Run 15 FMS Inclusive and Diffractive EM-jet A_N update

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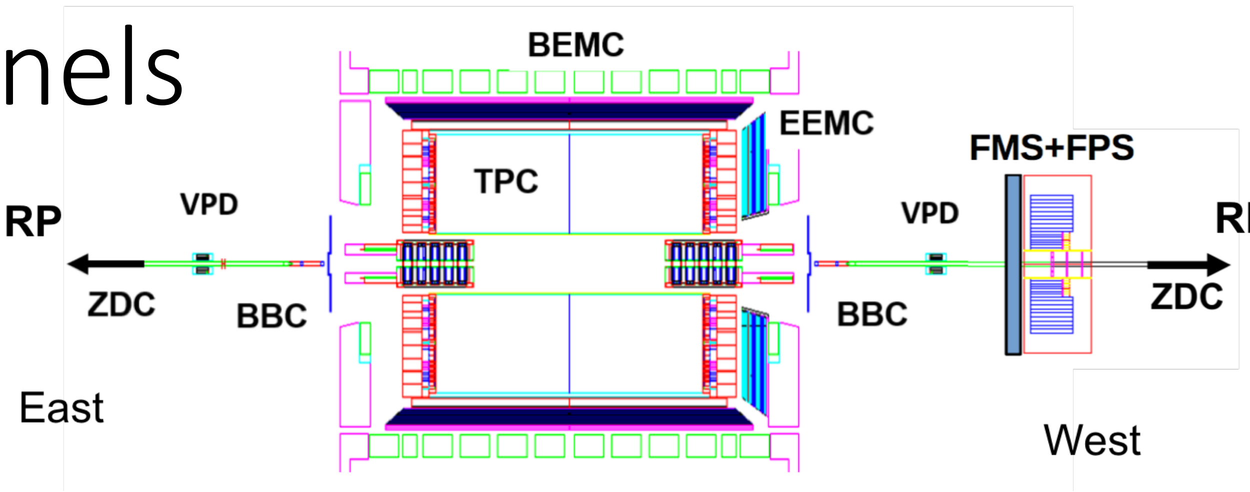
*Thanks for suggestions from Carl Gagliardi

General Information

- Data set: run 15 pp transverse $\sqrt{s} = 200$ GeV ,fms stream
  - (production_pp200trans_2015)
- Production type: MuDst ; Production tag: P15ik
- Trigger for FMS : FMS small board sum, FMS large board sum and FMS-JP.
- EM-jet reconstruction: Anti-k_T algorithm with R=0.7
  - EM-jet: the jet reconstructed using only photons (FMS point).

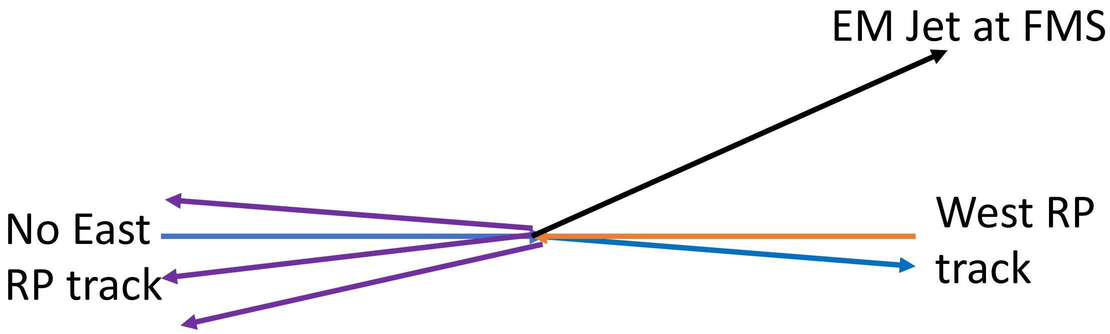
Diffractive process channels

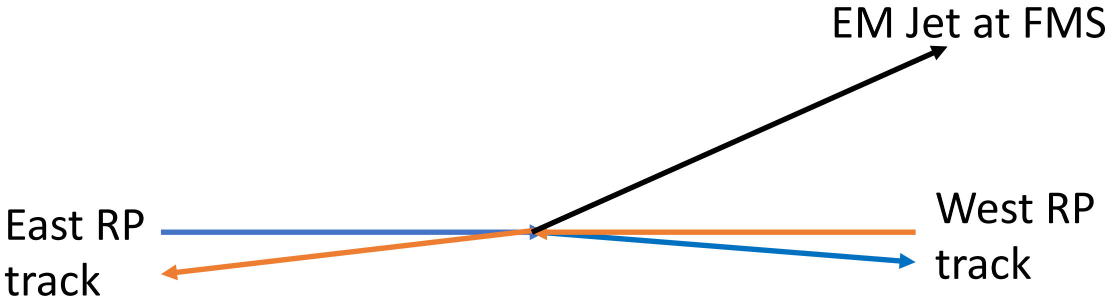


2 diffractive channels are considered.

