

A visualization of a particle collision, showing a dense cluster of particles on the right side, with many thin lines radiating outwards to the left, suggesting the expansion of the collision products.

Transverse Single-Spin Asymmetries of Direct Photons from Proton-Proton Collisions at Forward Rapidity

Oleg Eyser

for the STAR Collaboration

Fall Meeting of the Division of Nuclear Physics
of the American Physical Society

Pittsburgh, October 2017

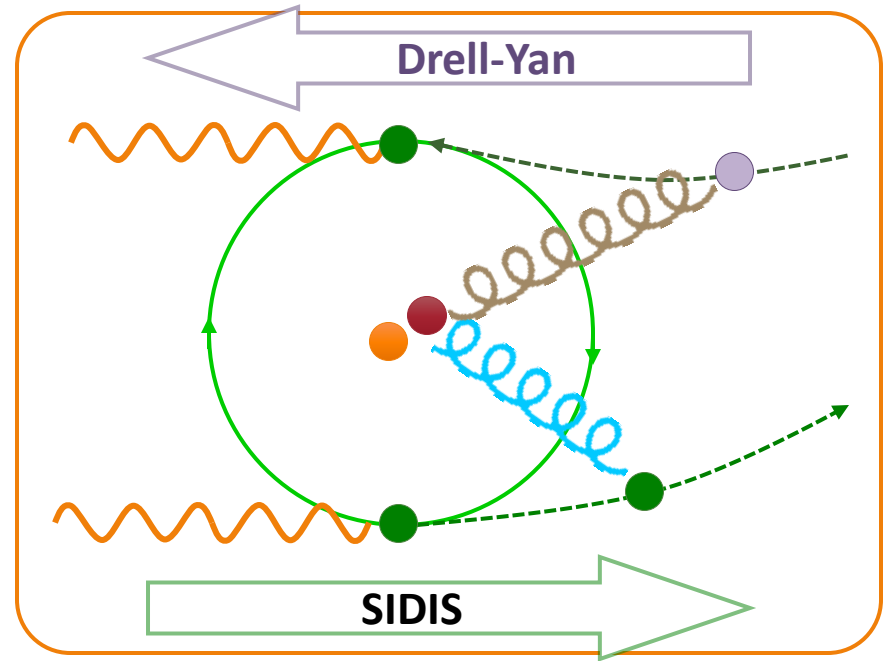
Nucleon Structure

New era in QCD studies

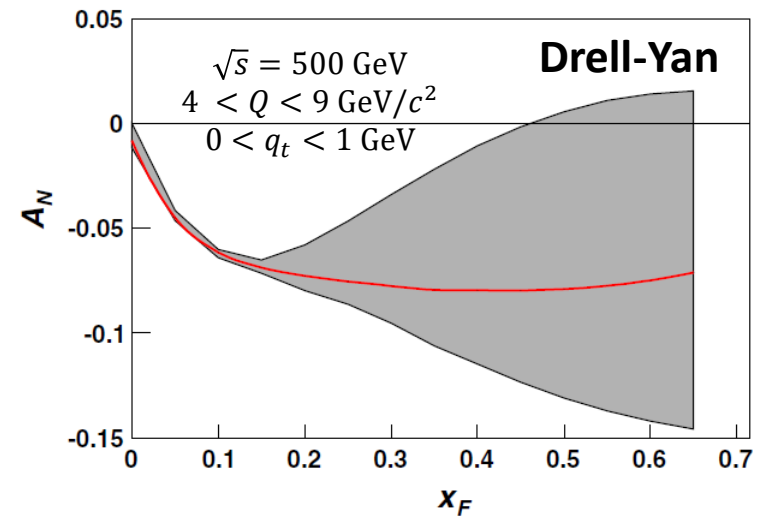
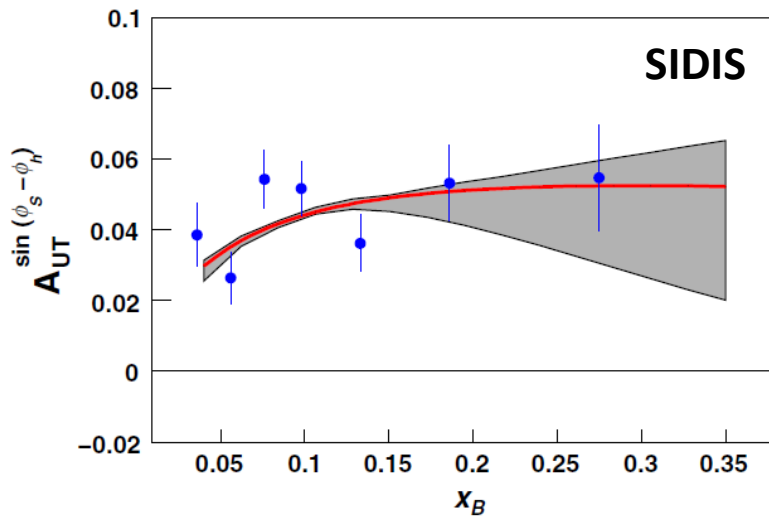
- Transverse spin asymmetries for nucleon tomography
- Transverse momentum dependent distribution functions

