Two particle correlations at ALICE

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for the ALICE collaboration

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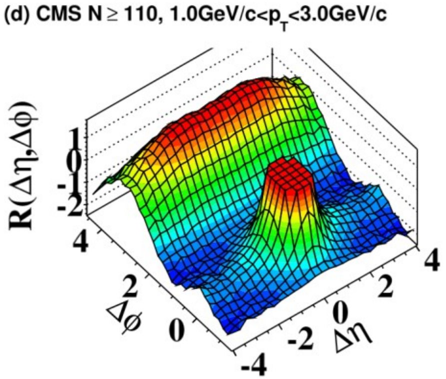
p+p collisions at LHC & ALICE

p+p physics at LHC

- Higgs, SUSY, BH, extra dims = BSM physics

p+p physics at LHC & ALICE

- Reference for HI physics (parton energy loss, nuclear modification of FF in excited medium, k_T broadening, ...)
- Study of non-perturbative QCD phenomena (k_T)
- Test bench for pQCD (parton showering, ISR/FSR)
- Search for collective phenomena



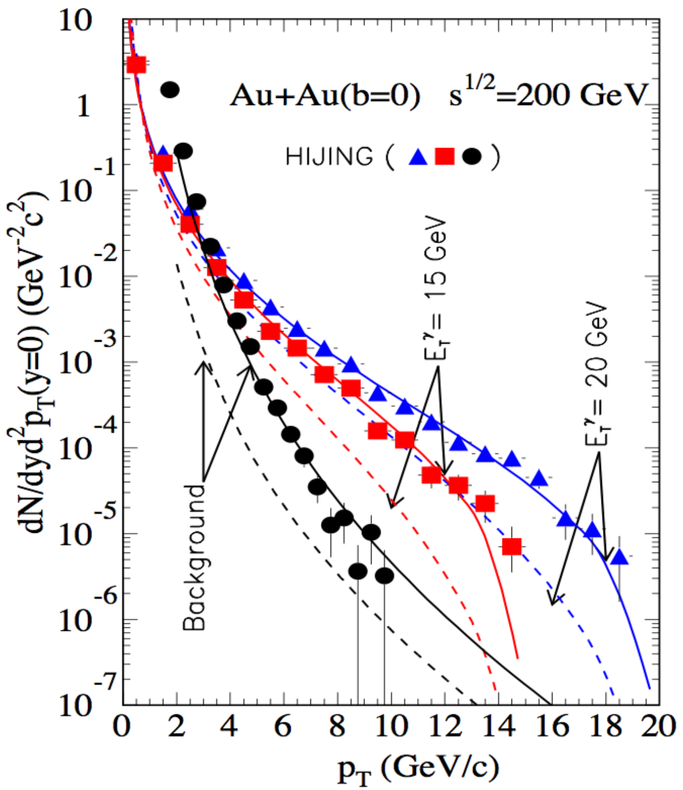
Method – two high-p_T particle correlations particle

CMS, arXiv:1009.4122.

Medium modification of fragmentation function

X.N. Wang, Z. Huang, and I. Sarcevic: arXiv:hep-ph/9605213 v1 :

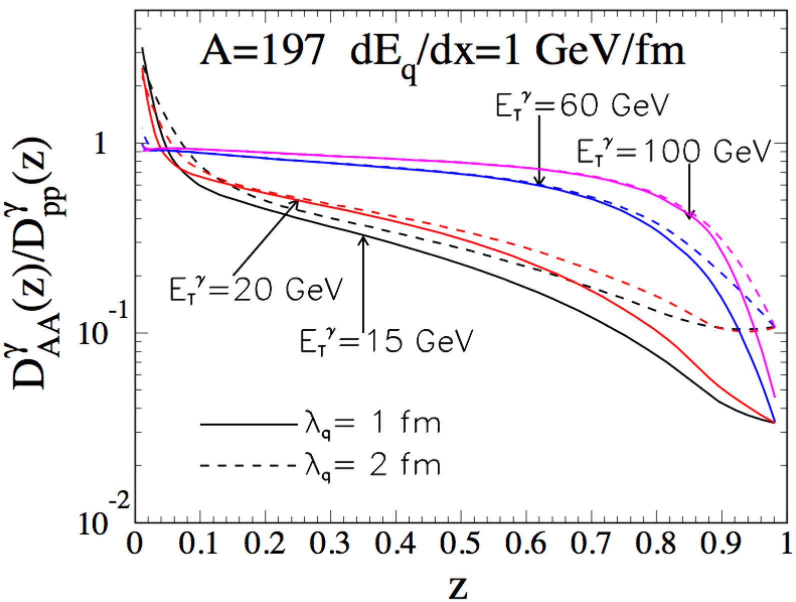
Use medium modification of FF to study partonic dE/dx.



p_T distribution of charged hadrons in γ-tagged jets in central Au+Au.

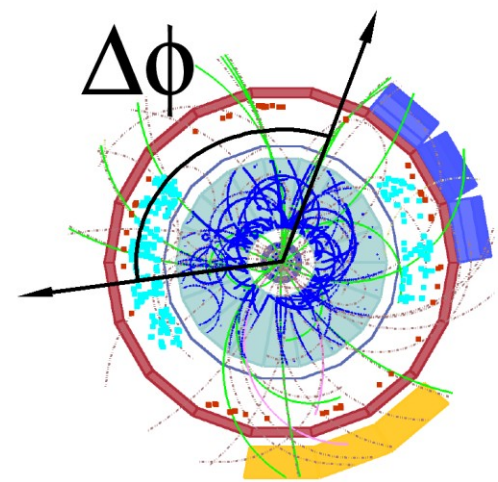
no dE/dx (solid lines),

dE/dx = 1 GeV/fm (dashed lines)



Ratio of the the inclusive FF of γ-tagged jet with and without energy loss in central Au+Au for a fixed dE_q/dx = 1 GeV/fm. Sensitive window 10 < E_T^γ < 20 GeV

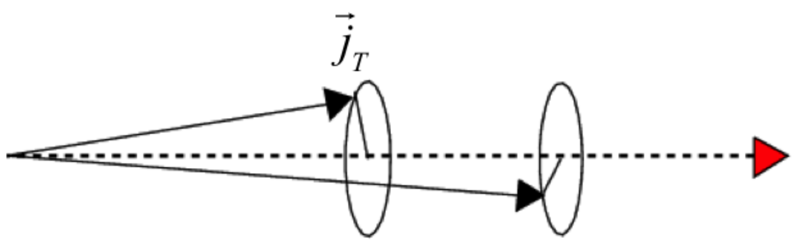
Leading particle correlations



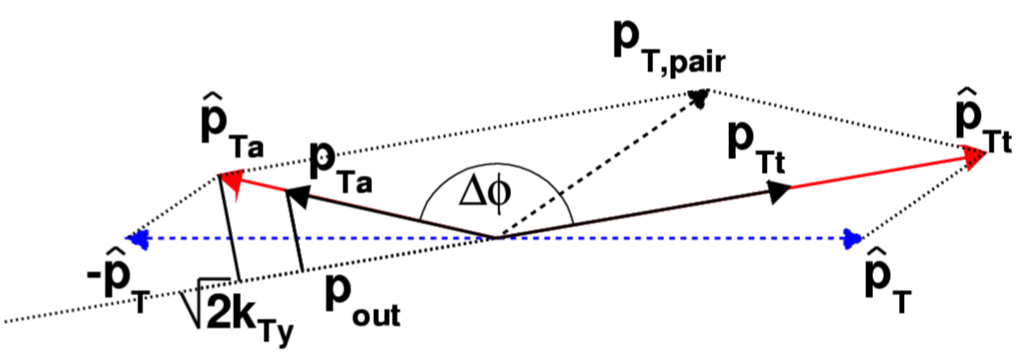
2-part correlation:

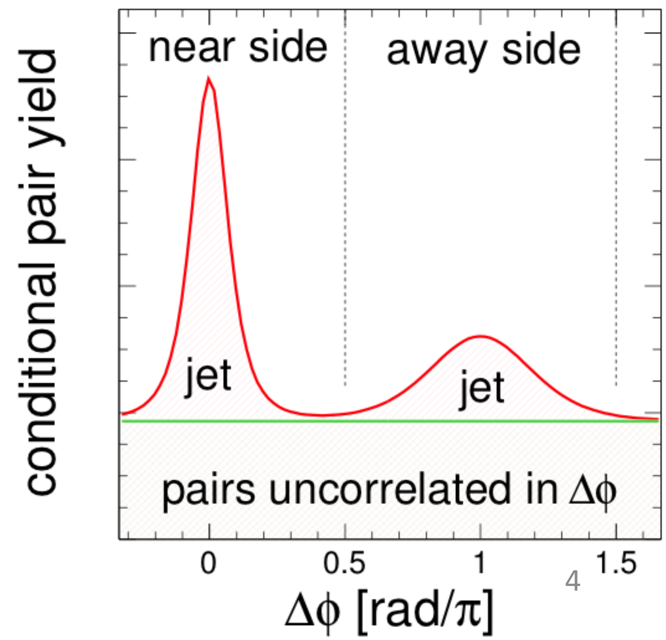
- Jet properties studied on statistical bases

- Near side (intra jet) : Single jet properties
  jet transverse fragmentation momentum j_T

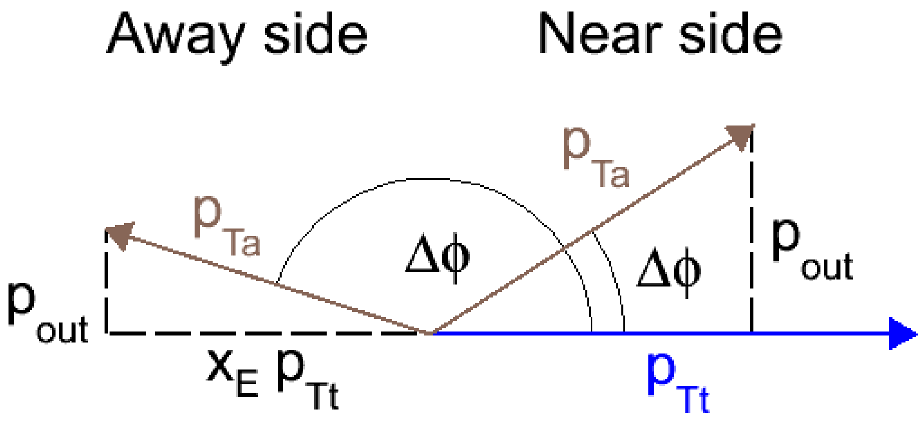


- Away side (inter jet) : Di-jet properties
  accoplanarity + mom. imbalance due to k_T