Require:

- Contain only 1 west RP track.
- Either no east side RP track or only 1 east side RP track.
- sum of west side tracks energy (west side proton + EM Jet) less than beam energy





Event selection and corrections

- **FMS**
  - 8 Triggers, veto on FMS-LED
  - bit shift, bad / dead / hot channel masking (include fill by fill hot channel masking)
  - Jet reconstruction: StJetMaker2015 , Anti-kT, R<0.7 , FMS point energy > 2 GeV, $\boldsymbol{p_T > 1}$ **GeV/c, trigger p_T threshold cut**, FMS point as input.
  - Apply energy correction.
- **Only allow acceptable beam polarization (up/down).**
- **Vertex** (Determine vertex z priority according to TPC , VPD, BBC.)
  - Vertex $|z| < 80\ cm$
- **Roman Pot and Diffractive process: (Diffractive EM-jet A_N analysis only)**
- Acceptable cases: (in next slide)
  1. Only 1 west RP track + no east RP track
  2. Only 1 east RP track + only 1 west RP track
  - RP track must be good track:
  a) Each track hits > 6 planes
  b) $-2 < \theta_X < 2$ mrad , $1.5 < |\theta_y| < 4.5$ mrad
  - Sum of west RP track energy and all EM Jet energy (see detail in table)
- **BBC ADC sum cuts: (Diffractive EM-jet A_N analysis only)**
  - West Large BBC ADC sum < 60 and West Small BBC ADC sum < 100

Corrections:

EM-jet energy correction and Underlying Event correction

x_F	E sum Cut
0.1 - 0.15	$E_{sum} < 108$ GeV
0.15 - 0.2	$E_{sum} < 108$ GeV
0.2 - 0.25	$E_{sum} < 110$ GeV
0.25 - 0.3	$E_{sum} < 110$ GeV
0.3 – 0.45	$E_{sum} < 115$ GeV

