Cumulants, pp collisions at √s = 13 TeV

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1. 동기

현재까지 사람들이 pp충돌과 PYTHIA에 대해 확인한 것:

식별된 여러 종류의 단일 입자 분포가 잘 맞는다.

제한적이지만 식별된 두 입자간 상관 분포가 잘 맞는다.

지속적인 토의사항:

Jet production/modification/fragmentation, Flow 등.

→ 식별된 다수 입자들의 고차 운동량 상관.

물리적으로 잘 정의된 접근이 있는가?

Key variable: Multiplicity 에 대한 의존도

2. Cumulants란 무엇인가?

체계적으로 저차원의 상관을 제거한 본질적인 상관

예: $\langle\langle e^{in(\phi_1-\phi_2)}\rangle\rangle$, $\langle\langle e^{in(\phi_1+\phi_2-\phi_3-\phi_4)}\rangle\rangle$ $\langle\langle e^{ip\psi-in\phi_1}\rangle\rangle$, $\langle\langle e^{ip\psi-in(\phi_1+\phi_2)}\rangle\rangle$

2. Cumulants란 무엇인가?

$\rho_2(\phi_a, \phi_b)$에 내재된 상관 관계

$$\bar{\rho}_2(\phi_a, \phi_b) \equiv \rho_2(\phi_a, \phi_b) - \bar{\rho}_1(\phi_a)\bar{\rho}_1(\phi_b)$$

$$\rho_2(\phi_a, \phi_b) = \bar{\rho}_2(\phi_a, \phi_b) + \bar{\rho}_1(\phi_a)\bar{\rho}_1(\phi_b)$$

$\bar{\rho}_2(\phi_a, \phi_b)$: 두 개의 입자가 갖는 본질적인 상관(intrinsic correlation)

$$\begin{aligned}
\left\langle\left\langle e^{in(\phi_j-\phi_k)}\right\rangle\right\rangle &= \int_0^{2\pi}\int_0^{2\pi} e^{in(\phi_j-\phi_k)}\{\rho_2(\phi_j,\phi_k) - \bar{\rho}_1(\phi_j)\bar{\rho}_1(\phi_k)\}d\phi_j d\phi_k \\
&= \int_0^{2\pi}\int_0^{2\pi} e^{in(\phi_j-\phi_k)}\rho_2(\phi_j,\phi_k)d\phi_j d\phi_k - \left[\int_0^{2\pi} e^{in\phi_j}\bar{\rho}_1(\phi_j)d\phi_j\right]\left[\int_0^{2\pi} e^{-in\phi_k}\bar{\rho}_1(\phi_k)d\phi_k\right] \\
&= \left\langle e^{in(\phi_j-\phi_k)}\right\rangle - \left\langle e^{in\phi_j}\right\rangle\left\langle e^{-in\phi_k}\right\rangle
\end{aligned}$$

2. Cumulants란 무엇인가?

Cumulants with a selected particle

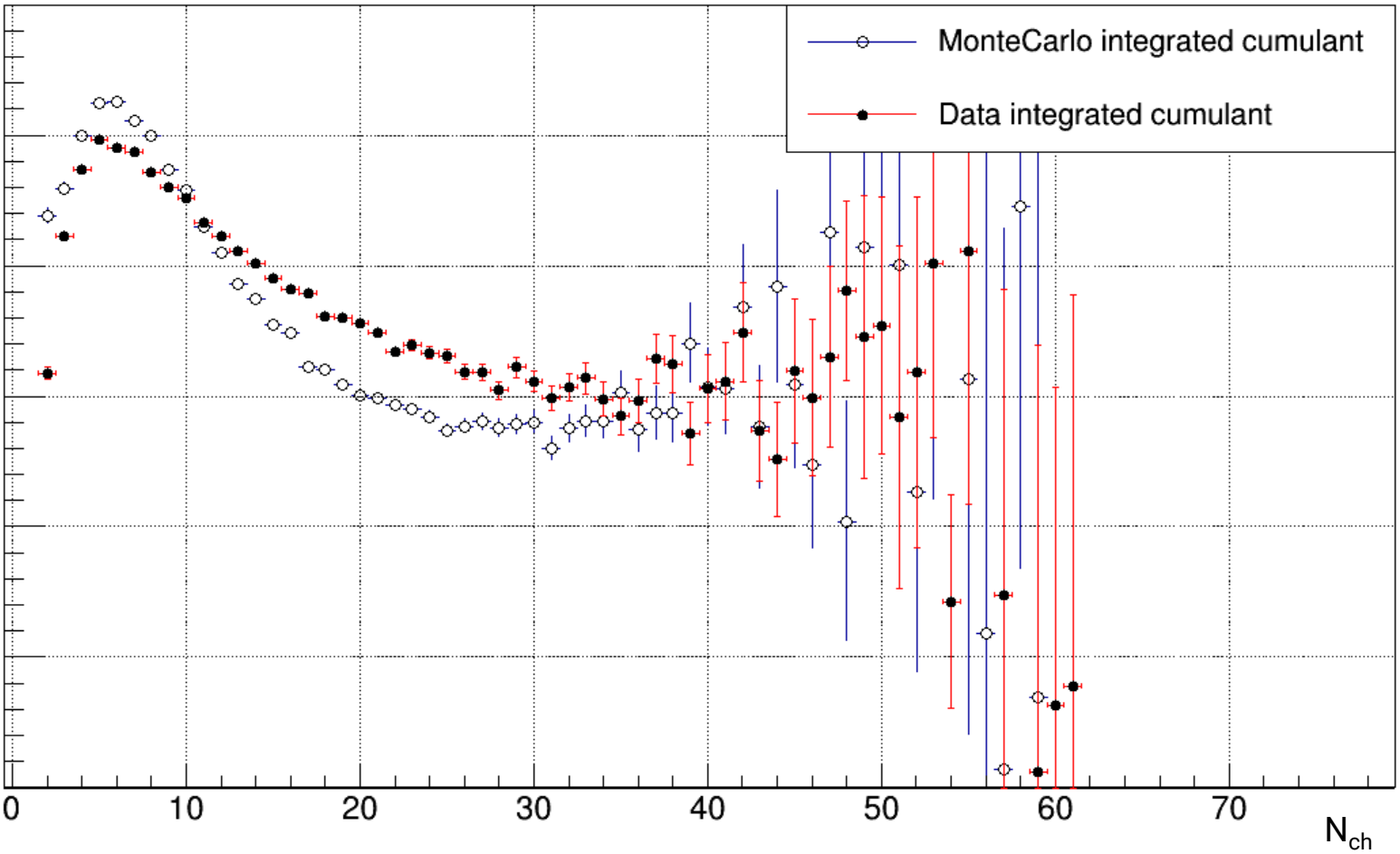
$$\left\langle\left\langle e^{ip\psi-in\phi_1}\right\rangle\right\rangle = \left\langle e^{ip\psi-in\phi_1}\right\rangle - \left\langle e^{ip\psi}\right\rangle\left\langle e^{-in\phi_1}\right\rangle$$

$$\left\langle\left\langle e^{ip\psi-in(\phi_1+\phi_2)}\right\rangle\right\rangle = \left\langle e^{ip\psi-in(\phi_1+\phi_2)}\right\rangle - \left\langle e^{ip\psi}\right\rangle\left\langle e^{-in(\phi_1+\phi_2)}\right\rangle$$