Two-particle observables



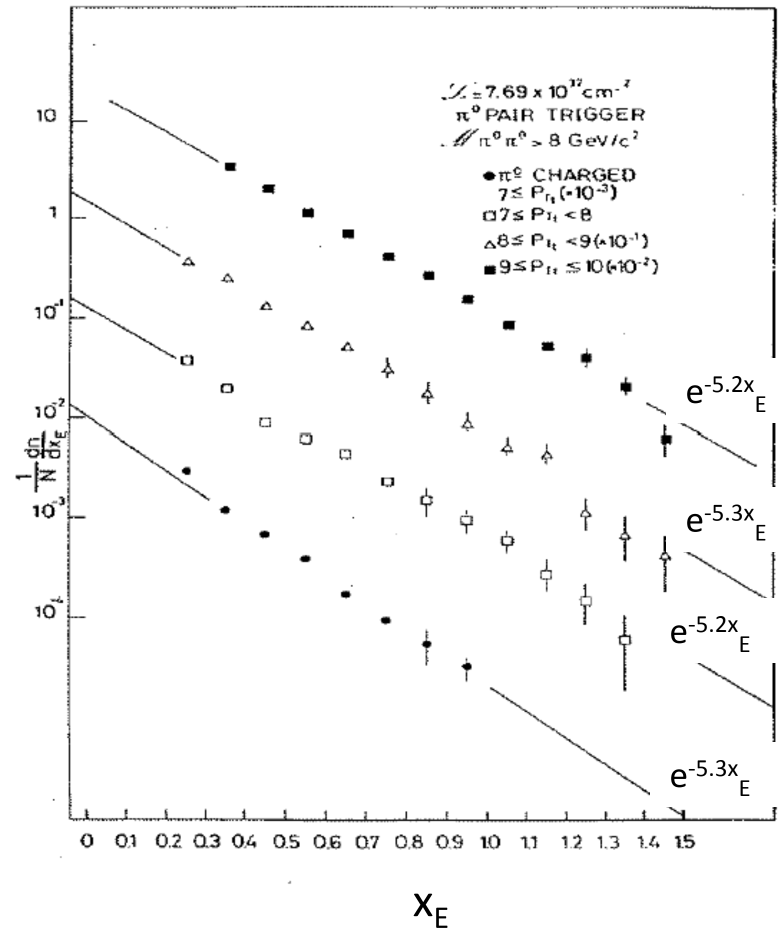
- Relative azimuthal angle $$\Delta\phi = \phi_{assoc} - \phi_{trigger}$$
- Transverse comp. wrt trigger $$p_{out} = p_{Ta} \sin\Delta\phi$$
  - jet shape (jet frag. Trans. mom j_T)
  - di-jet acoplanarity (k_T)
- Longitudinal comp. wrt. Trigger $$x_E = -\frac{p_{Ta}}{p_{Tt}} \cos\Delta\phi$$
  - related to Fragmentation Function

However, does x_E have anything to do with FF?

- Since 1970ties till 2006 (*PRD 74, 072002 (2006)*) it was believed that

  $dN/dx_E \approx FF$

- CCOR data – the slope seems to be constant as expected from the universality of the Fragmentation Function.



CCOR Physics Scripta 19, 116-123 (1979)
π^0 trigger not a leading particle

Simple xE kinematics arguments

Trigger particle

Associated particle

Assoc jet

$$x_E \equiv -\frac{\vec{p}_{Tt}\cdot\vec{p}_{Ta}}{p_{Tt}^2} = -\frac{p_{Ta}}{p_{Tt}}\cos\Delta\phi \; ; \; \left.\frac{z_a \hat{p}_{Ta}}{z_t \hat{p}_{Tt}}\right|_{\Delta\phi\to\pi} \; ; \; \left.\frac{z_a}{\langle z_t\rangle}\right|_{\Delta\phi\to\pi\wedge k_T\to 0} = z_a\Big|_{\Delta\phi\to\pi\wedge k_T\to 0\wedge z_t\to 1}$$

Trigger jet

1. For the back-to-back $\cos(\Delta\varphi)\to 1 \;\Rightarrow\; p_{t,a}\to z_{t,a}\hat{p}_{Tta}$ and $x_E = \frac{z_a \hat{p}_{Ta}}{z_t \hat{p}_{Tt}}$

AND

2. For $k_T \to 0$ (no di-jet imbalance) $x_E = \frac{z_a}{z_t}$

AND

3. For $\langle z_t\rangle \to 1$ (e.g. gamma-jet correlations) $x_E = z_a$

x_E is then a fragmentation variable

Or Bjorken “parent-child relation” and the “trigger bias”

The reasons why $x_E = z_a$ equivalence has been generally adopted follows:

–Bjorken “parent-child” rel.[*Phys. Rev.*, **1973**, *D8*, 4098]

–Jacob “trigger bias” [*Phys.Rept.*, **1978**, *48*, 28]

Assumptions:

1. jet-spectrum has power law shape ~ $p^{-n}_{T,jet}$

2. Power n doesn’t vary much with p_T

pQCD and power law

Dimensional analysis:

$$[\sigma]=\mathrm{GeV}^{-2} \text{ and } \left[E\frac{d^3\sigma}{d^3p}\right]=GeV^{-4}$$

then pp $\rightarrow a+X$ kinematics is completely fixed by the two dimensional quantities s and p_T and two angles φ and ϑ. Any combination of s and p_T preserving dims

$$E\frac{d^3\sigma}{d^3p}=\frac{p_T^4}{s^4}g(x_T,\vartheta)=\frac{p_T^4}{256}\frac{x_T^8}{p_T^8}g(x_T,\vartheta)=\frac{1}{p_T^4}g(x_T,\vartheta)$$

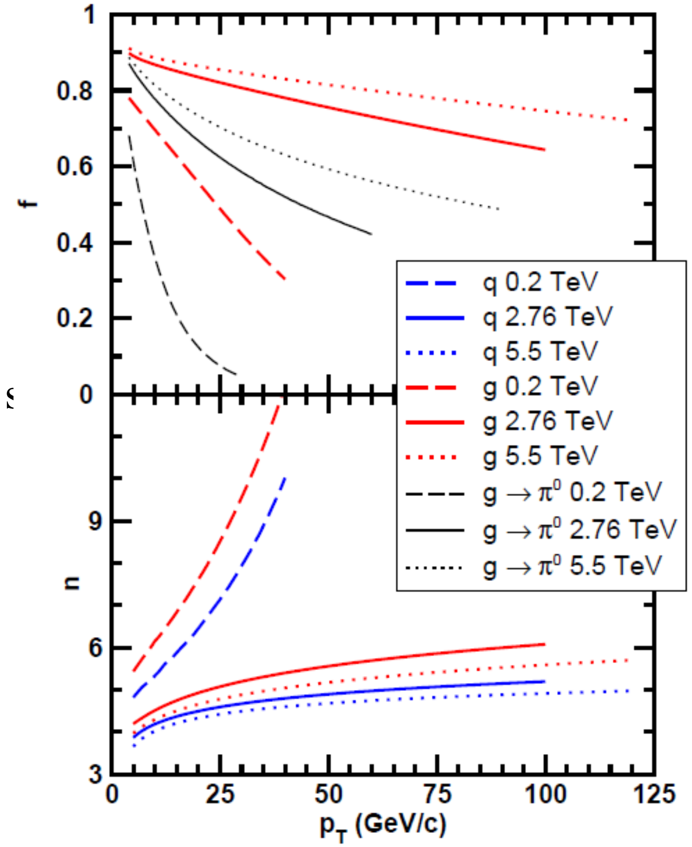
However

- Running $\alpha(Q^2)$
- PDF evolution
- k_T smearing
- Higher-twist phenomena

$$n^{++}\rightarrow n\left(x_T,\sqrt{s}\right)$$

$$n\sim 8\ @\ \mathrm{RHIC}$$

$$n\sim 6\ @\ \mathrm{LHC}$$



Courtesy of W. A. Horowitz

Or Bjorken "parent-child relation" and the "trigger bias"

Final state parton invar. Dist. $f_q(\hat{p}_T)$

$$\frac{1}{p_T}\frac{dN}{dp_T} \approx \int_{xT}^{1} A D_h^q(z)\left(\frac{p_T}{z}\right)^{-n}\frac{dz}{z^2} \approx \frac{A}{p_T^n}\int_{xT}^{1} D_h^q(z) z^{n-2}\, dz$$

$$f_q(\hat{p}_T) \propto \hat{p}_T^{-n} \approx \frac{1}{p_T}\frac{dN}{dp_T} \quad \text{where } n \sim 6 \text{ @ 7TeV}$$

Trigger bias
Small z fragments strongly suppressed

Parent-child rel.
Jet cross section has
The "same" shape as
Particle cross section

Mean z

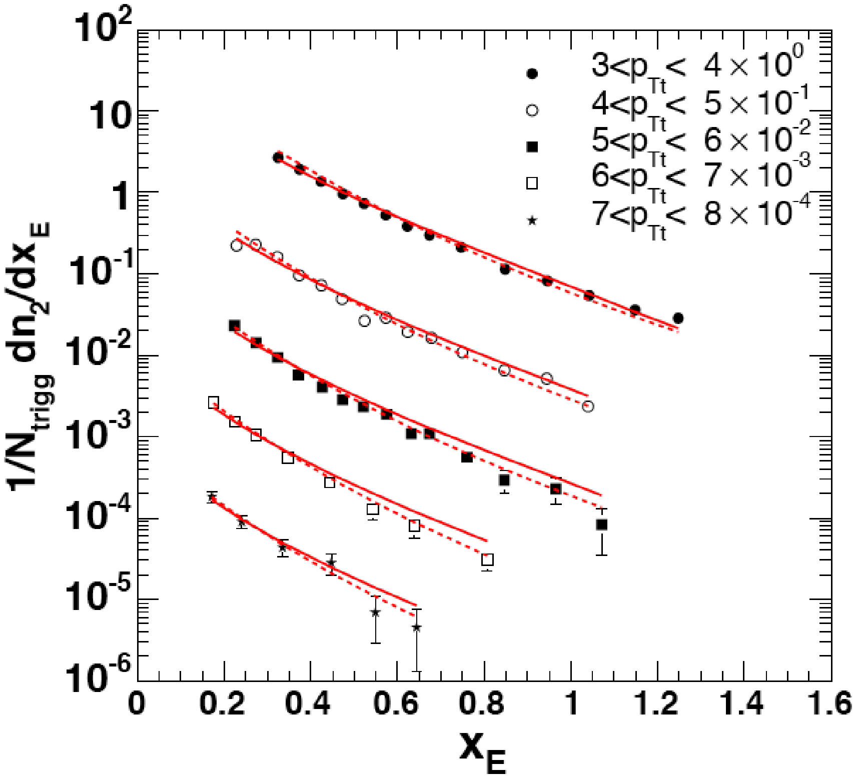
$$\langle z \rangle = \frac{1}{N}\int_{xT}^{1} z D_h^q(z)\left(\frac{p_T}{z}\right)^{-n}\frac{dz}{z^2}$$

