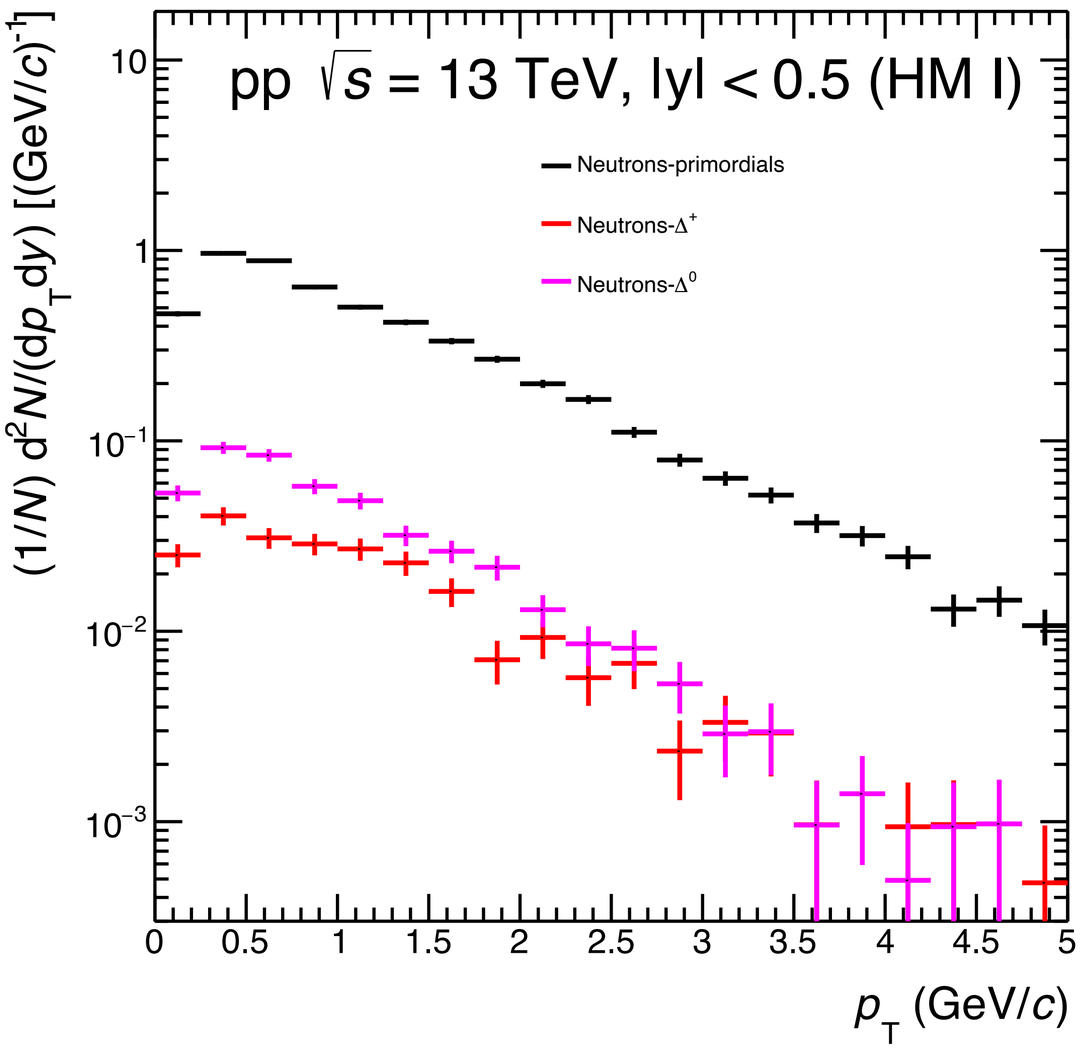
Proton Comparison (HM I)