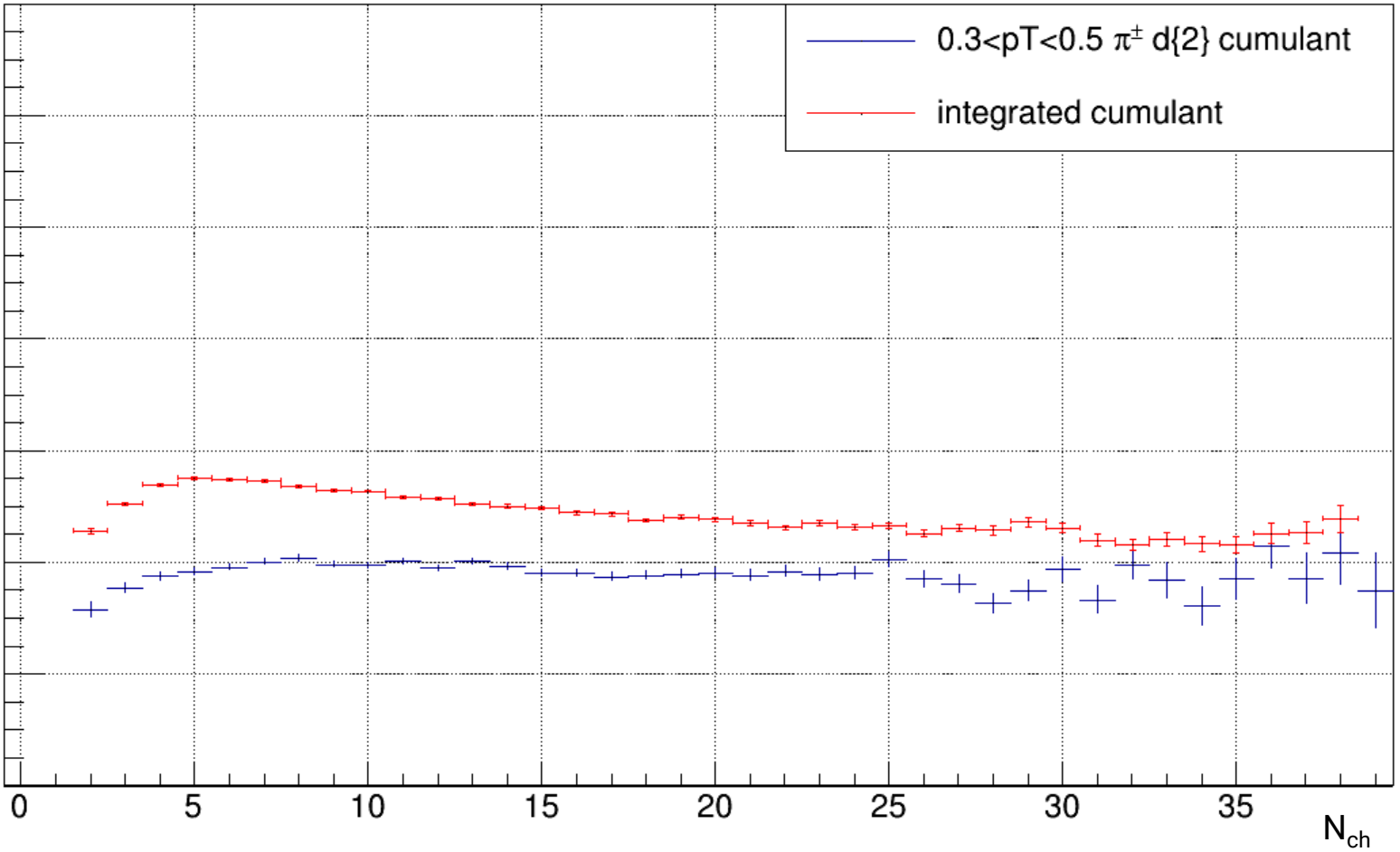
$$-2\left\langle e^{ip\psi-in\phi_1}\right\rangle\left\langle e^{-in\phi_1}\right\rangle + 2\left\langle e^{ip\psi}\right\rangle\left\langle e^{-in\phi_1}\right\rangle^2$$