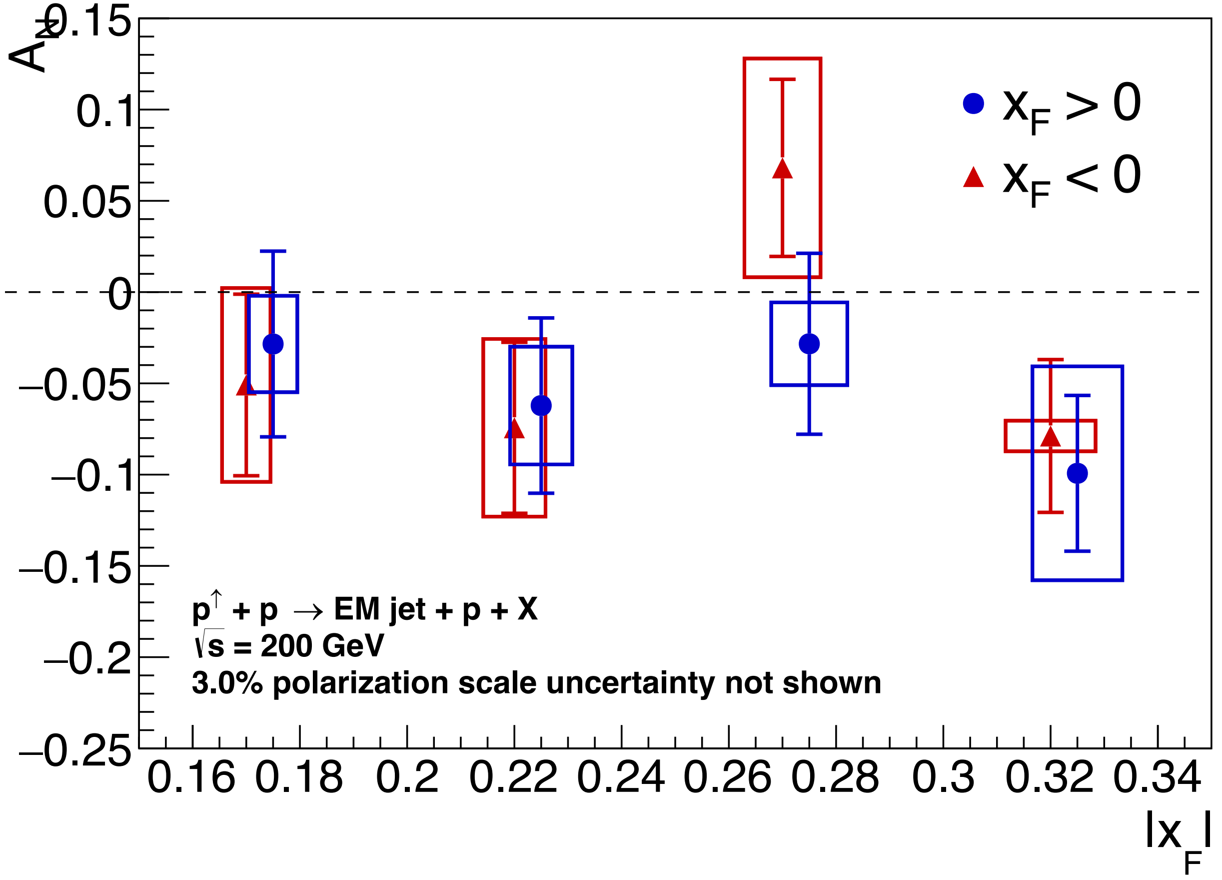
Apply the trigger threshold p_T cut

- The EM-jet p_T based on the trigger threshold are listed as follows, with 15% increase. Consistent with inclusive EM-jet A_N analysis

Trigger name	Trigger ID	15% increase p_T cut [GeV]
FMS-JP0	480810 / 480830	1.84
FMS-JP1	480809 / 480829	2.76
FMS-JP2	480808 / 480828	3.68
FMS-sm-bs1	480801	1.26
FMS-sm-bs1	480821 / 480841	1.15
FMS-sm-bs2	480802 / 480822	1.84
FMS-sm-bs3	480803	2.53
FMS-sm-bs3	480823 / 480843	2.18
FMS-lg-bs1	480804	1.26
FMS-lg-bs1	480824 / 480844	1.15
FMS-lg-bs2	480405 / 480425	1.84
FMS-lg-bs3	480406 / 480426	2.76