Resonance cocktail

Events: 200M MB (~10K HM) events





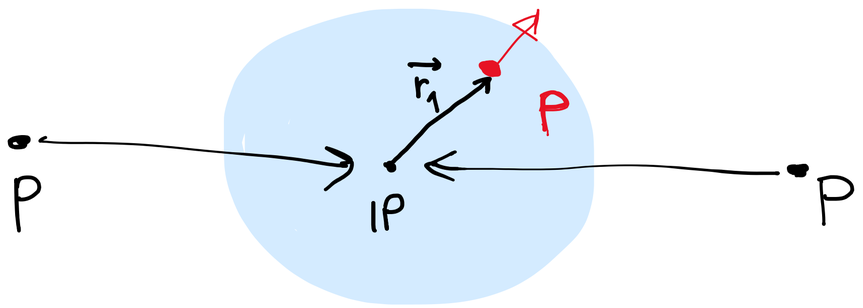
- To be tested with all the statistics (1.5 B MB, ~70K HM)

To do…

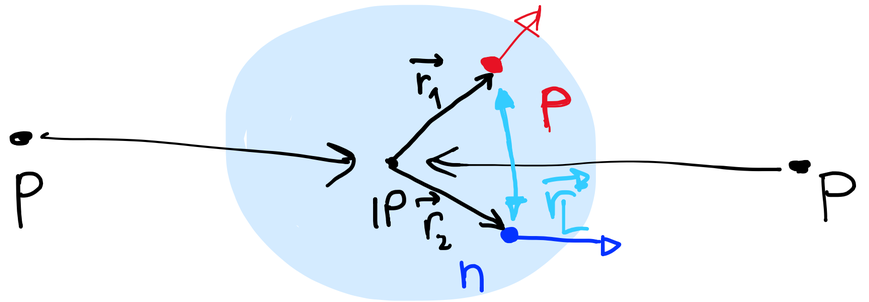
Pythia 8 simulations :

- implement HM trigger selection
- run equivalent of 300 M events MB
- check charged particle multiplicity distributions for HM pp + protons spectra
- add deuterons to anti d
- produce B2 as done for data
- run r_eff pythia source && r_core pythia
- check resonance cocktail and extract angular distribution

Prompt p(bar) + prompt n(bar)



IP = (0,0,0) Lab frame



IP = (0,0,0) Lab frame

$\vec{r}_1$ = position of prompt p produced in the lab frame

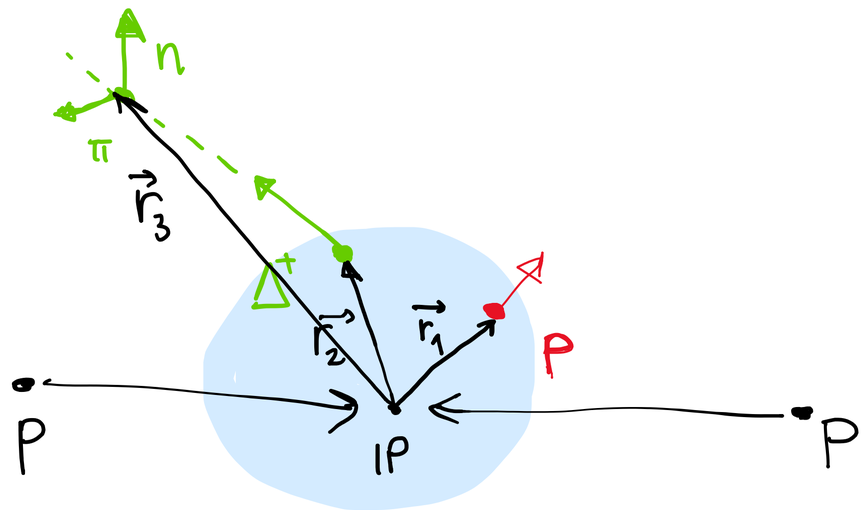
$\vec{r}_2$ = position of prompt n produced in the lab frame