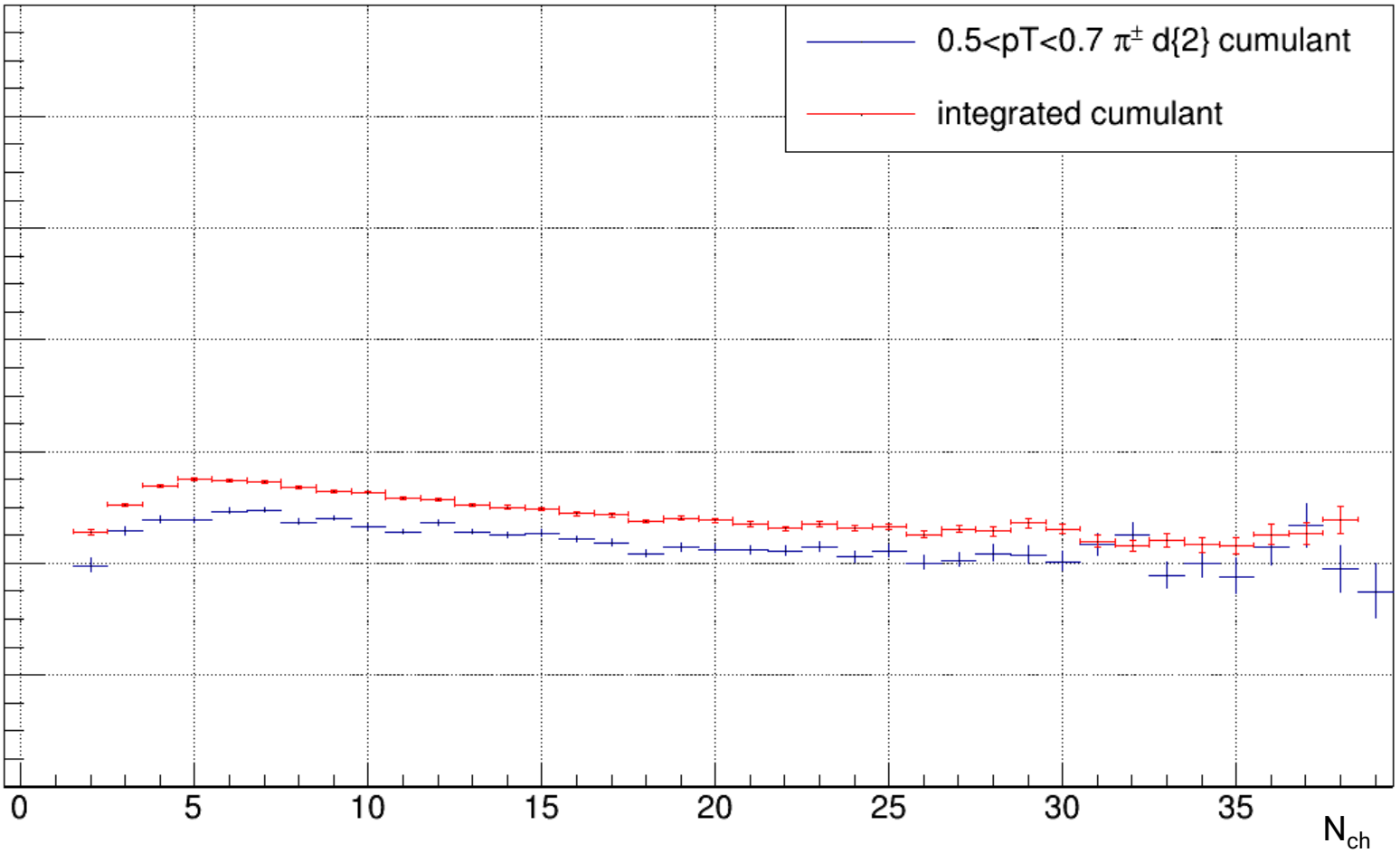
3. 현재 진행상황

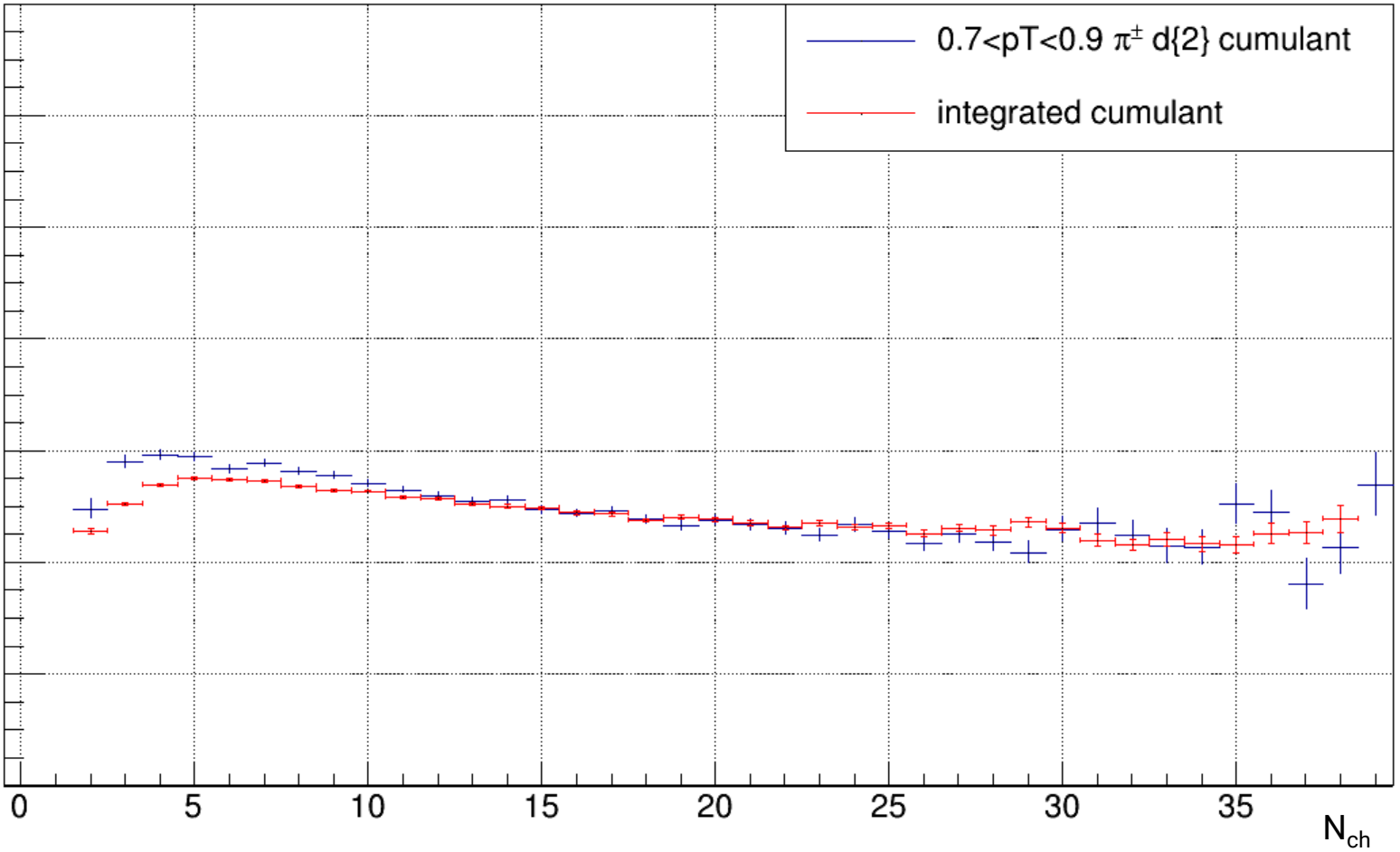
Cumulants

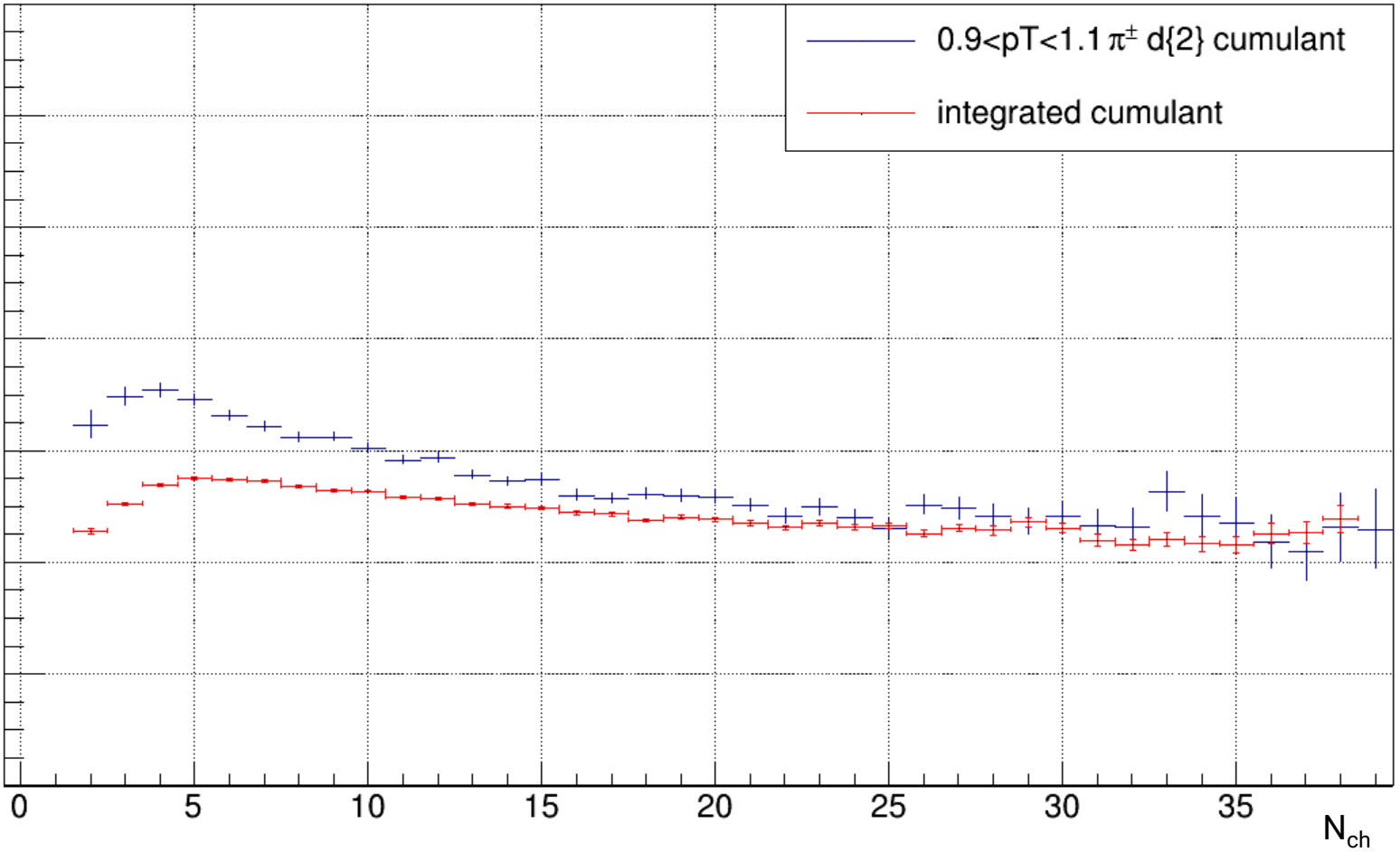

<<exp(2i(ϕ1-ϕ2))>>
MonteCarlo integrated cumulant
Data integrated cumulant
0
10
20
30
40
50
60
70
Nch