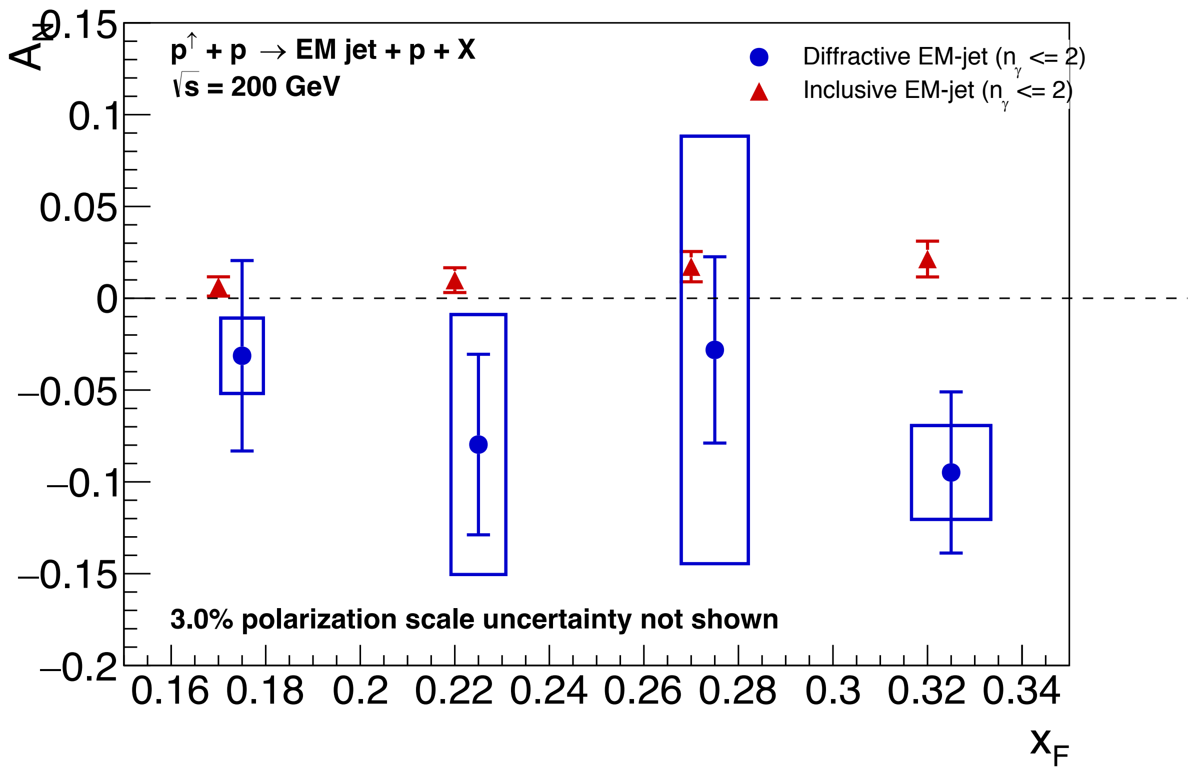
Run 15 diffractive EM-jet A_N results

- Cross-ratio method is used to extract the A_N results.
- Totally show 4 x_F bins, due to the limited statistics.
  - $0.1 < |x_F| < 0.2$, $0.2 < |x_F| < 0.25$, $0.25 < |x_F| < 0.3$, $0.3 < |x_F| < 0.45$
- All photon multiplicity EM-jets
- About 1.9 sigma for non-zero A_N



Comparison between inclusive and diffractive EM-jet A_N

- $\boldsymbol{p_T > 1}$ GeV/c, only considering photon multiplicity 1 or 2
- T-test are applied to investigate non-consistency between two analyses.



One sample T-test

- Do the one sample T-test for inclusive and diffractive EM-jet A_N to check if they are consistent.
  - Compare only EM-jet with all photons (only statistical uncertainty)
- Check for $p_T > 1\ GeV/c$ with trigger threshold cut

Inclusive EM-jet A_N	stat	Diffractive EM-jet A_N	stat	**d = Inclusive EM-jet A_N - Diffractive EM-jet A_N**	d/stat
0.00237253	0.00278996	-0.0261313	0.0509407	0.02850383	0.55871191
0.00416809	0.000606968	-0.0622117	0.0480207	0.06637979	1.38220576
0.00892035	0.000439491	-0.027319	0.0496243	0.03623935	0.73024564
0.0118818	0.000442939	-0.0992779	0.0426701	0.1111597	2.60495549

Results	d/d_sta
mean:	1.3190297
Stdev	0.92778341
count:	4
t	2.46245668
P	**< 10%**

$$t = \frac{\bar{x} - \mu}{s/\sqrt{n-1}}$$

Where $\bar{x}$ is the average of the A_N difference over uncertainty **(d/stat),** μ is 0 for this hypothesis, s is standard derivation, n is number of data points.

t Table

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$
one-tail	**0.50**	**0.25**	**0.20**	**0.15**	**0.10**	**0.05**	**0.025**
two-tails	**1.00**	**0.50**	**0.40**	**0.30**	**0.20**	**0.10**	**0.05**
df							
1	0.000	1.000	1.376	1.963	3.078	6.314	12.71
2	0.000	0.816	1.061	1.386	1.886	2.920	4.303
3	0.000	0.765	0.978	1.250	1.638	2.353	3.182

One sample T-test

- Do the one sample T-test for inclusive and diffractive EM-jet A_N to check if they are consistent.
  - **Compare only EM-jet with 1 or 2 photons**
- About 1 sigma non-consistency are obtained for both analyses.

Inclusive EM-jet A_N	sta	sys	Diffractive EM-jet A_N	sta	sys	**d = Inclusive EM-jet A_N - Diffractive EM-jet A_N**	d/sta	d/sta+sys
0.00642878	0.00437334	0.00032144	-0.0313224	0.0518561	0.0205252	0.03775118	0.72542358	0.67482057
0.00986271	0.000886606	0.00049314	-0.079678	0.0491682	0.0708062	0.08954071	1.82081419	1.03864218
0.0172103	0.000651766	0.00086052	-0.0281373	0.0507298	0.116416	0.0453476	0.8938308	0.35708584
0.0213545	0.000659429	0.00106773	-0.0948827	0.0438875	0.0255548	0.1162372	2.64822743	2.28809159

Results	d/sta	d/sta+sys
t	2.95561745	2.23067249
P	**<10%**	**<20%**

$$t = \frac{\bar{x} - \mu}{s/\sqrt{n-1}}$$

Where $\bar{x}$ is the average of the A_N difference over uncertainty **(d/uncertainty),** μ is 0 for this hypothesis, s is standard derivation, n is number of data points.