$$0.2 \text{ TeV} \rightarrow \langle z \rangle = 0.7 \quad \text{RHIC } \pi^0$$

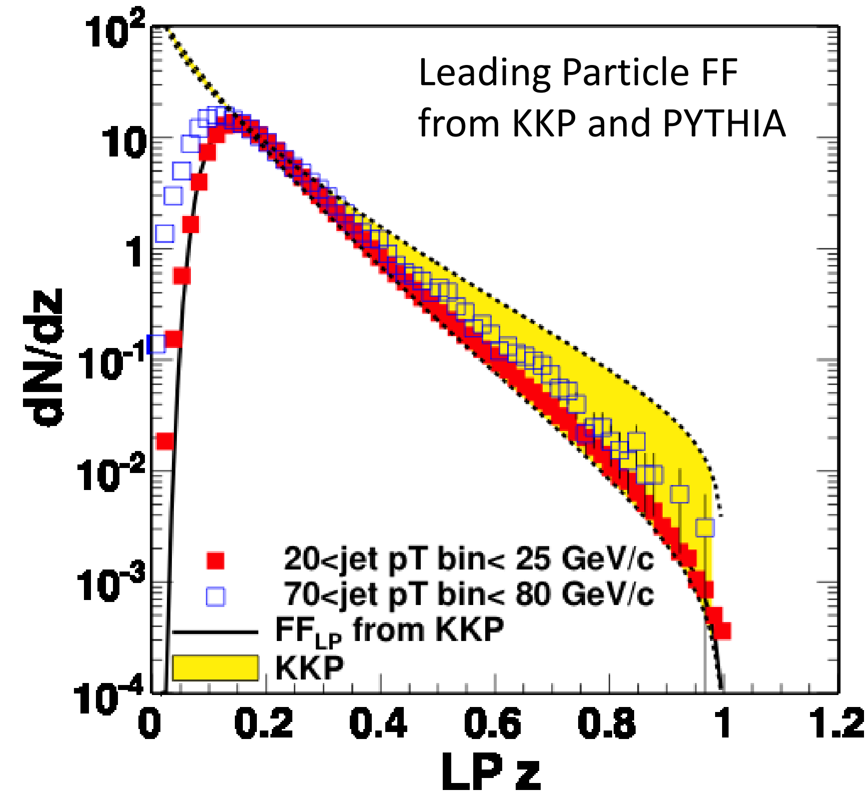
$$0.9 \text{ TeV} \rightarrow \langle z \rangle = 0.6 \pm 0.05$$

$$7.0 \text{ TeV} \rightarrow \langle z \rangle = 0.55 \pm 0.05 \qquad 0.05 \text{ coming from } D_h^q(z)$$

Dihadron $\langle z_t \rangle \neq 1$: x_E by PHENIX



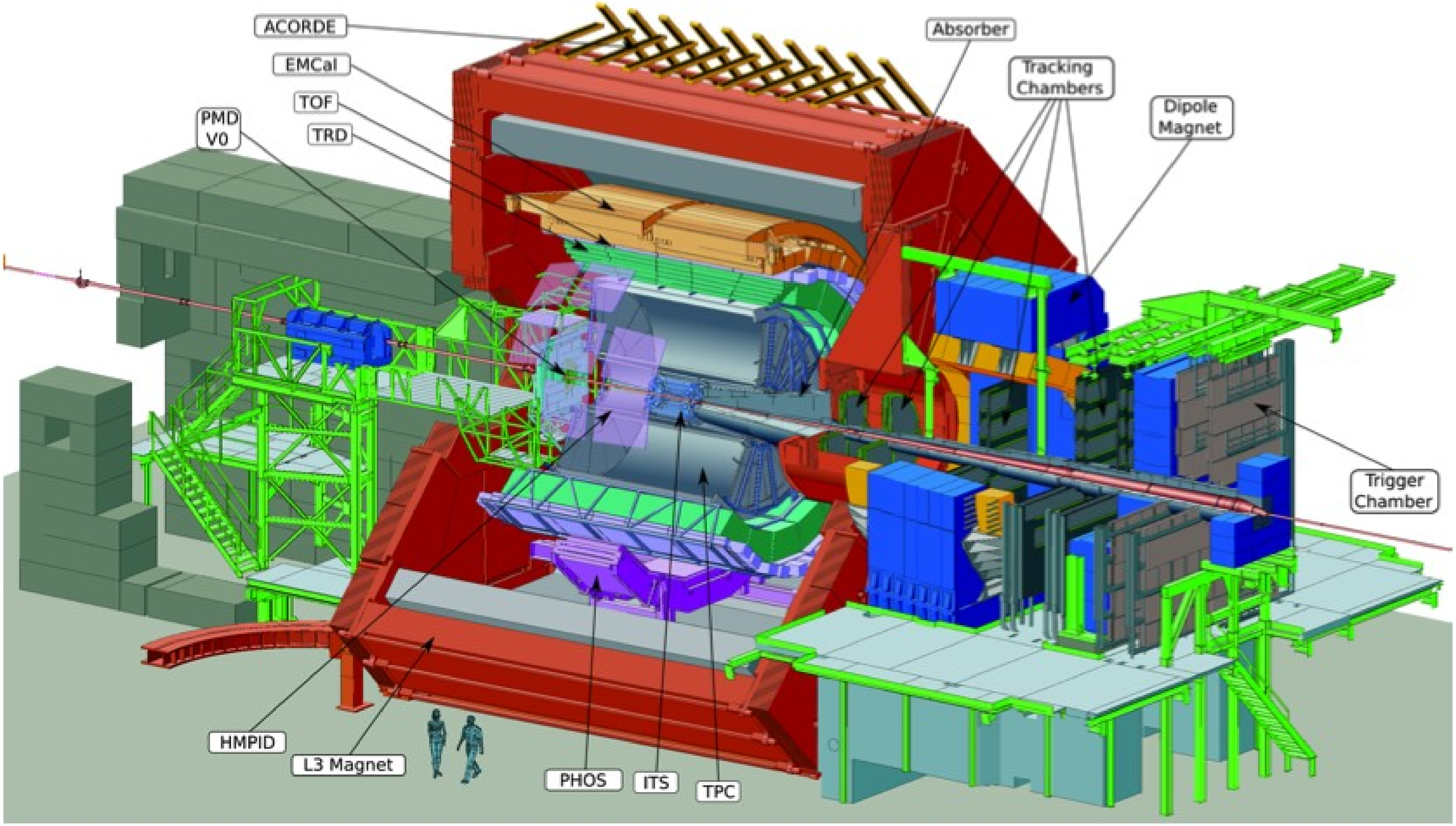
PHENIX, Phys. Rev D 74, 072002 (2006)



fixed p_{Tt} while varying p_{Ta} changes $\langle z_a \rangle$ and $\langle z_t \rangle$.

Left figure: Measured dN/dx_E compared with dN/dx_E calculated using FF of quark $D_q \propto (-8.2\ z)$ (solid line) and gluon $D_g \propto (-11.4\ z)$ (dashed line) from LEP.

x_E distributions in ALICE



Analysis details

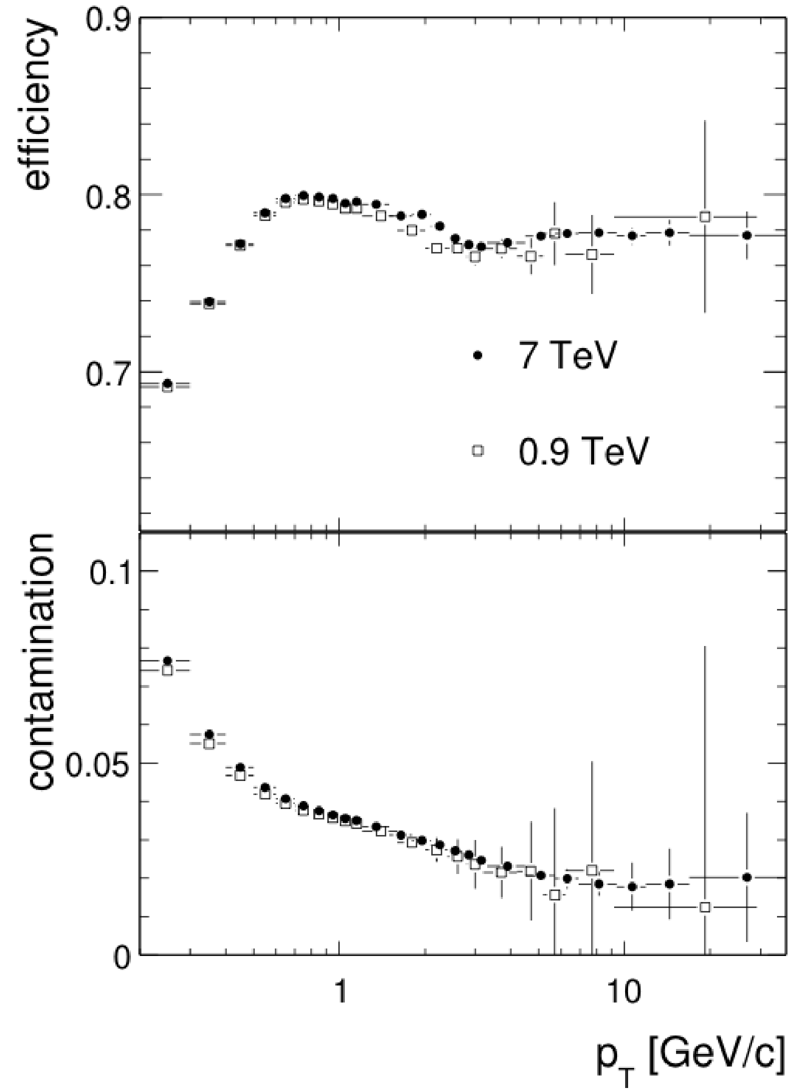
Analyzed p+p runs from 2010:

√s = 0.9 TeV (10 Mevents, 110 μb^{-1})

√s = 7 TeV (370 Mevents, 6 nb^{-1})

Analysis cuts:

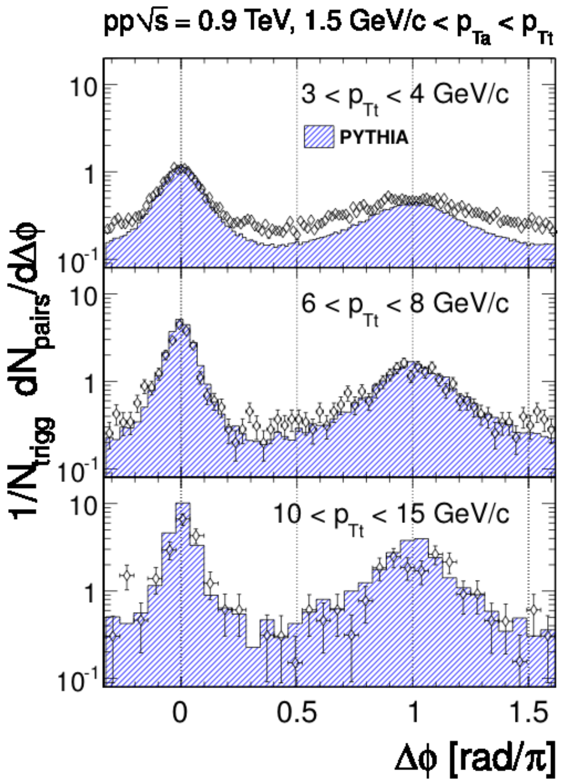
- min. bias trigger + |vertex z| < 10 cm
- ITS + TPC tracking
- primary tracks
  (tight cut on DCA to vertex)
- charged tracks with $|\eta| < 0.8$