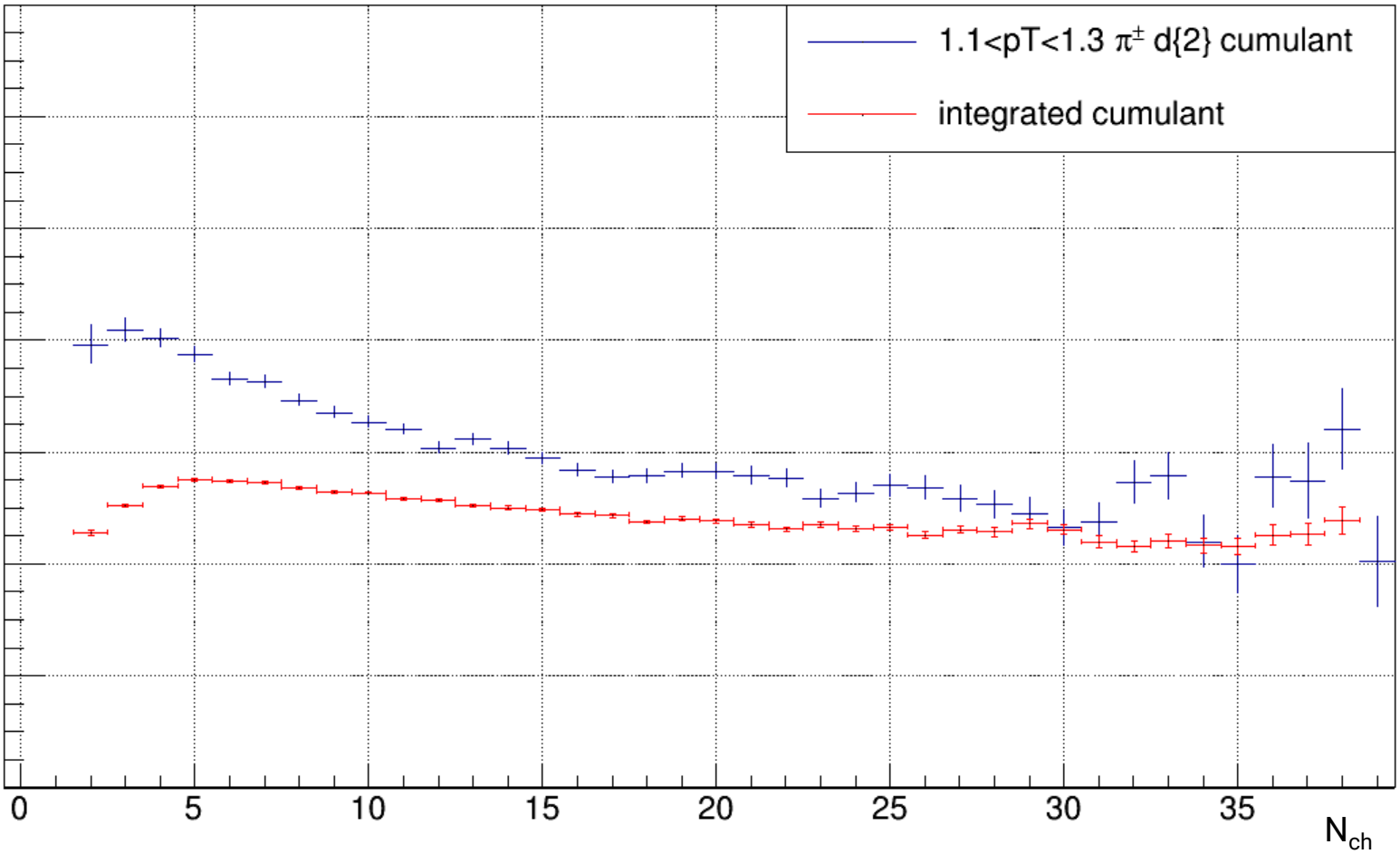
Cumulant with a selected particle

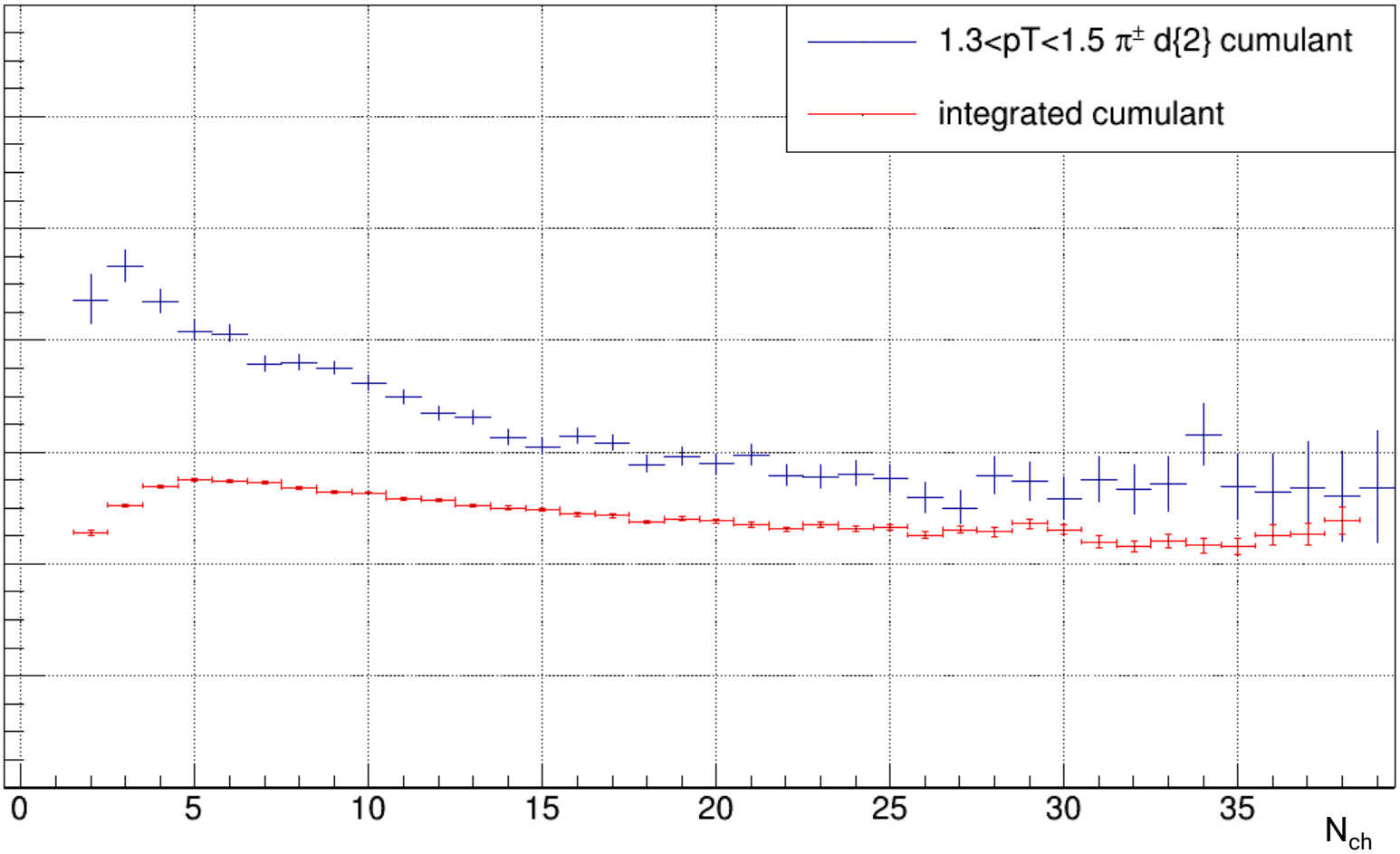

Re{<<exp(2i(ψ-ϕ1))>>} 0.3<pT<0.5 π±
0.3<pT<0.5 π± d{2} cumulant
integrated cumulant
0
5
10
15
20
25
30
35
Nch