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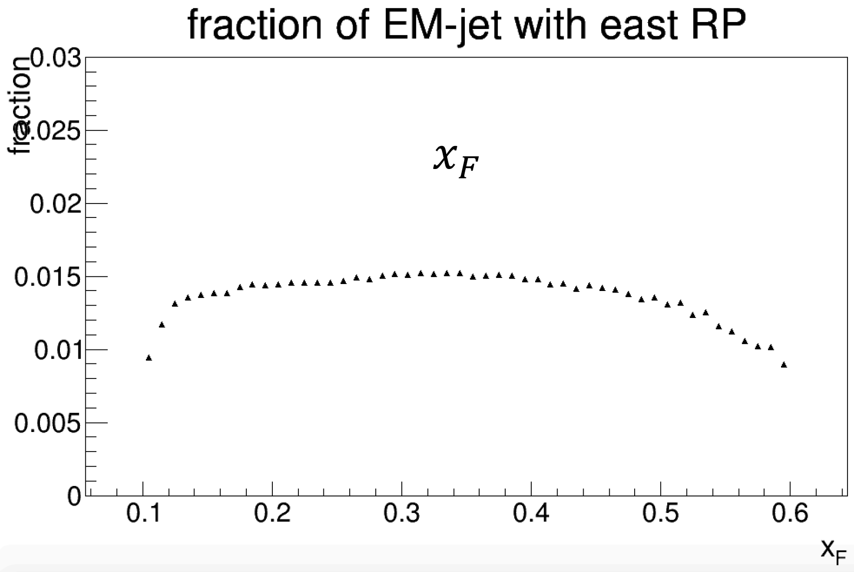
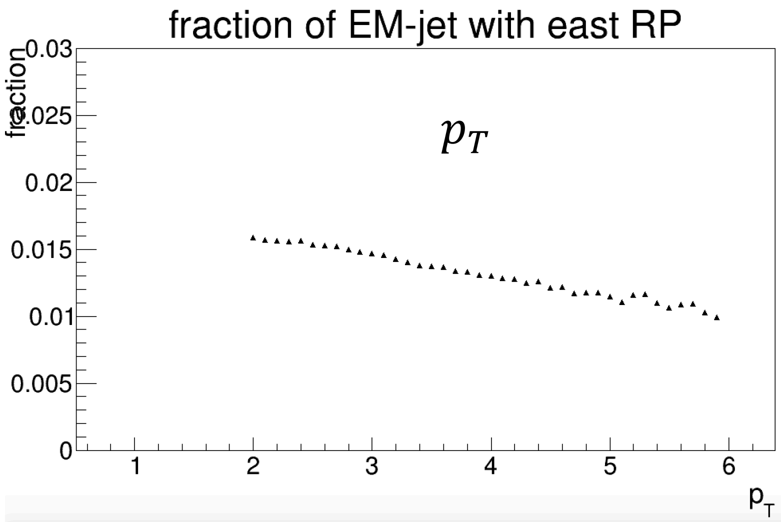
East RP track coincidence study

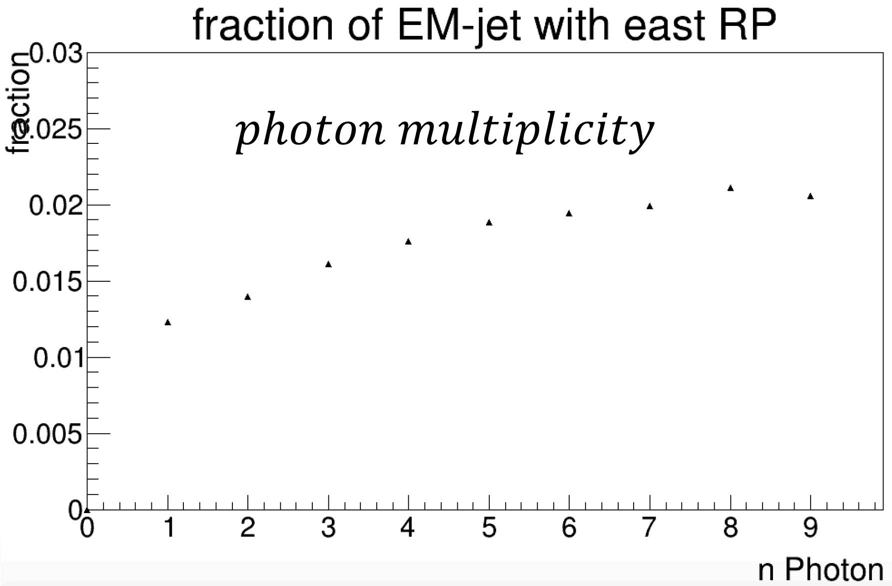
- Goal: Investigate the possible contribution of east side RP track intact events to inclusive EM-jet A_N.
- Data set: 6 fills (as test) from run 15 FMS stream
  - Only consider the runs with RP response.
- Event selection:
  - EM-jet cuts are same as diffractive EM-jet A_N analysis (Slide 4)
  - Only 1 east side RP track, and this east RP track must be good track (Slide 4)
  - No sum energy cuts and BBC ADC sum cuts.