$\vec{r}_L$ = distance between p and n in lab frame = $\vec{r}_1 - \vec{r}_2$

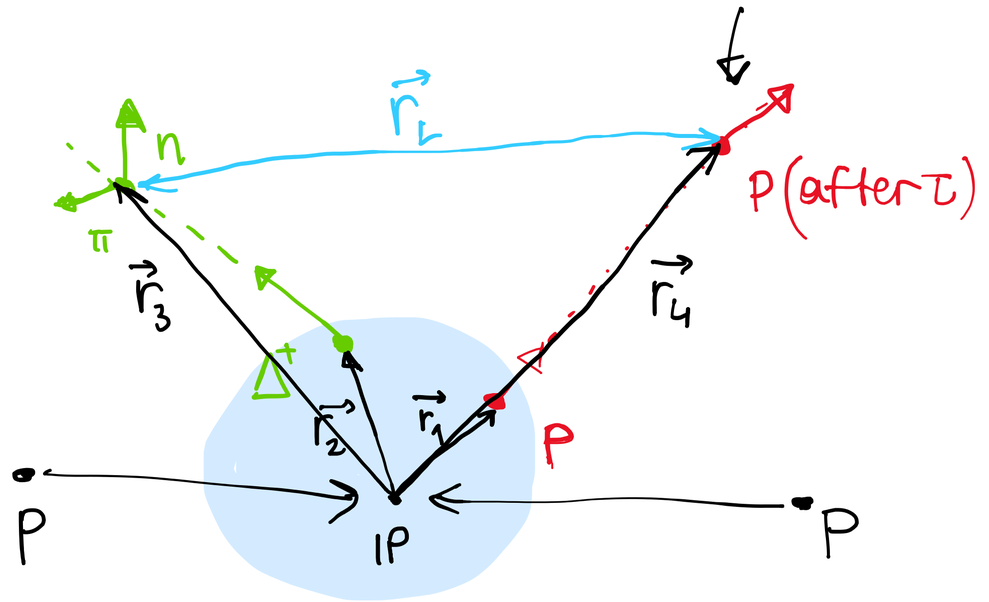
$r_L = \| \vec{r}_L \| = | \vec{r}_1 - \vec{r}_2 |$

r_L → Lorentz transformation → r = distance between nucleons in c.o.m. of the pair