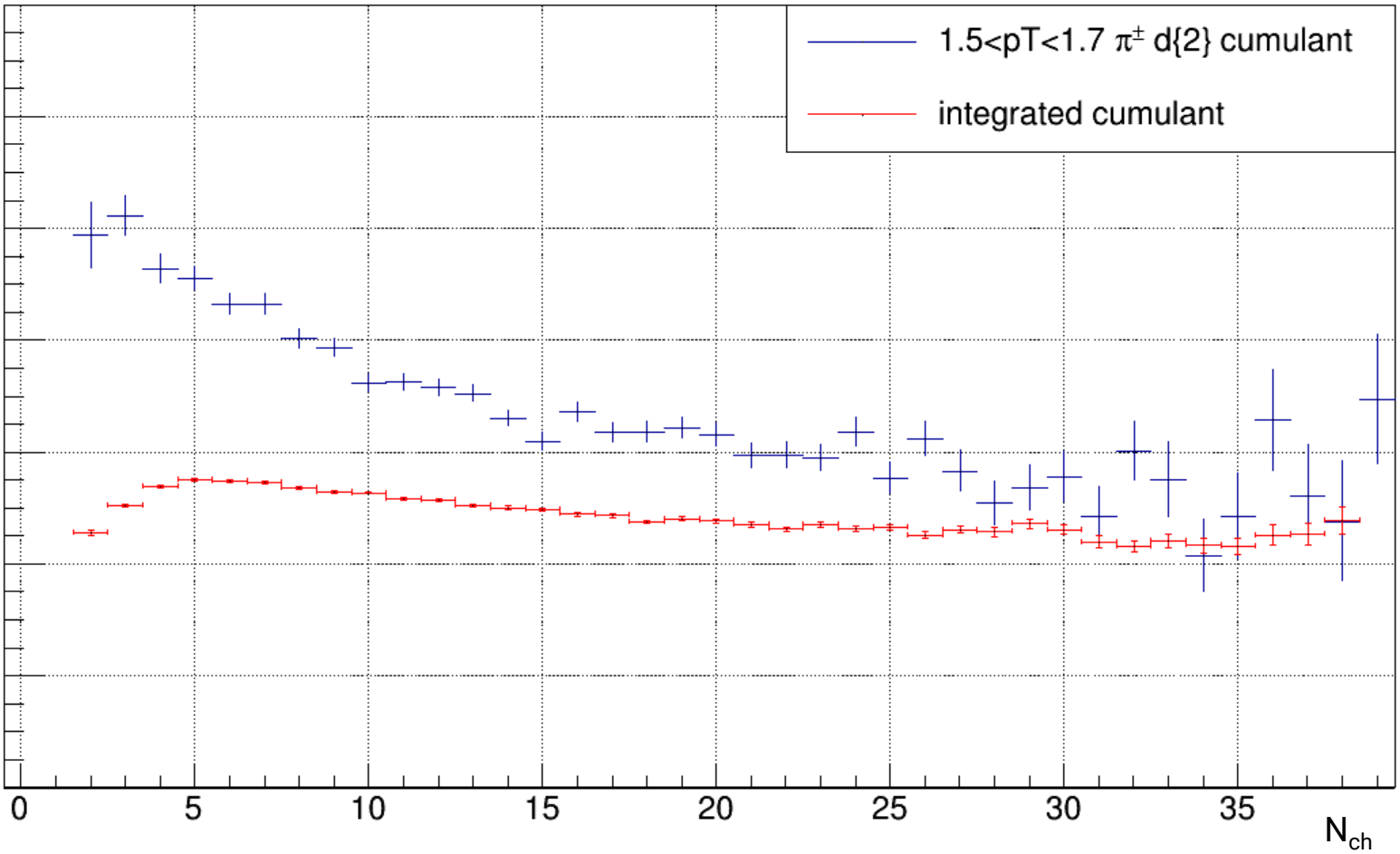

Re{<<exp(2i(ψ-ϕ1))>>} 0.5<pT<0.7 π±
0.5<pT<0.7 π± d{2} cumulant
integrated cumulant
0
5
10
15
20
25
30
35
Nch

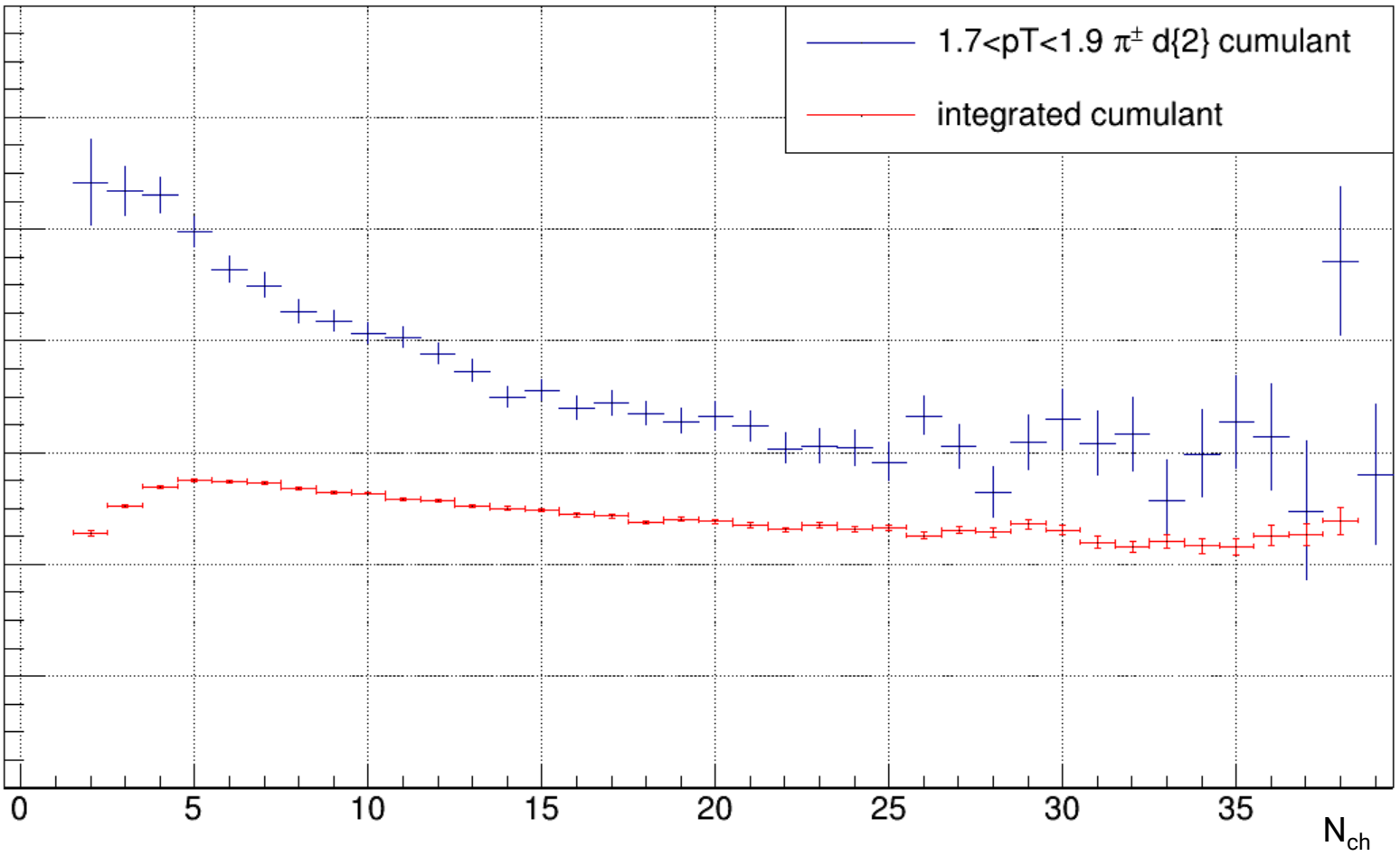

Re{<<exp(2i(ψ-ϕ1))>>} 0.7<pT<0.9 π±
0.7<pT<0.9 π± d{2} cumulant
integrated cumulant
0
5
10
15
20
25
30
35
Nch