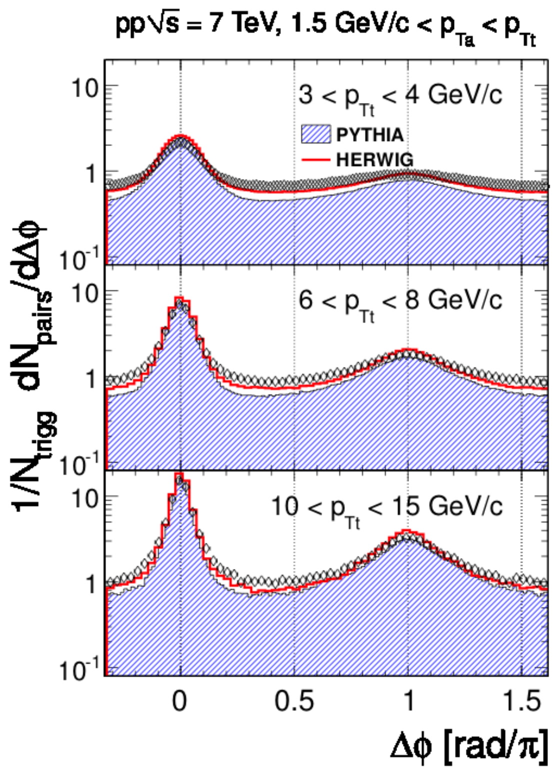


dN/dΔφ distributions from p+p at √s = 0.9 and 7 TeV

√s from 0.9 to 7 TeV :

- broadening of away side peak
- increase of pedestal





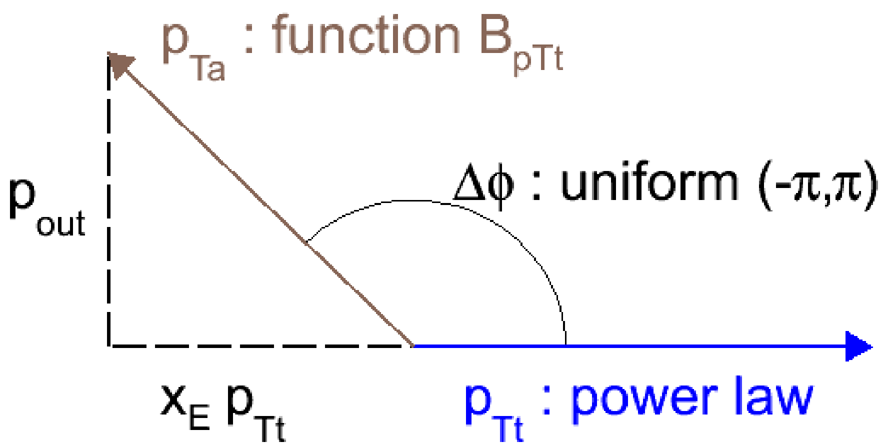
Charged tracks in pseudorapidity range |η|<0.8

Estimate of x_E and p_{out} background

Bg. pairs = assoc. particle is uncorrelated with the trigger in azimuth

- Isotropic in $\Delta\phi$
- $dN_{bg}/dp_{Ta} \,|p_{Tt} = B_{pTt}\,(p_{Ta})$

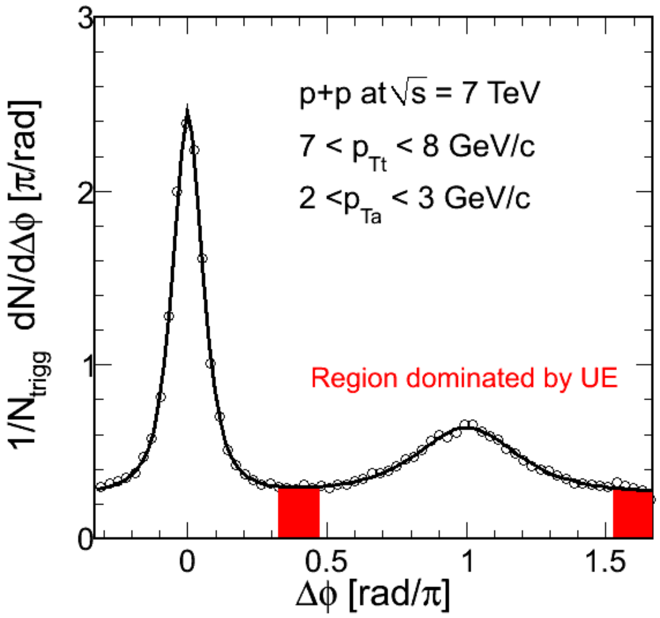
$\Rightarrow$ Bg. component of x_E and p_{out} can be estimated with a toy MC

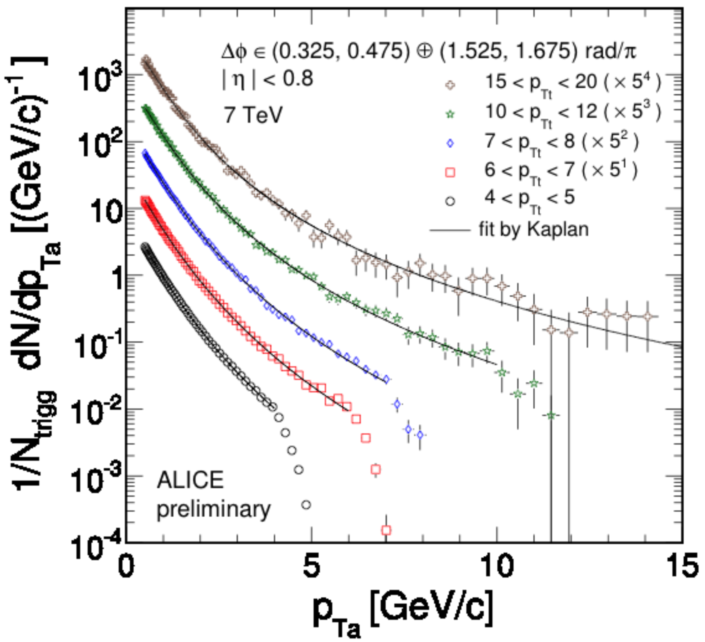


- check that $p_{Ta,min} < p_{Ta} < p_{Tt}$ (or $p_{Ta,min} < p_{Ta} < p_{Ta,max}$)
- absolute normalization: $dN/d\Delta\phi$ (x_E) or directly from fit (p_{out})
- Where to get the function B?

How to assess $B_{pTt}(p_{Ta})$?

- $B_{pTt}(p_{Ta}) \approx$ trigger associated dN/dp_{Ta} distributions of particles from the regions around minima of $dN/d\Delta\phi$.





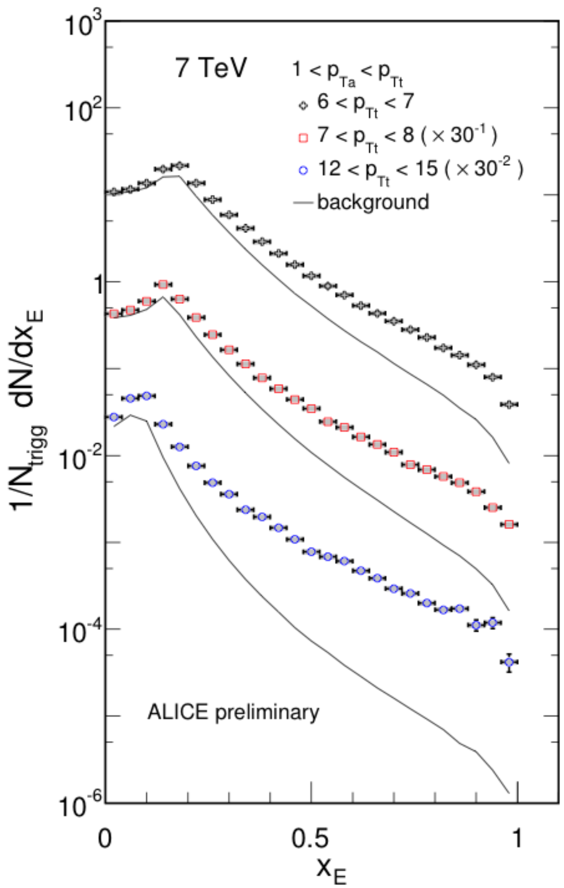
Region dominated by UE
$\Delta\phi$ = (0.325, 0.475) + (1.525,1.675) rad/π

Fit by Kaplan in $p_{Ta} < p_{Tt,min}$
Tail affected by $p_{Ta} < p_{Tt}$

Measured x_E and p_{out} and background

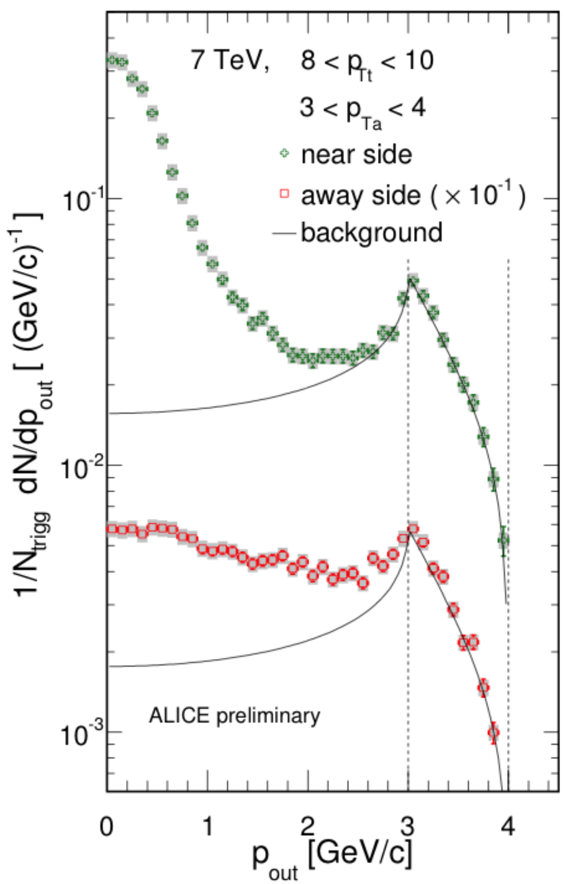
x_E at away side :

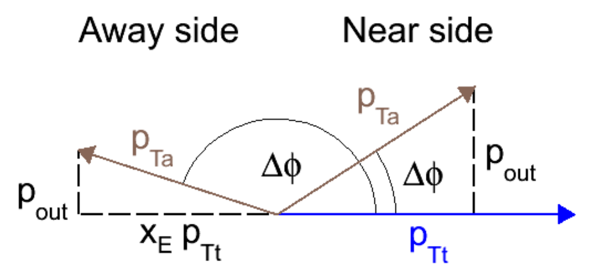
$x_E = -\,(p_{Ta} / p_{Tt})\,\cos\Delta\phi$



p_{out} at near side and away side :