Primordials p(bar) + n(bar) from resonance



SHIFTED PRIMORDIAL



$\vec{r}_2$ = position of prompt resonance

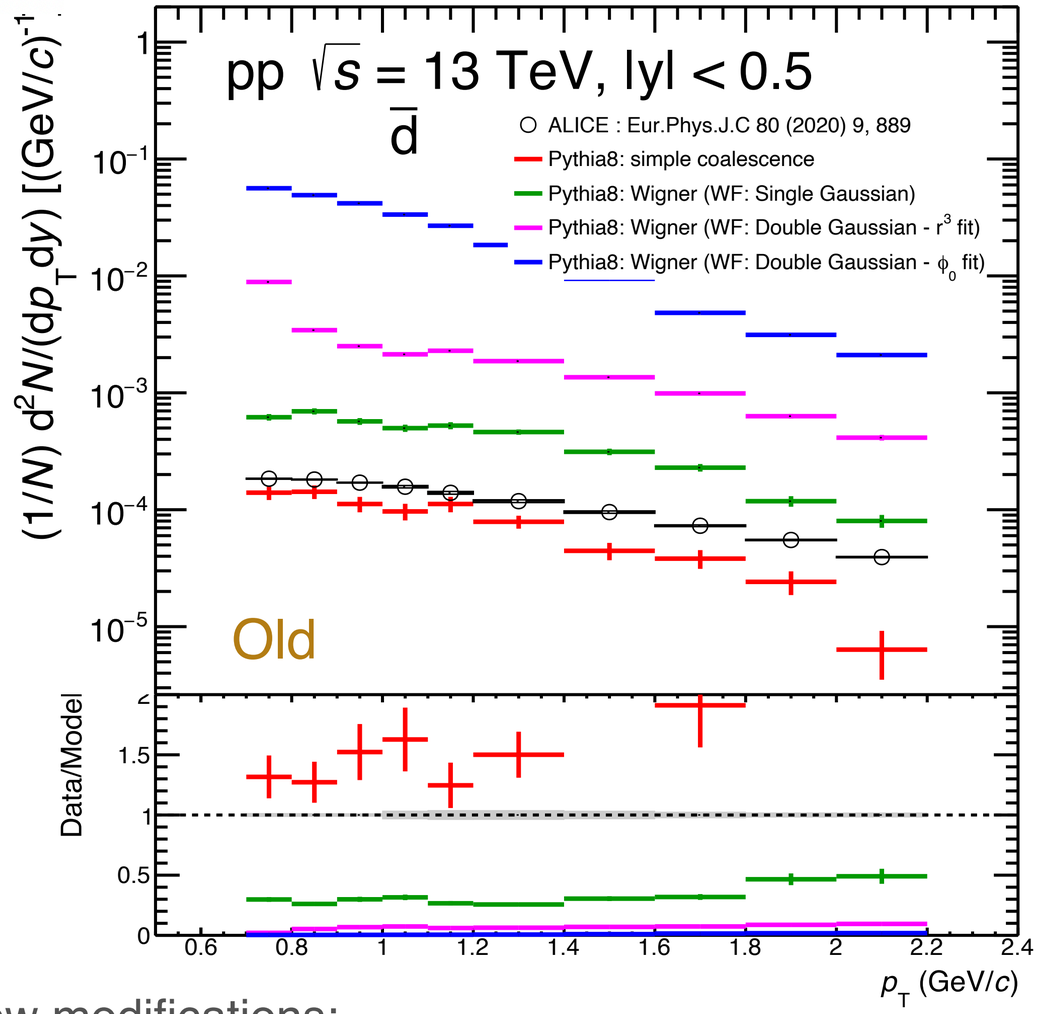