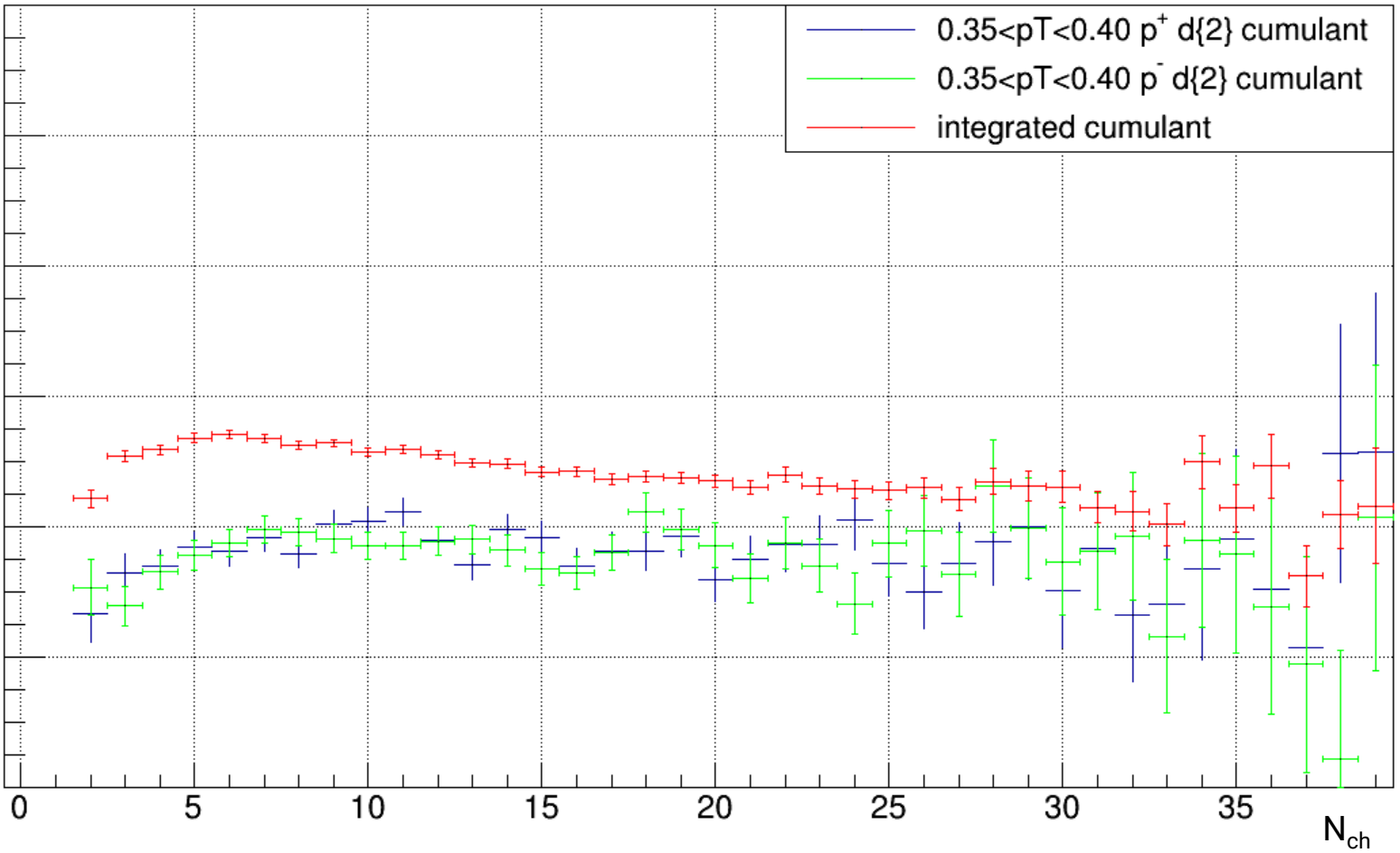

Re{<<exp(2i(ψ-ϕ1))>>} 0.9<pT<1.1 π±
0.9<pT<1.1 π± d{2} cumulant
integrated cumulant
0
5
10
15
20
25
30
35
Nch

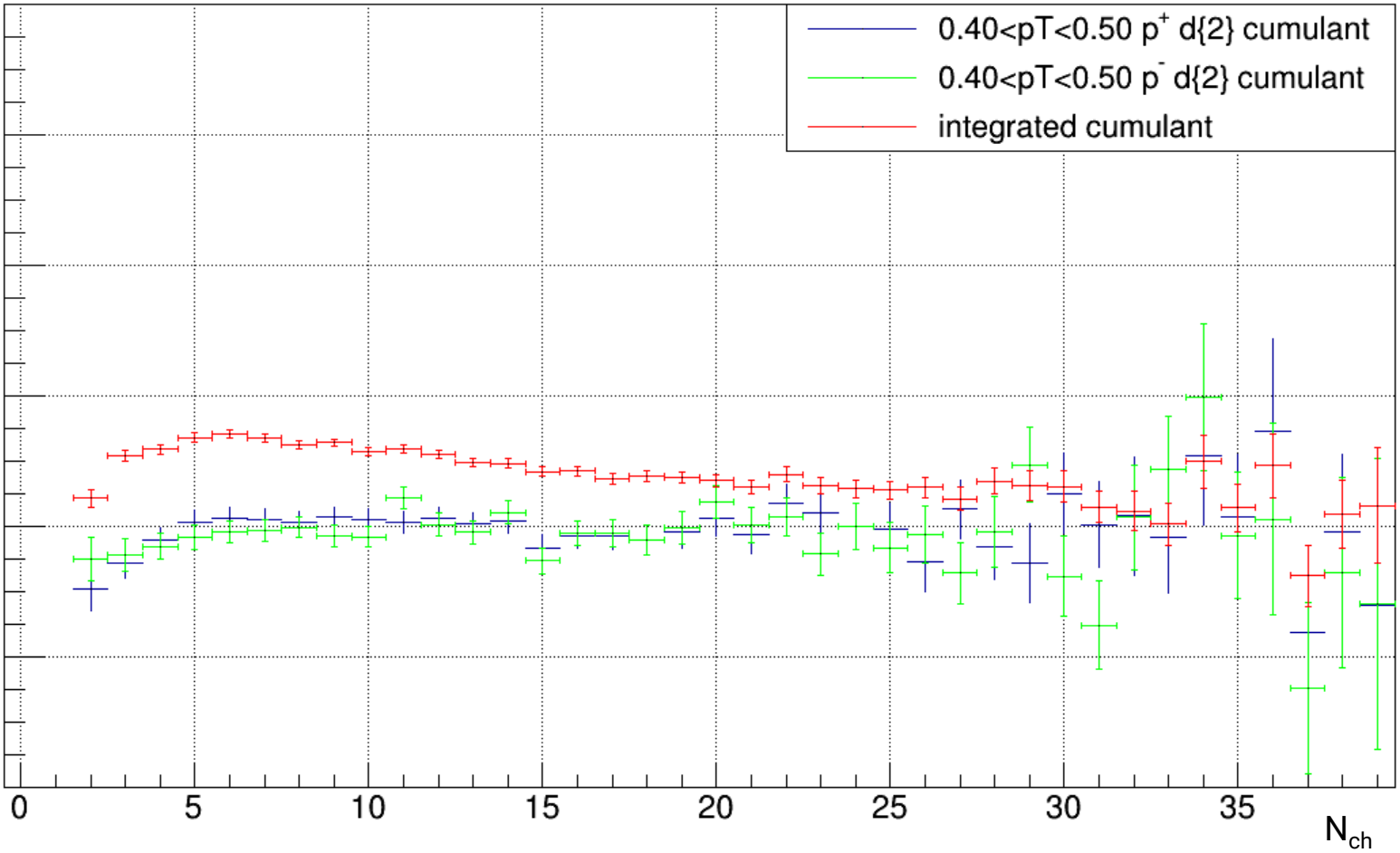

Re{<<exp(2i(ψ-ϕ1))>>} 1.1<pT<1.3 π±
1.1<pT<1.3 π± d{2} cumulant
integrated cumulant
0
5
10
15
20
25
30
35
Nch