$p_{out} = p_{Ta} \sin\Delta\phi$





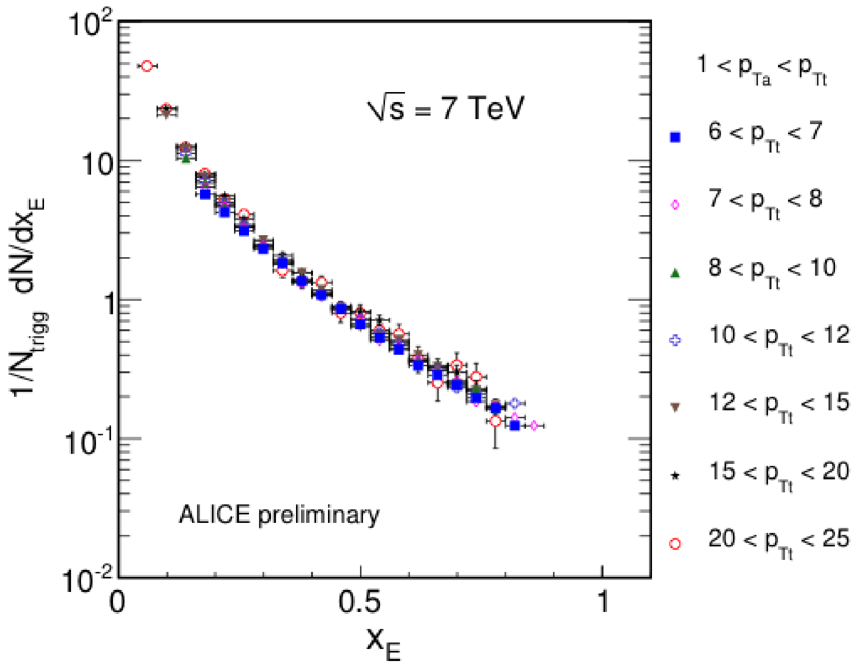
Horn structure in p_{out} bg results from Jacobian

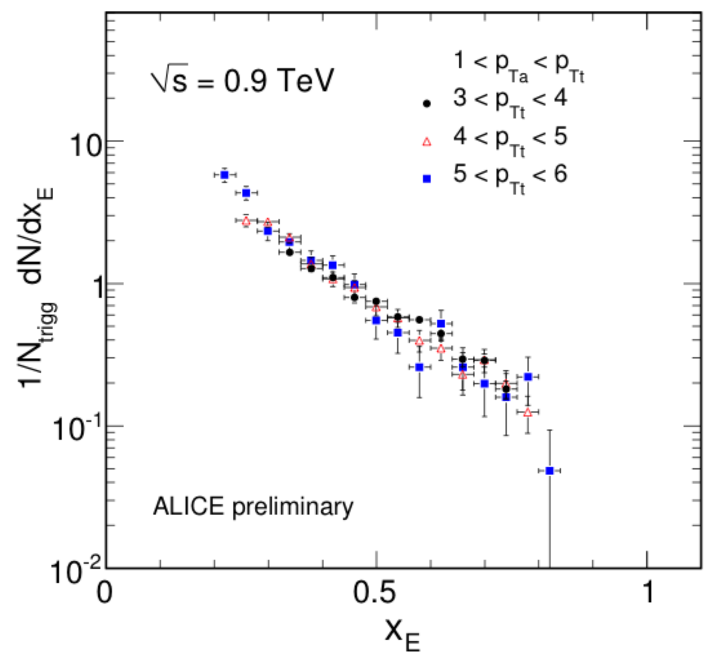
$$\frac{dN_{bg}}{dp_{out}} = \frac{dN_{bg}}{d\Delta\phi}\frac{d\Delta\phi}{dp_{out}}$$

$$\frac{dN_{bg}}{dp_{out}} \propto \left(p_{Ta}\cos\Delta\phi\right)^{-1}$$

for p_{Ta} fixed

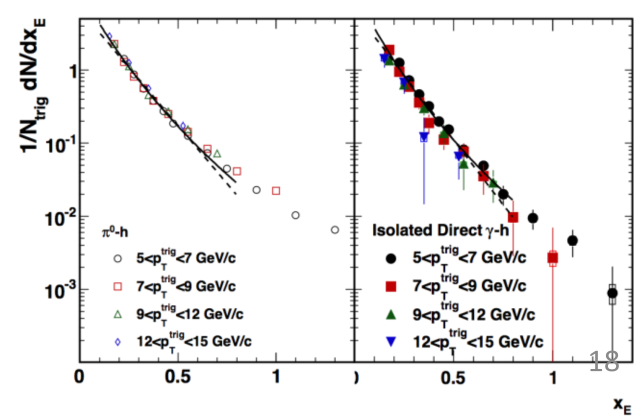
x_E signal from ALICE



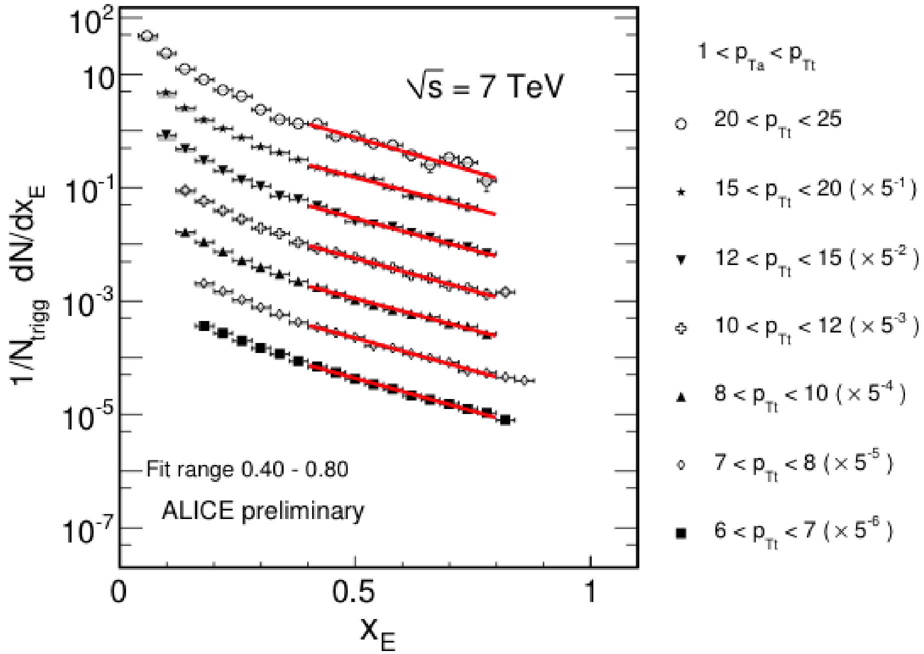


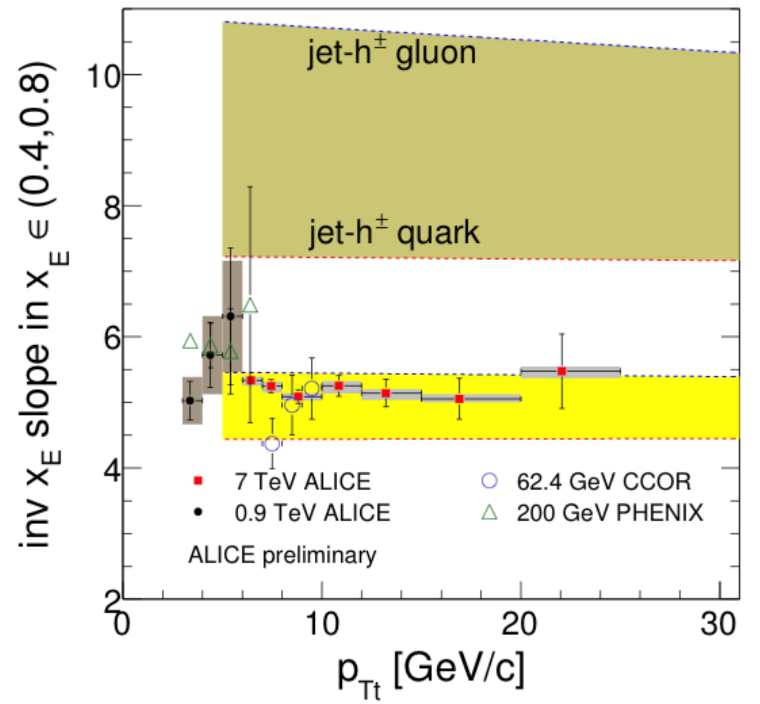
For given √s all x_E distributions seem to
follow one universal trend
as it is suggested also by π^0-h and γ_{dir}-h
data from PHENIX

PHENIX arXiv:1006.1347v1 [hep-ex] :



Inverse x_E slope





- Fit dN/dx_E by exponential in range x_E = (0.4, 0.8)
- 7 TeV data exhibit uniform x_E slope over a wide p_{Tt} range
- similar slopes for different √s

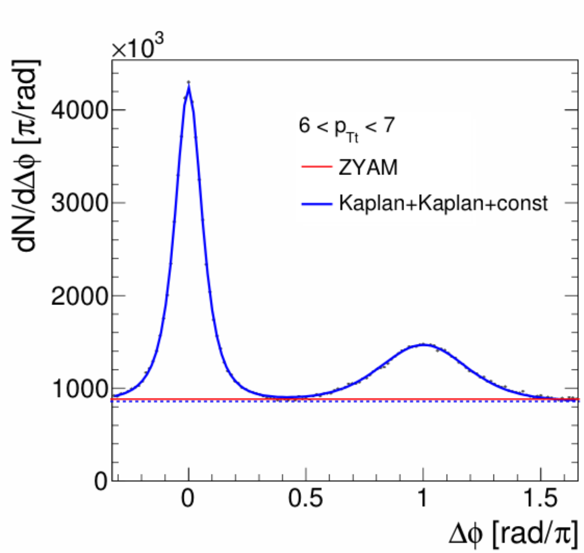
CCOR Physics Scripta 19, 116-123 (1979)
PHENIX, Phys. Rev D 74, 072002 (2006)