Fraction of EM-jets with 1 east RP track

- Fraction= $\frac{n_{EM-jets\ with\ 1\ east\ RP\ track}}{n_{EM-jets}}$
- The probability of away-side proton intact as diffractive event is highest at low EM-jet p_T or large photon multiplicity.
- These are the kinematic regions where the inclusive EM-jet A_N is smallest, so the large A_N doesn't arise from such diffractive events where the away-side proton remains intact.







Plans for paper proposal and discussion

- We plan to publish the results for inclusive and diffractive EM-jet A_N for run 15 FMS data
- We plan to give 2 papers:
  1. One PLB paper: focus on diffractive EM-jet A_N for run 15 FMS, including Figure in slide 6, as well as the east RP coincidence study and inclusive EM-jet A_N separated by photon multiplicity.
  2. One PRD paper: focus on inclusive EM-jet A_N for run 15 FMS, as well as the comparison with diffractive EM-jet A_N for run 15 FMS, including Figure in slide 7.
- Discussion:
  1. Is one paper proposal fine for both papers ; or we need to do separate paper proposal?

Conclusion

- Run 15 inclusive and diffractive EM-jet A_N analyses are close to finalized and start to proceed to paper proposal and preparation.
- Diffractive EM-jet A_N analysis systematic uncertainties might need to better considered.

Back up

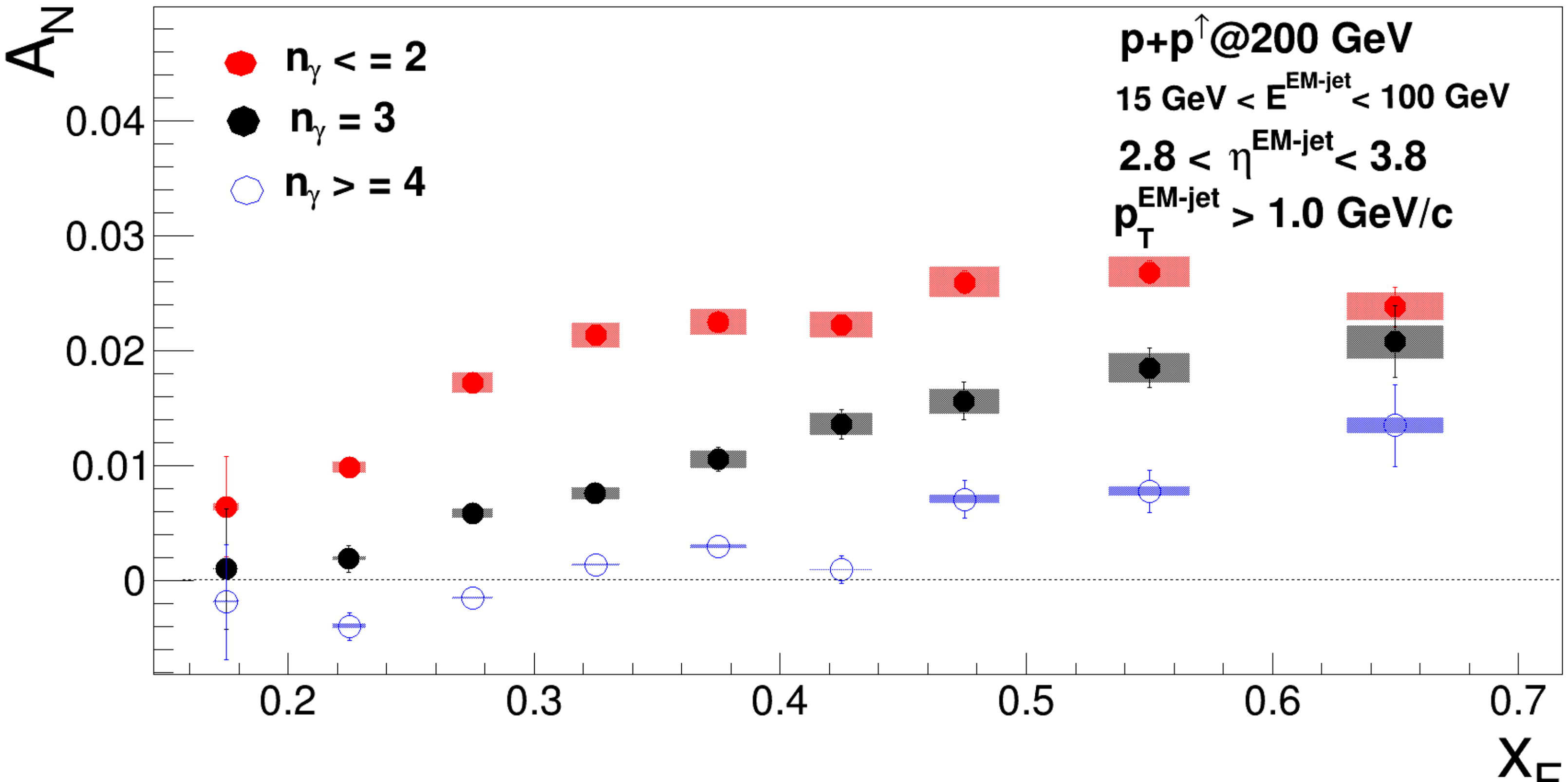
Systematic uncertainty for residual background