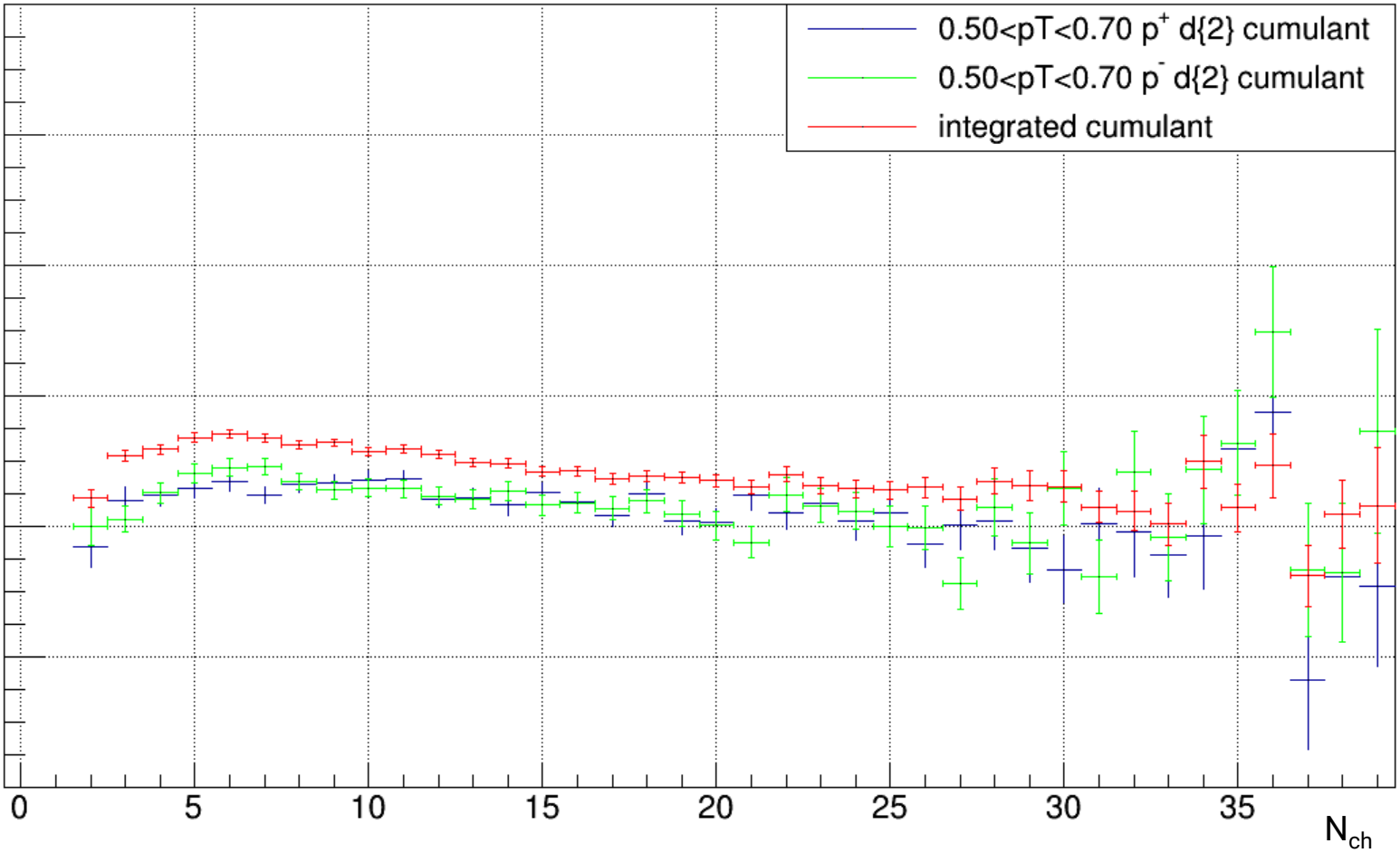

Re{<<exp(2i(ψ-ϕ1))>>} 1.3<pT<1.5 π±
1.3<pT<1.5 π± d{2} cumulant
integrated cumulant
0
5
10
15
20
25
30
35
Nch

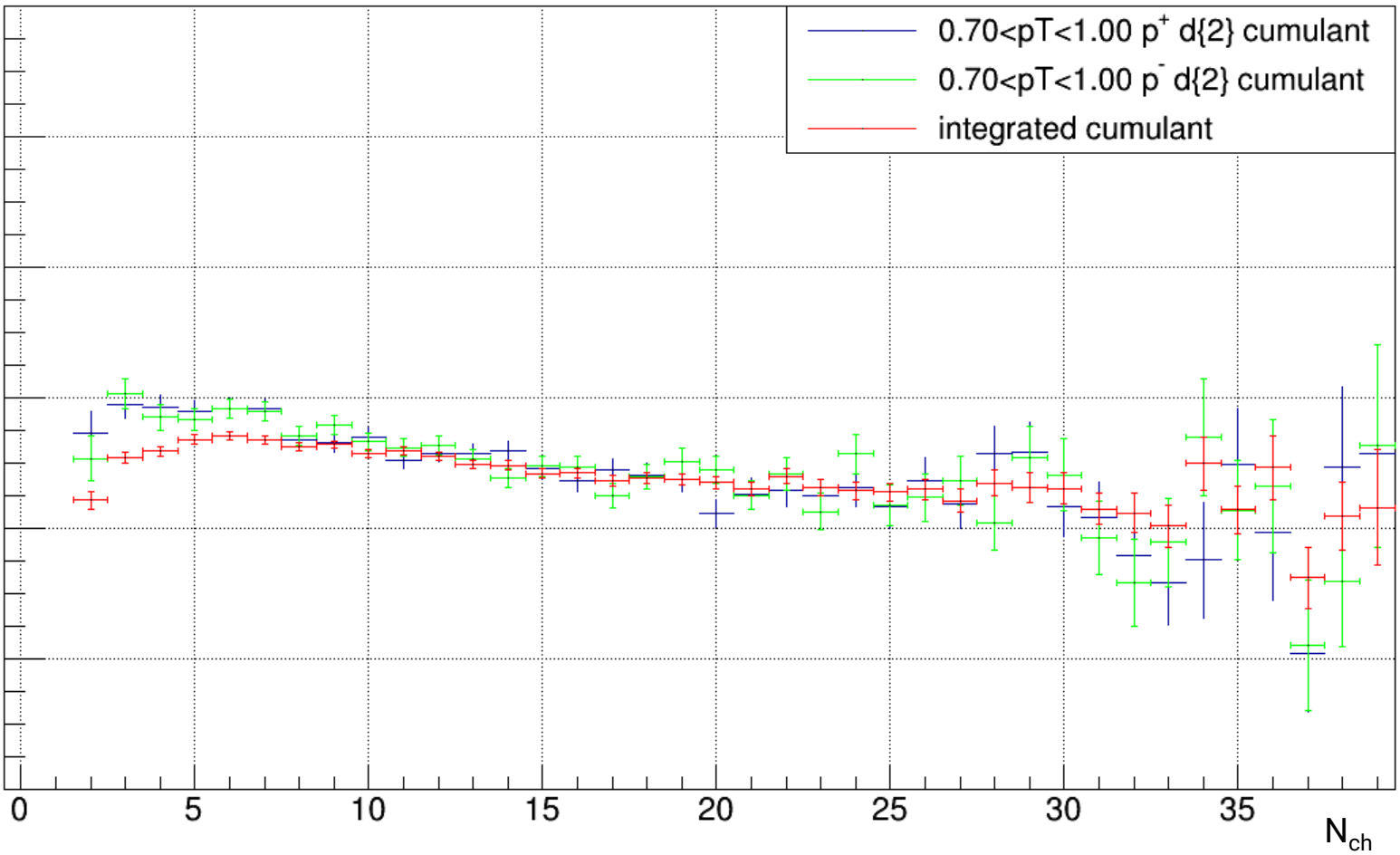

Re{<<exp(2i(ψ-ϕ1))>>} 1.5<pT<1.7 π±
1.5<pT<1.7 π± d{2} cumulant
integrated cumulant
0
5
10
15
20
25
30
35
Nch