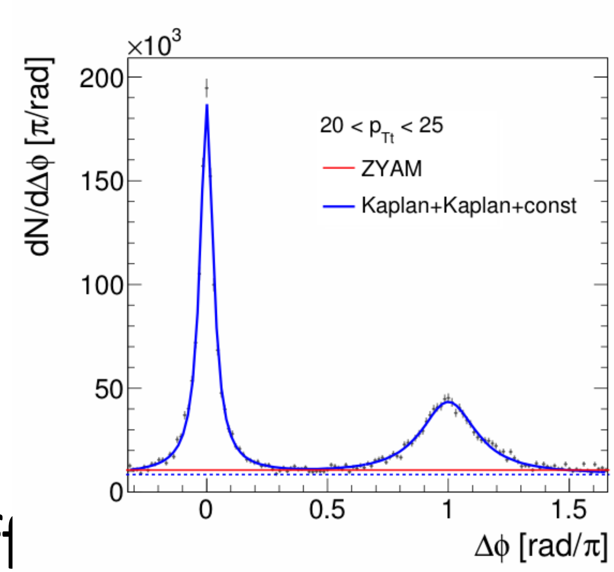
- High-x_E tail -> Inverse slope measures $\langle z_t \rangle$
- Low-x_E tail -> measures ⟨\hat{x}$_h$⟩ see Mike's talk earlier today

Sources of Systematic Uncertainties

- Absolute normalization of background

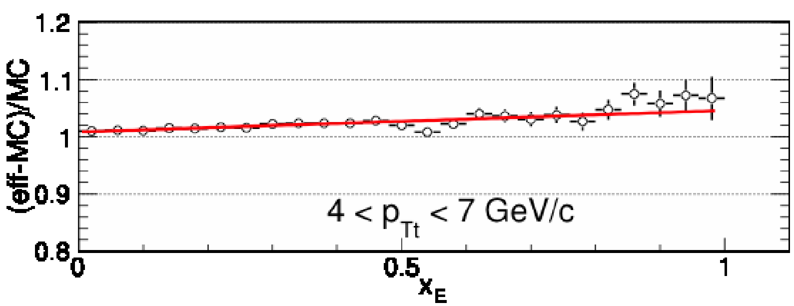
(fit dN/d$\Delta\phi$ by Kaplan+Kaplan+const or use ZYAM ?)

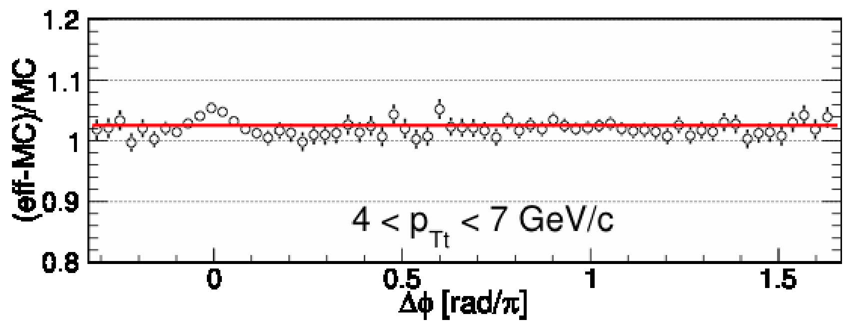




- Correction o… eff…

(motivated by simulation : per trigger normalized reconstructed + eff. corrected /input MC)

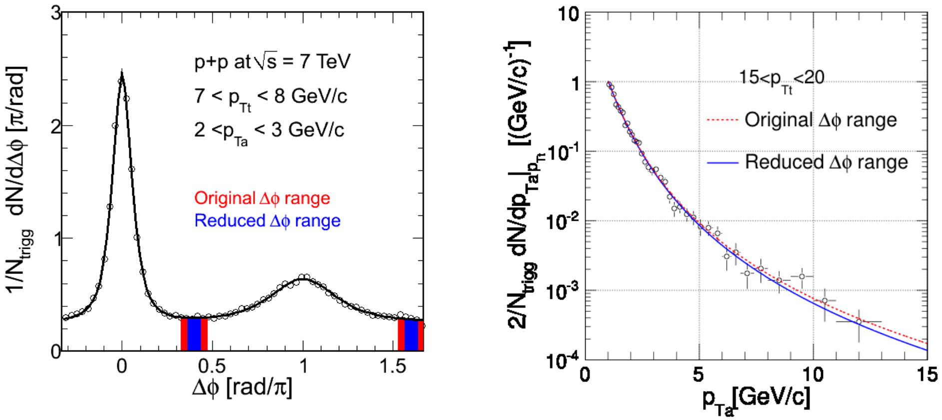




Sources of Systematic Uncertainties

- Variability of $dN/dp_{Ta}|_{pTt}$ with selected $\Delta\phi$ range

  (assess $dN/dp_{Ta}|_{pTt}$ from two times narrower range)



- Parameterization of $dN/dp_{Ta}|p_{Tt}$

  (in toy MC sample p_{Ta} directly from the measured $dN/dp_{Ta}|p_{Tt}$)

- Parameterization of dN/dp_{Tt}

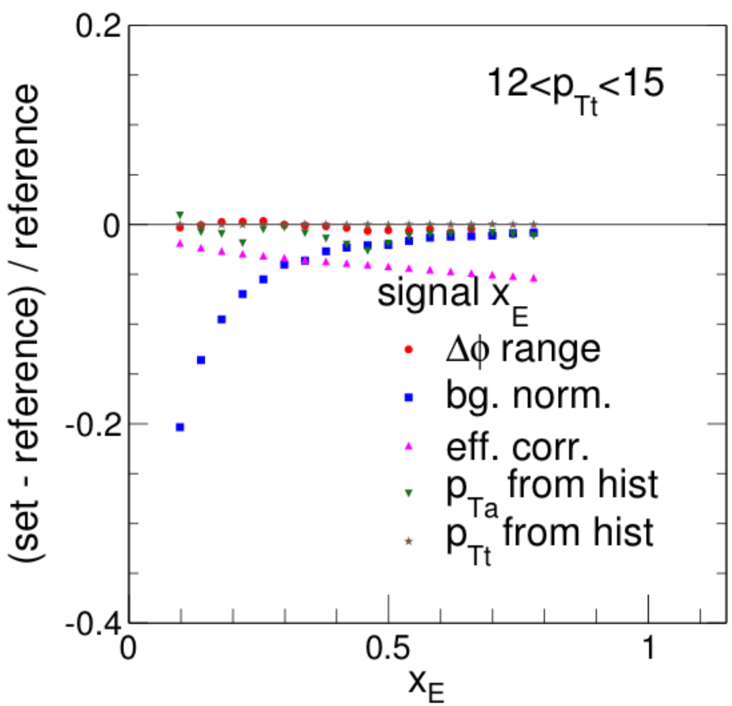
  (in toy MC sample p_{Tt} directly from the measured dN/dp_{Tt})

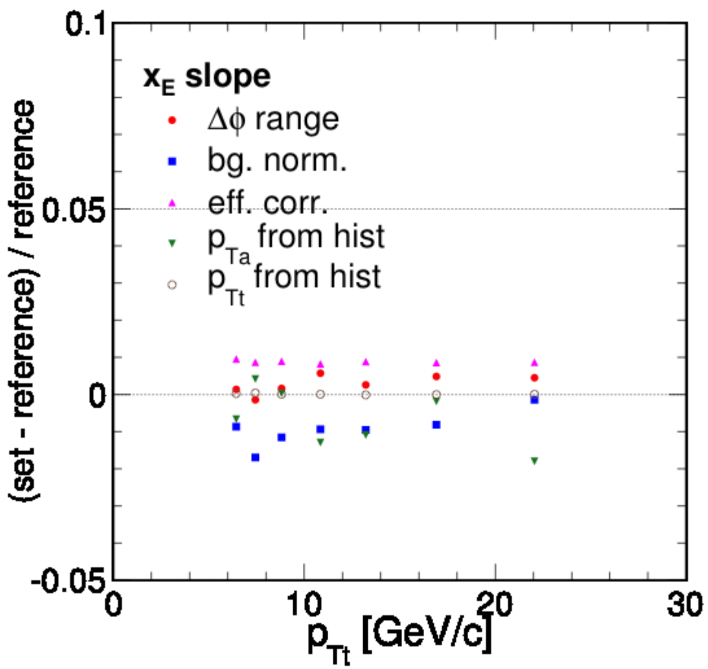
Sources of Systematic Uncertainties

- Absolute normalization of background ("bg. norm")
- Correction on reconstruction efficiency ("eff. corr.")
- Variability of $dN/dp_{Ta}|_{pTt}$ with selected $\Delta\phi$ range ("$\Delta\phi$ range")
- Parameterization of $dN/dp_{Ta}|p_{Tt}$ ("pTa from hist")
- Parameterization of dN/dp_{Tt} ("pTt from hist")

overall upper syst. uncertainty = Σ positive deviations

overall lower syst. uncertainty = Σ negative deviations

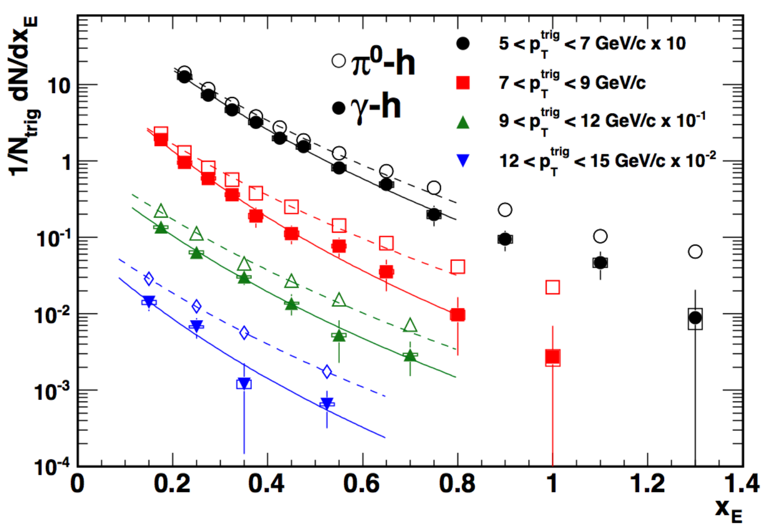


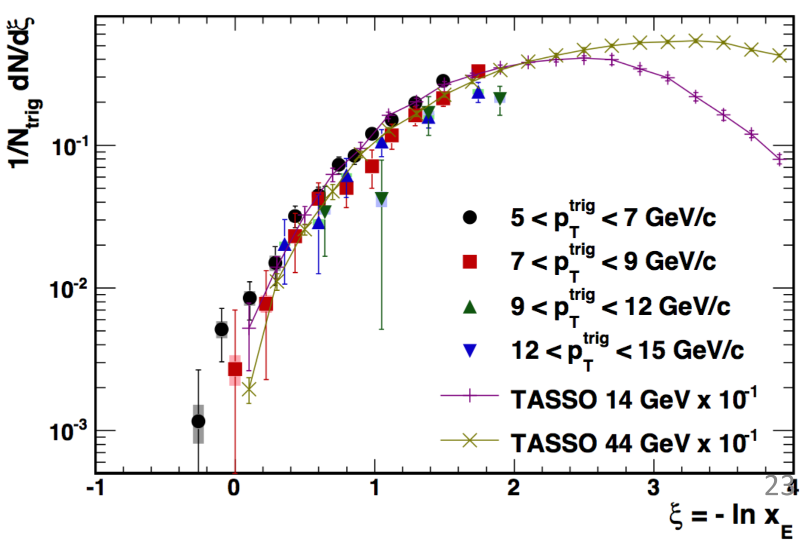


Future goals

- x_E from di-hadron correlation is not a direct measurement of fragmentation function
- Continue the analysis in pp and HI using as a trigger
  - isolated hadron (higher twist)
  - direct photons (x_E should be FF modulo k_T smearing)

PHENIX arXiv:1006.1347v1 [hep-ex] : correlation γ_{dir} -h





Summary

The leading particle associated yield p+p a $\sqrt{s}$ =0.9 and 7 TeV was analyzed in order to study jet fragmentation.