- Systematic uncertainties for residual background effect mainly come from the cut for selecting signal from background.
  - Energy sum cut: change the energy sum cut to check the uncertainty.
  - Small BBC ADC sum cut: change 100 to 105
  - Large BBC ADC sum cut: change 60 to 65
- Ring of fire
  - Trigger: fms-sm-bs3

x_F	E sum Cut original	E sum cut for systematic
0.1 - 0.15	E_{sum} < 108 GeV	E_{sum} < 112 GeV
0.15 - 0.2	E_{sum} < 108 GeV	E_{sum} < 112 GeV
0.2 - 0.25	E_{sum} < 110 GeV	E_{sum} < 114 GeV
0.25 - 0.3	E_{sum} < 110 GeV	E_{sum} < 114 GeV
0.3 – 0.45	E_{sum} < 115 GeV	E_{sum} < 120 GeV

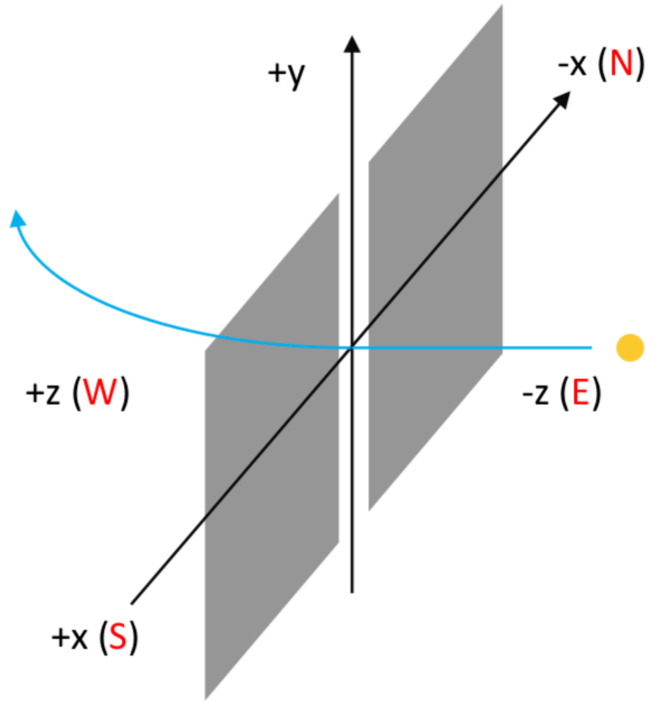
Inclusive EM-jet A_N result

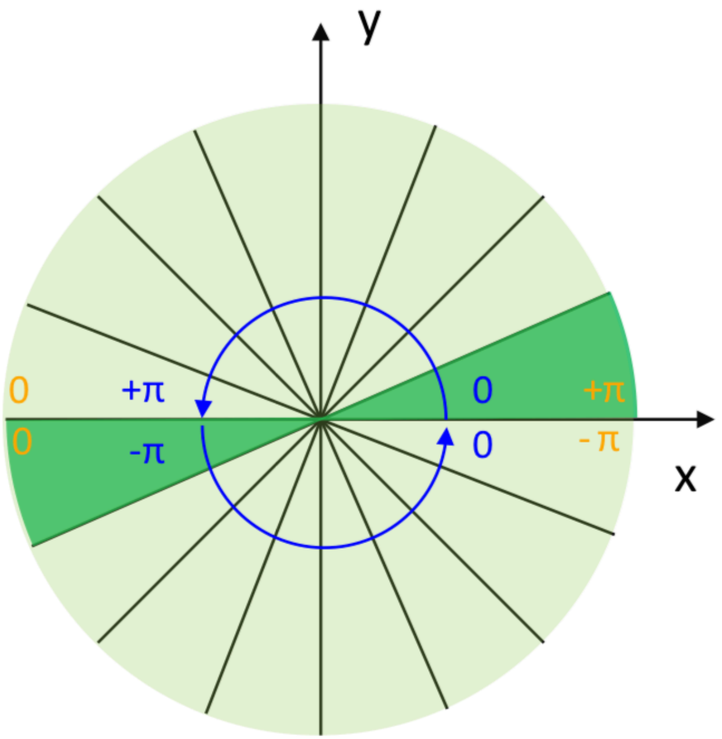
- Inclusive EM-jet A_N result with EM-jet $p_T > 1GeV/c$ cut.