$\vec{r}_3$ = position of nucleon when produced from resonance decay after τ

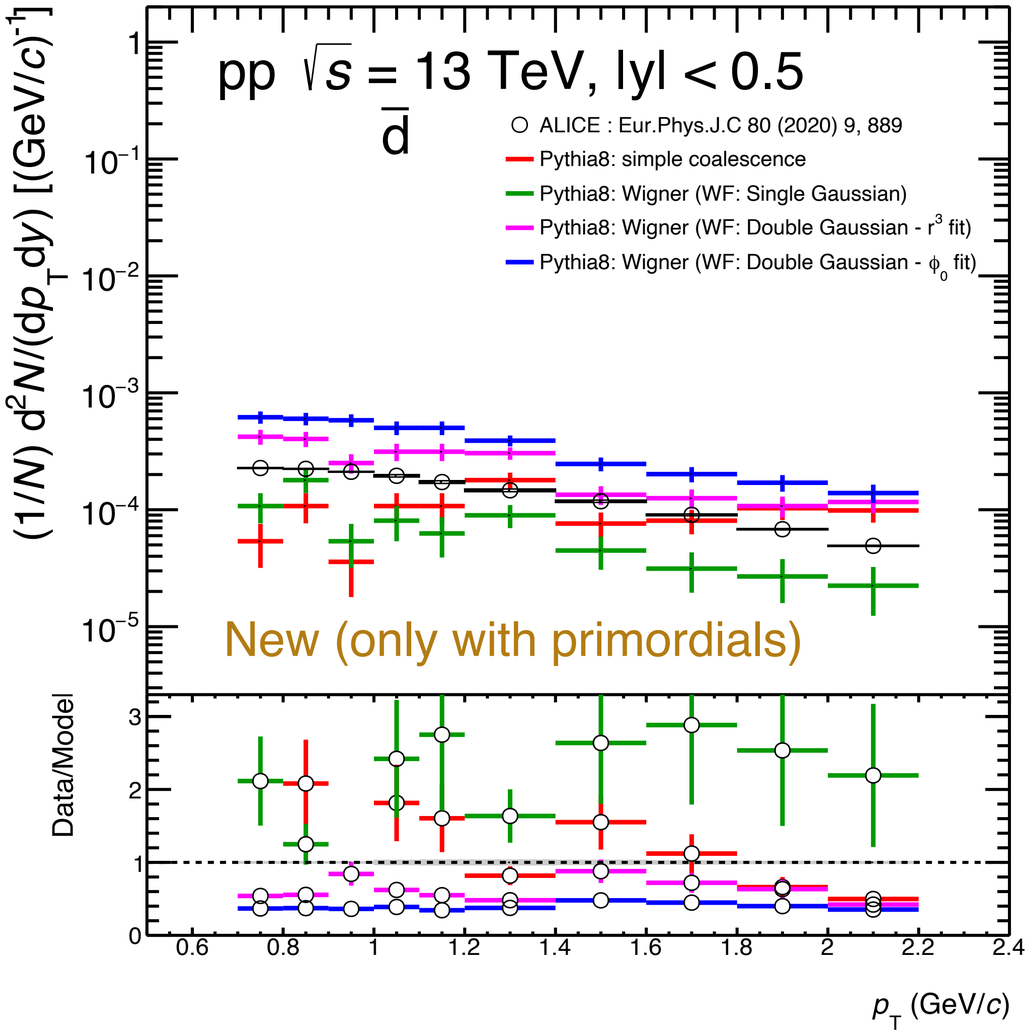
$\vec{r}_4$ = position of prompt nucleon when the other becomes available, after τ