- $\Delta\phi$: increase of yield of associated particles uncorrelated with trigger in azimuth when going from $\sqrt{s}$ =0.9 to 7 TeV

- away side dN/dxE :
  - ALICE data seem to follow one universal trend independent of p_{Tt} for given $\sqrt{s}$
  - inverse dN/dx_E slopes from 0.9 and 7 TeV are compatible with lower $\sqrt{s}$ measurements (CCOR, PHENIX)

Backup slides

Preliminary Inverse x_E slope

Table 16: Inverse x_{E} slopes extracted from the ALICE measurement of $p+p$ at $\sqrt{s}=7$ TeV. Range of the fit was $x_{\mathrm{E}} \in (0.4, 0.8)$. ALICE preliminary.

$p_{\mathrm{Tt,min}}$ [GeV/c]	$p_{\mathrm{Tt,max}}$ [GeV/c]	Mean p_{Tt} [GeV/c]	inverse x_{E} slope	Stat. err.	Syst. err. high	Syst. err. low
4	5	4.41	5.17	0.049	0.075	0.17
5	6	5.43	5.26	0.061	0.057	0.19
6	7	6.44	5.34	0.079	0.059	0.082
7	8	7.44	5.25	0.099	0.069	0.097
8	10	8.82	5.09	0.10	0.055	0.059
10	12	10.85	5.25	0.16	0.074	0.12
12	15	13.22	5.14	0.21	0.059	0.11
15	20	16.91	5.05	0.31	0.068	0.051
20	25	22.06	5.48	0.57	0.072	0.11
25	30	27.16	6.5	1.1	0.15	0.12

Table 17: Inverse x_{E} slopes extracted from the ALICE measurement of $p+p$ at $\sqrt{s}=0.9$ TeV. Range of the fit was $x_{\mathrm{E}} \in (0.4, 0.8)$. ALICE preliminary.

$p_{\mathrm{Tt,min}}$ [GeV/c]	$p_{\mathrm{Tt,max}}$ [GeV/c]	Mean p_{Tt} [GeV/c]	inverse x_{E} slope	Stat. err.	Syst. err. high	Syst. err. low
3	4	3.38	5.03	0.29	0.36	0.36
4	5	4.39	5.72	0.49	0.59	0.59
5	6	5.41	6.3	1.0	0.84	0.84

Prelim. away side x_E signal (0.9 TeV)

Table 14: Away side dN/dx_E signal for $p_{Tt} \in (4,5)$ GeV/c where the mean p_{Tt} is 4.39 GeV/c. Associated particle was in the range 1 GeV/$c < p_{Ta} < p_{Tt}$. Data for p+p at $\sqrt{s}$=0.9 TeV. ALICE preliminary.

x_E	dN/dx_E	Stat. err.	Syst. err. high	Syst. err. low
0.259	3.02	0.38	0.21	0.10
0.299	2.86	0.28	0.10	0.16
0.339	2.20	0.21	0.10	0.15
0.379	1.43	0.16	0.032	0.14
0.419	1.12	0.13	0.022	0.20
0.459	0.96	0.11	0.015	0.18
0.499	0.703	0.096	0.010	0.13
0.539	0.586	0.084	0.0074	0.11
0.579	0.407	0.070	0.0055	0.079
0.619	0.356	0.063	0.0038	0.061
0.659	0.235	0.052	0.0066	0.051
0.699	0.293	0.054	0.012	0.047
0.739	0.200	0.045	0.010	0.037
0.779	0.127	0.037	0.0013	0.031

Table 15: Away side dN/dx_E signal for $p_{Tt} \in (5,6)$ GeV/c where the mean p_{Tt} is 5.41 GeV/c. Associated particle was in the range 1 GeV/$c < p_{Ta} < p_{Tt}$. Data for p+p at $\sqrt{s}$=0.9 TeV. ALICE preliminary.

x_E	dN/dx_E	Stat. err.	Syst. err. high	Syst. err. low
0.219	6.5	0.92	0.095	2.2
0.259	4.77	0.61	0.0012	1.4
0.299	2.60	0.42	0.00054	0.86
0.339	2.13	0.32	0.00044	0.59
0.379	1.56	0.26	0.00055	0.47
0.419	1.42	0.23	0.00033	0.32
0.459	1.04	0.19	0.042	0.23
0.499	0.59	0.15	0.048	0.16
0.539	0.48	0.13	0.046	0.13
0.579	0.28	0.10	0.044	0.096
0.619	0.54	0.13	0.042	0.089
0.659	0.273	0.094	0.040	0.064
0.700	0.210	0.083	0.033	0.052
0.740	0.168	0.074	0.034	0.041
0.780	0.228	0.082	0.029	0.038
0.820	0.054	0.045	0.023	0.023

Table 13: Away side dN/dx_E signal for $p_{Tt} \in (3,4)$ GeV/c where the mean p_{Tt} is 3.38 GeV/c. Associated particle was in the range 1 GeV/$c < p_{Ta} < p_{Tt}$. Data for p+p at $\sqrt{s}$=0.9 TeV. ALICE preliminary.

x_E	dN/dx_E	Stat. err.	Syst. err. high	Syst. err. low
0.339	1.65	0.11	0.029	0.12
0.379	1.276	0.093	0.0065	0.10
0.419	1.104	0.079	0.0049	0.080
0.459	0.796	0.065	0.018	0.057
0.499	0.748	0.058	0.033	0.048
0.539	0.586	0.049	0.039	0.051
0.579	0.557	0.045	0.037	0.038
0.619	0.444	0.039	0.041	0.026
0.659	0.294	0.033	0.036	0.019
0.699	0.288	0.031	0.036	0.018
0.739	0.182	0.025	0.024	0.014

Prelim. away side x_E signal (7 TeV)

Table 5: Away side dN/dx_E signal for $p_{Tt} \in (6,7)$ GeV/c where the mean p_{Tt} is 6.44 GeV/c. Associated particle was in the range 1 GeV/c < p_{Ta} < p_{Tt}. Data for p+p at $\sqrt{s}$=7 TeV. ALICE preliminary.

x_E	dN/dx_E	Stat. err.	Syst. err. high	Syst. err. low
0.179	5.72	0.11	0.0023	0.64
0.219	4.231	0.071	0.018	0.40
0.259	3.126	0.051	0.036	0.27
0.299	2.308	0.038	0.039	0.19
0.339	1.824	0.030	0.023	0.14
0.379	1.361	0.024	0.023	0.11
0.419	1.082	0.020	0.019	0.095
0.459	0.856	0.017	0.012	0.067
0.499	0.661	0.015	0.014	0.048
0.539	0.532	0.013	0.0087	0.038
0.579	0.438	0.011	0.0070	0.034
0.619	0.3353	0.0098	0.0055	0.029
0.659	0.2852	0.0088	0.0036	0.022
0.699	0.2415	0.0079	0.0033	0.017
0.739	0.19599	0.0070	0.0068	0.014
0.779	0.1662	0.0063	0.0020	0.012
0.819	0.1239	0.0055	0.0029	0.0094

Table 6: Away side dN/dx_E signal for $p_{Tt} \in (7,8)$ GeV/c where the mean p_{Tt} is 7.44 GeV/c. Associated particle was in the range 1 GeV/c < p_{Ta} < p_{Tt}. Data for p+p at $\sqrt{s}$=7 TeV. ALICE preliminary.

x_E	dN/dx_E	Stat. err.	Syst. err. high	Syst. err. low
0.179	6.43	0.15	0.034	1.1
0.219	4.656	0.093	0.038	0.65
0.259	3.280	0.065	0.025	0.45
0.299	2.436	0.048	0.021	0.30
0.339	1.814	0.038	0.023	0.19
0.379	1.319	0.031	0.016	0.14
0.419	1.084	0.026	0.0080	0.11
0.459	0.854	0.022	0.012	0.080
0.499	0.719	0.019	0.0075	0.057
0.539	0.506	0.016	0.0053	0.042
0.579	0.466	0.015	0.0051	0.039
0.619	0.364	0.013	0.0051	0.028
0.659	0.309	0.012	0.0042	0.024
0.699	0.259	0.011	0.0021	0.025
0.739	0.1842	0.0091	0.0032	0.018
0.779	0.1695	0.0085	0.0014	0.017
0.819	0.1417	0.0077	0.0010	0.013
0.859	0.1235	0.0071	0.0022	0.0091

Table 7: Away side dN/dx_E signal for $p_{Tt} \in (8,10)$ GeV/c where the mean p_{Tt} is 8.82 GeV/c. Associated particle was in the range 1 GeV/c < p_{Ta} < p_{Tt}. Data for p+p at $\sqrt{s}$=7 TeV. ALICE preliminary.

x_E	dN/dx_E	Stat. err.	Syst. err. high	Syst. err. low
0.139	10.38	0.21	0.057	1.57
0.179	6.90	0.12	0.0008	0.89
0.219	4.702	0.080	0.024	0.50
0.259	3.290	0.058	0.038	0.31
0.299	2.478	0.045	0.033	0.21
0.339	1.879	0.037	0.023	0.14
0.379	1.397	0.030	0.025	0.11
0.419	1.100	0.026	0.020	0.089
0.459	0.851	0.022	0.014	0.077
0.499	0.663	0.019	0.012	0.057
0.539	0.533	0.017	0.011	0.040
0.579	0.439	0.015	0.0098	0.031
0.619	0.366	0.014	0.0063	0.028
0.659	0.329	0.013	0.0028	0.025
0.699	0.252	0.011	0.0048	0.021
0.739	0.225	0.010	0.0032	0.018
0.779	0.1648	0.009	0.0028	0.014

Table 8: Away side dN/dx_E signal for $p_{Tt} \in (10,12)$ GeV/c where the mean p_{Tt} is 10.85 GeV/c. Associated particle was in the range 1 GeV/c < p_{Ta} < p_{Tt}. Data for p+p at $\sqrt{s}$=7 TeV. ALICE preliminary.

x_E	dN/dx_E	Stat. err.	Syst. err. high	Syst. err. low
0.138	11.22	0.28	0.050	1.8
0.179	7.19	0.16	0.045	0.91
0.219	4.92	0.11	0.076	0.54
0.259	3.440	0.082	0.062	0.33
0.299	2.409	0.065	0.042	0.20
0.339	1.932	0.055	0.033	0.17
0.379	1.338	0.045	0.019	0.14
0.419	1.063	0.039	0.014	0.11
0.459	0.888	0.035	0.0074	0.078
0.499	0.723	0.031	0.0064	0.058
0.539	0.579	0.028	0.0045	0.047
0.579	0.479	0.025	0.0029	0.042
0.619	0.358	0.022	0.0018	0.030
0.659	0.315	0.020	0.0012	0.025
0.699	0.232	0.017	0.0008	0.016
0.739	0.211	0.016	0.00040	0.014
0.779	0.165	0.014	0.00049	0.012
0.819	0.179	0.015	0.00025	0.012