Transverse single spin asymmetry (A_N) calculation

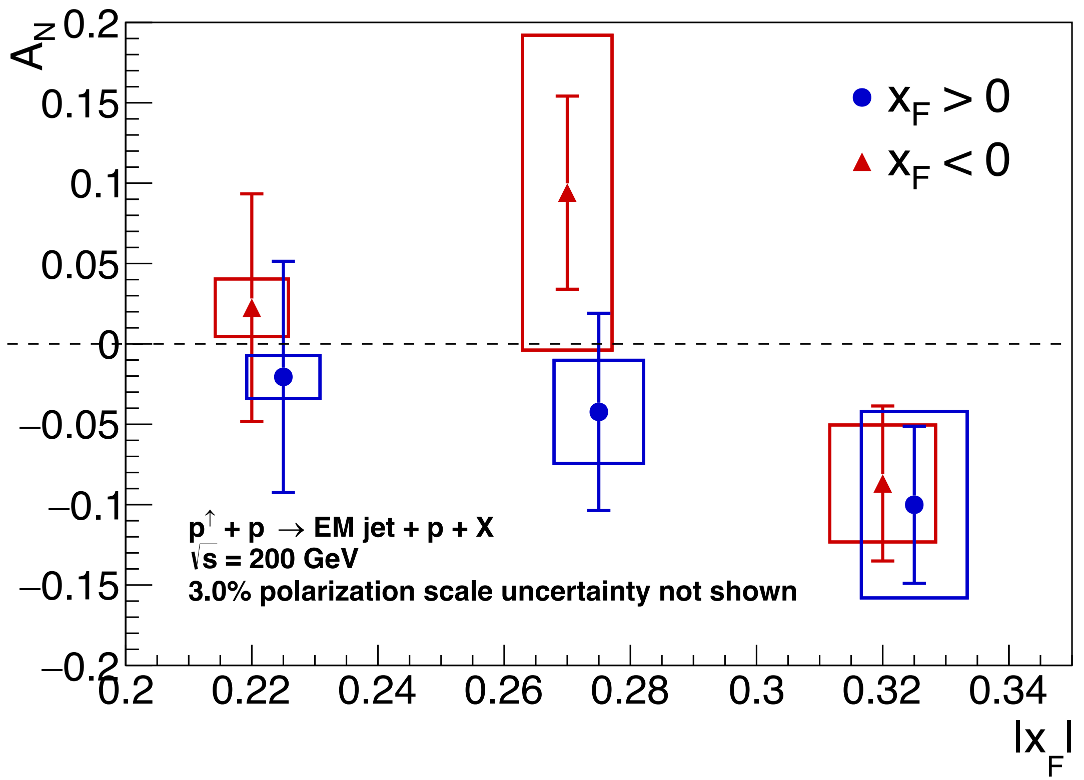
- We use **cross ratio** method to calculate the diffractive EM Jet A_N at FMS.
  - Raw A_N: $\varepsilon = \dfrac{\sqrt{N^{\uparrow}(\phi)N^{\downarrow}(\phi+\pi)}-\sqrt{N^{\downarrow}(\phi)N^{\uparrow}(\phi+\pi)}}{\sqrt{N^{\uparrow}(\phi)N^{\downarrow}(\phi+\pi)}+\sqrt{N^{\downarrow}(\phi)N^{\uparrow}(\phi+\pi)}} \approx pol * A_N * \cos(\phi)$
  - Plot A_N as a function of x_F, or p_T ($x_F = \dfrac{E_{EM\ jet}}{E_{Beam}}$)
  - Divide full ϕ range [-π , +π] into 16 bins.





Diffractive EM-jet 2GeV/c p_T cut

- If we apply 2 GeV p_T cut for diffractive EM-jet, A_N for $x_F < 0.2$ are unable to extract. Therefore, we look at 3 x_F bins: $0.2 < x_F < 0.25$, $0.25 < x_F < 0.3$, $0.3 < x_F < 0.45$.



Low photon multiplicity A_N and comparison with inclusive EM-jet A_N

- Diffractive EM-jet 2GeV/c p_T cut as well as trigger threshold cuts are applied, which are same p_T cut as inclusive EM-jets.
- Low photon multiplicity: 1 or 2 photons in EM-jet (compare with inclusive results)