$r_L = |\vec{r}_4 - \vec{r}_3|$ ⟶ r in com. frame

r_L ⟶ Lorentz transformation ⟶ r = distance between nucleons in c.o.m. of the pair

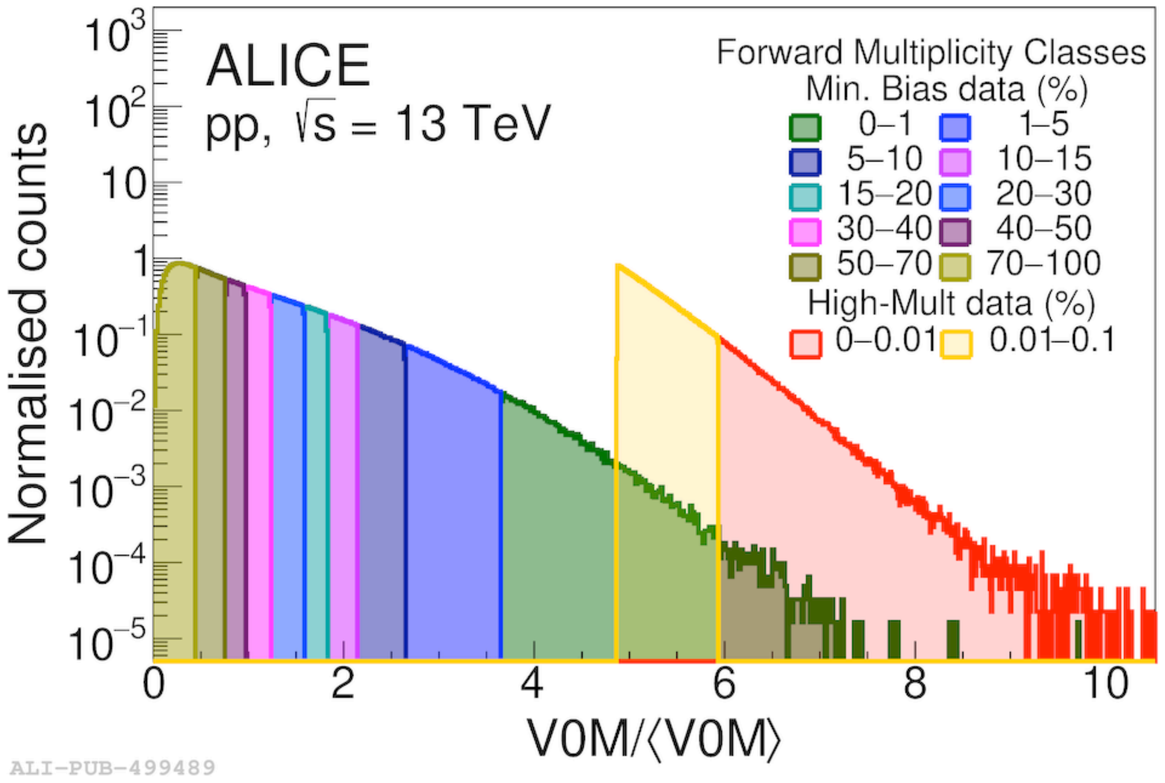
Comparison of deuterons



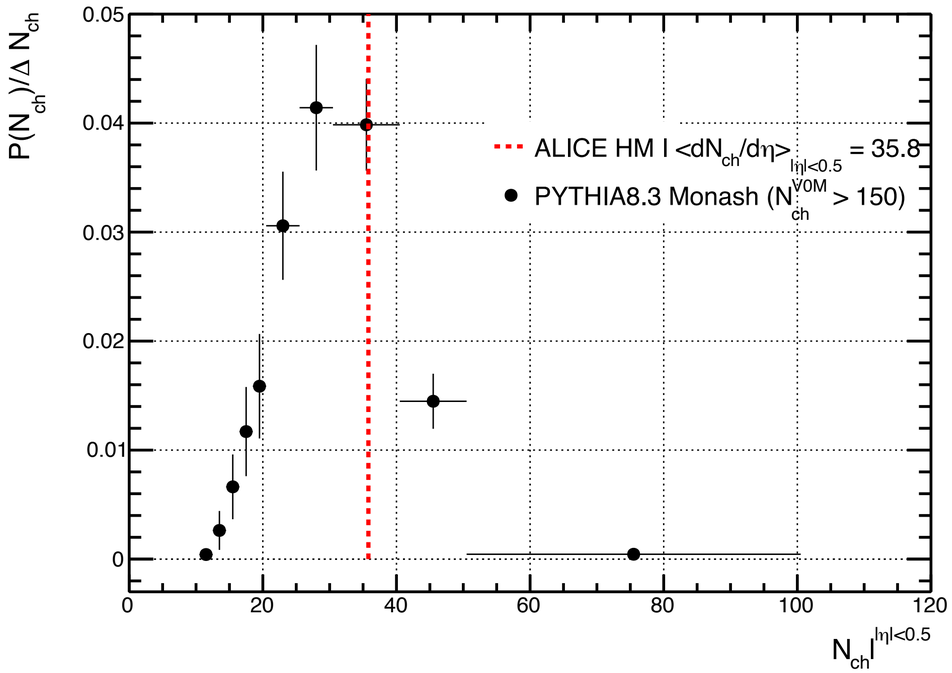


- New modifications:
  - We have the correct vertex information from Pythia now (earlier it was set to 0 by default)
  - The plot is obtained only with primordials and treatment for resonances ongoing!

HM trigger mult. distribution



	Forward Multiplicity Estimator		
	$\sqrt{s}$ (TeV)		
	5.02	7	13
$\Delta\sigma/\sigma_{\mathrm{MB_{AND>0}}}$	$\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta \rangle \pm$uncorrelated systematic uncert		
0–0.01%	24.53±0.23±0.31	29.13±0.25±0.44	35.82±0.33±0.33
0.01–0.05%	22.42±0.21±0.23	26.27±0.23±0.30	32.21±0.29±0.29
0.05–0.1%	21.14±0.20±0.22	24.70±0.22±0.25	30.13±0.27±0.27
0.01–0.1%	21.71±0.20±0.21	25.40±0.22±0.26	31.05±0.28±0.28



Eur. Phys. J. C 81 (2021) 630