Prelim. away side x_E signal (7 TeV)

Table 9: Away side dN/dx_E signal for $p_{Tt} \in (12, 15)$ GeV/c where the mean p_{Tt} is 13.22 GeV/c. Associated particle was in the range 1 GeV/c < p_{Ta} < p_{Tt}. Data for p+p at $\sqrt{s}$=7 TeV. ALICE preliminary.

x_E	dN/dx_E	Stat. err.	Syst. err. high	Syst. err. low
0.098	21.15	0.71	0.19	4.6
0.138	12.08	0.32	0	2.0
0.179	7.58	0.19	0.021	0.99
0.219	5.01	0.13	0.014	0.59
0.259	3.40	0.10	0.013	0.31
0.299	2.669	0.084	0.0001	0.20
0.339	1.797	0.068	0.00047	0.15
0.379	1.549	0.061	0	0.12
0.419	1.176	0.053	0	0.10
0.459	0.880	0.045	0.0001	0.082
0.499	0.633	0.038	0	0.056
0.539	0.565	0.036	0.00002	0.044
0.579	0.512	0.034	0.00004	0.037
0.619	0.399	0.030	0	0.031
0.659	0.328	0.027	0	0.022
0.699	0.249	0.024	0.00004	0.020
0.739	0.222	0.022	0	0.018
0.779	0.173	0.019	0	0.014

Table 10: Away side dN/dx_E signal for $p_{Tt} \in (15, 20)$ GeV/c where the mean p_{Tt} is 16.91 GeV/c. Associated particle was in the range 1 GeV/c < p_{Ta} < p_{Tt}. Data for p+p at $\sqrt{s}$=7 TeV. ALICE preliminary.

x_E	dN/dx_E	Stat. err.	Syst. err. high	Syst. err. low
0.098	23.62	0.81	0.21	4.8
0.138	12.76	0.36	0.30	2.0
0.178	7.87	0.23	0.18	0.99
0.219	5.54	0.18	0.10	0.53
0.259	3.82	0.14	0.062	0.32
0.299	2.61	0.12	0.038	0.20
0.339	2.08	0.10	0.024	0.14
0.379	1.56	0.087	0.021	0.10
0.419	1.124	0.074	0.017	0.077
0.459	0.898	0.066	0.0056	0.067
0.499	0.817	0.062	0.0062	0.062
0.539	0.711	0.058	0.0040	0.053
0.579	0.496	0.048	0.0016	0.038
0.619	0.356	0.041	0.0020	0.028
0.659	0.333	0.039	0.0017	0.023
0.699	0.300	0.037	0.0025	0.020
0.739	0.229	0.033	0.0037	0.016

Table 11: Away side dN/dx_E signal for $p_{Tt} \in (20, 25)$ GeV/c where the mean p_{Tt} is 22.1 GeV/c. Associated particle was in the range 1 GeV/c < p_{Ta} < p_{Tt}. Data for p+p at $\sqrt{s}$=7 TeV. ALICE preliminary.

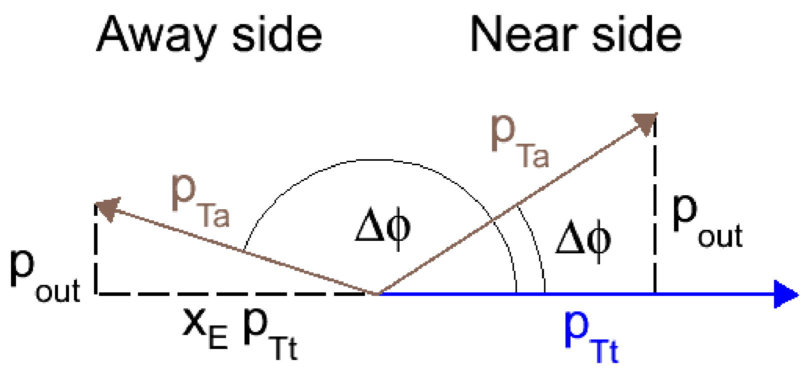
x_E	dN/dx_E	Stat. err.	Syst. err. high	Syst. err. low
0.058	47.8	2.7	0.085	9.9
0.098	23.45	0.95	0.60	3.5
0.138	12.50	0.54	0.19	1.2
0.178	8.02	0.40	0.24	0.54
0.219	5.28	0.32	0.14	0.33
0.259	4.10	0.27	0.072	0.24
0.299	2.37	0.21	0.087	0.16
0.339	1.61	0.17	0.064	0.11
0.379	1.36	0.16	0.035	0.093
0.419	1.33	0.15	0.034	0.085
0.459	0.80	0.12	0.043	0.060
0.499	0.80	0.12	0.039	0.056
0.539	0.60	0.10	0.033	0.045
0.579	0.565	0.099	0.023	0.040
0.619	0.378	0.081	0.020	0.030
0.659	0.253	0.067	0.018	0.023
0.699	0.337	0.076	0.017	0.024
0.739	0.277	0.069	0.014	0.022
0.779	0.133	0.049	0.012	0.014

Two particle observables

$$\Delta\phi = \phi_{assoc} - \phi_{trigger}$$

$$p_{out} = p_{Ta} \sin \Delta\phi$$

$$x_E = -\frac{p_{Ta}}{p_{Tt}} \cos \Delta\phi$$



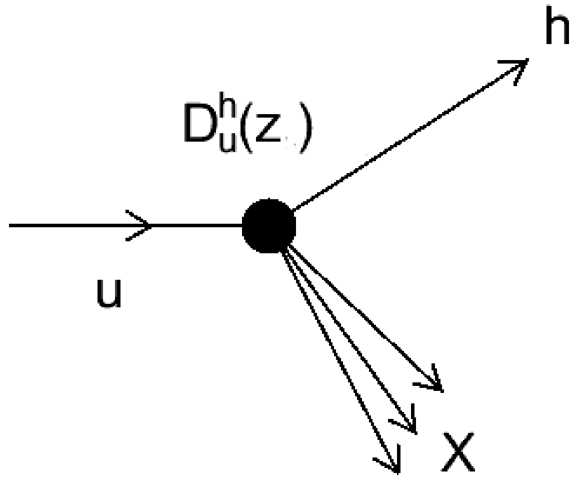
Near side pout related to j_T
Away side pout related to k_T folded with j_T

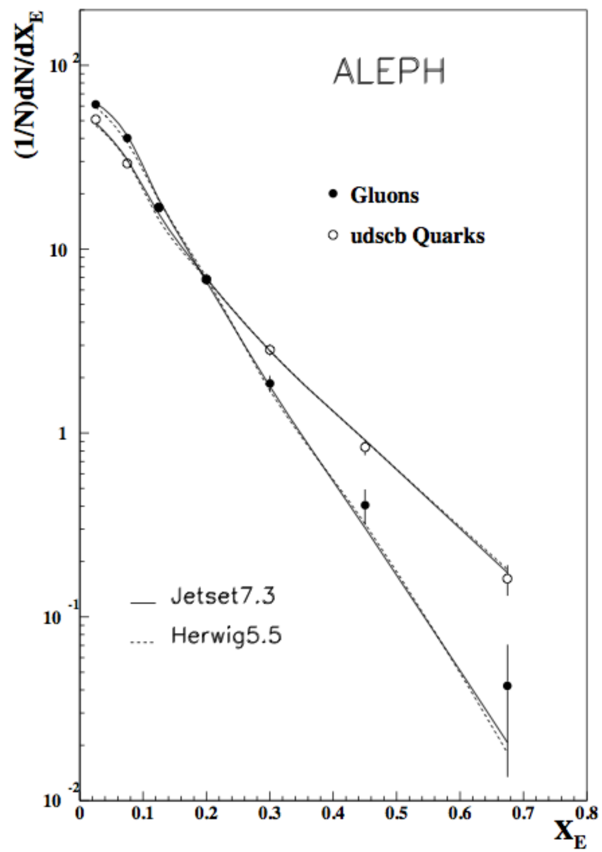
p_{Tt} trigger particle p_T
p_{Ta} associated particle p_T
$\varepsilon(p_T)$ efficiency correction
$R_{\Delta\eta}$ acceptance correction

$$\left.\frac{d^2N}{dp_{Ta}\,d\Delta\phi}\right|_{pTt} = \frac{R_{\Delta\eta}}{\varepsilon(p_{Tt})N_{\mathrm{trigg}}} \frac{d^2N_{\mathrm{raw}}\,\varepsilon(p_{Tt})\varepsilon(p_{Ta})}{dp_{Ta}\,d\Delta\phi}$$

Fragmentation function

$D_q^h(z,Q^2)$ ≡ probability that parton q produces a hadron h carrying fraction z the original parton energy.





Jet analysis in e+e−, p-anti p, pp
⇒ FF of quarks is harder than for gluons.

ALEPH collab: Phys. Lett.B384 (1996) 353. FF for natural flavor mix quark and gluon jets.

Which questions does HI physics address?

- QCD phase diagram

  (nature of phase transitions, critical point)
- Structure of QCD vacuum

  (chiral symmetry restauration, confinement)
- Interaction of the medium with embedded partons/had.

  (jet quenching, dE/dx)
- Does the medium affect vacuum properties of partons/had.?

  (Γ, fragmentation function)

Some of the questions can be addressed with the high p_T probes:
jets, γ_{dir}

Trigger associated momentum distributions

- trigger = γ_{dir}, assoc = hadron : folding only over assoc FF

$$\left.\frac{dN}{dp_{Ta}}\right|_{pT\gamma} = \int_{pTa}^{\sqrt{s}/2} d\hat{p}_{Ta}\, \Sigma'(\hat{p}_{Ta}|p_{T\gamma}) \frac{1}{\hat{p}_{Ta}} D\left(\frac{p_{Ta}}{\hat{p}_{Ta}}\right)$$

- trigger=hadron, assoc=hadron : folding over trigger and assoc. FF

$$\left.\frac{dN}{dp_{Ta}}\right|_{pTt} = \int_{pTt}^{\sqrt{s}/2} d\hat{p}_{Tt} \int_{pTa}^{\sqrt{s}/2} d\hat{p}_{Ta}\, \Sigma'\left(\hat{p}_{Ta}|p_{Tt}\right) \frac{1}{\hat{p}_{Ta}} D\left(\frac{p_{Ta}}{\hat{p}_{Ta}}\right) D\left(\frac{p_{Tt}}{\hat{p}_{Tt}}\right)$$

Σ' = distribution of $\hat{p}_{Ta}$ of assoc. partons when the trigger p_{Tt} is fixed