Re{<<exp(2i(ψ-ϕ1))>>} 1.7<pT<1.9 π±
1.7<pT<1.9 π± d{2} cumulant
integrated cumulant
0
5
10
15
20
25
30
35
Nch


Re{<<exp(2i(ψ-ϕ1))>>} 0.35<pT<0.40 p
0.35<pT<0.40 p+ d{2} cumulant
0.35<pT<0.40 p- d{2} cumulant
integrated cumulant
0
5
10
15
20
25
30
35
Nch


Re{<<exp(2i(ψ-ϕ1))>>} 0.40<pT<0.50 p
0.40<pT<0.50 p+ d{2} cumulant
0.40<pT<0.50 p- d{2} cumulant
integrated cumulant
0
5
10
15
20
25
30
35
Nch


Re{<<exp(2i(ψ-ϕ1))>>} 0.50<pT<0.70 p
0.50<pT<0.70 p+ d{2} cumulant
0.50<pT<0.70 p- d{2} cumulant
integrated cumulant
0
5
10
15
20
25
30
35
Nch


Re{<<exp(2i(ψ-ϕ1))>>} 0.70<pT<1.00 p
0.70<pT<1.00 p+ d{2} cumulant
0.70<pT<1.00 p- d{2} cumulant
integrated cumulant
0
5
10
15
20
25
30
35
Nch

Cumulant with a selected particle

Deuteron에 대한 cumulants 분석이 진행중

PYTHIA에는 존재하지 않으나 coalescence로 생성될 것.

Electron 에 대한 cumulants 분석이 진행중

pT에 따라 light/charm/beauty hadron 의 상관특성을 보일 것.

4. 계획

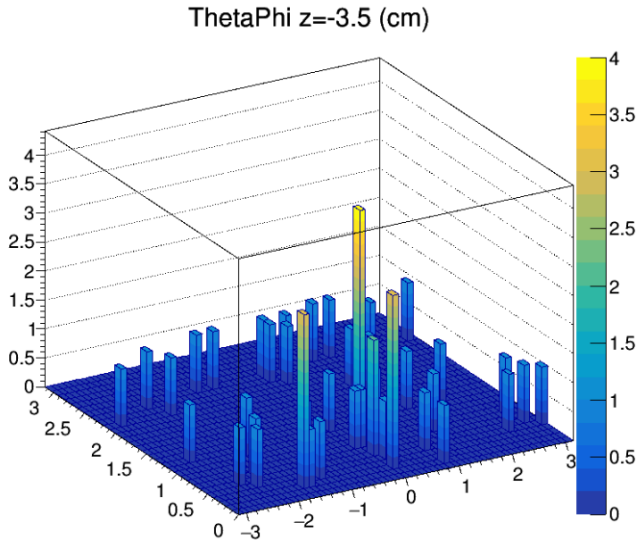
Completion of cumulant analysis: Approval(final)

Challenging, aggressive effort will be made.

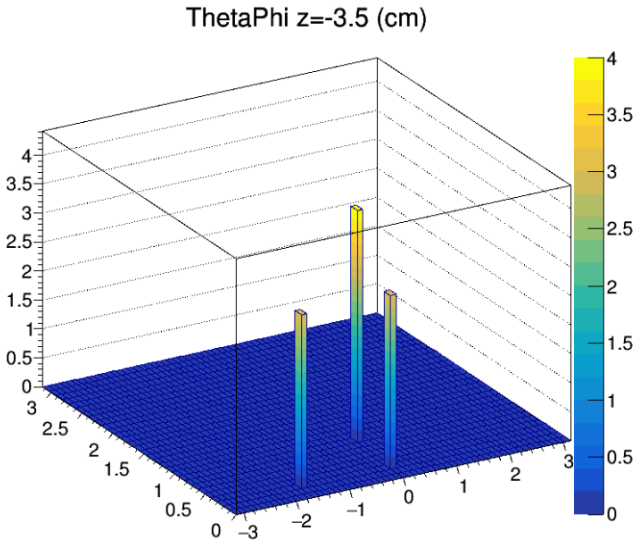
졸업 (2023.02)

Quick Track Finding with Jaehyun

We assume (φ,θ) bins with more than 3 hits contain a track, and associated clusters within +- π/30 (φ) and +- π/30 (θ) to the seed track.

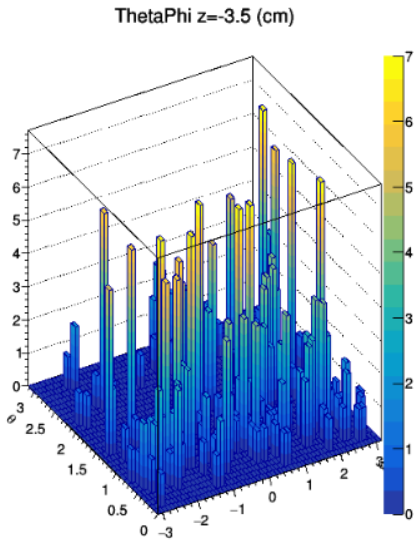


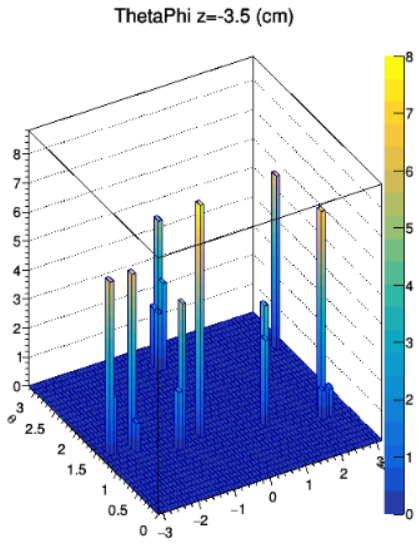
Cluster distribution (φ,θ)

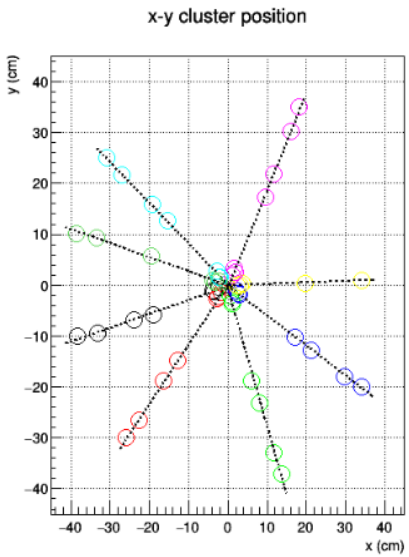


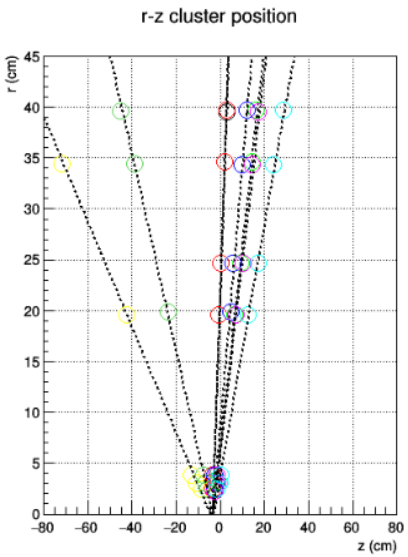
(φ,θ) for Track seed

Quick Track Finding with Jaehyun









Run 505600 Orbit 417241153 BC 1782