Compare SIDIS and Drell-Yan production

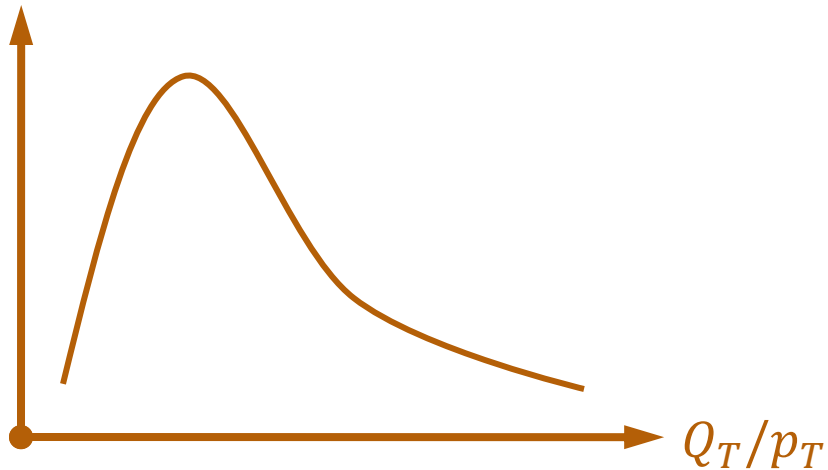
- Non-universality of spin-orbit correlations (Sivers function et al.)



Gamberg, Kang, Prokudin
PRL 110, 232301 (2013)
with HERMES data



Factorization and Scale



$$Q^2 \gg Q_T^2 \gtrsim \Lambda_{QCD}^2 \quad Q^2, Q_T^2 \gg \Lambda_{QCD}^2$$

$$-\int d^2 k_{\perp} \frac{|k_{\perp}^2|}{M} f_{1T}^{\perp q}(x, k_{\perp}^2) = T_{q,F}(x, x)$$

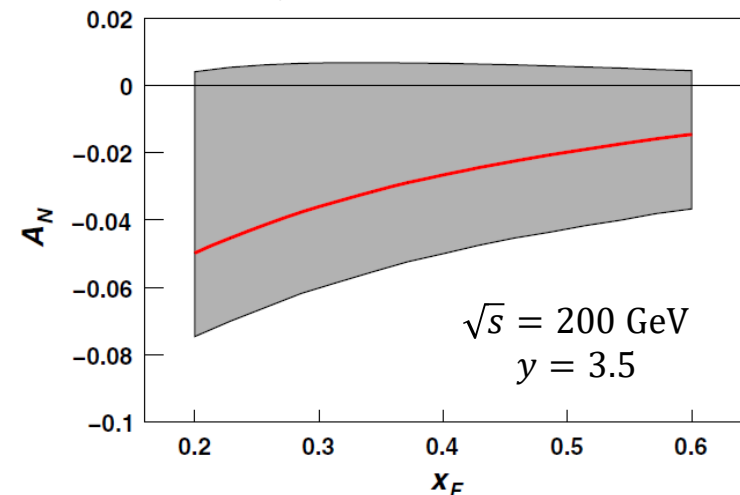
$f_{1T}^{\perp q}$: Sivers TMD function

$T_{q,F}$: Efremov-Teryaev-Qiu-Sterman correlator

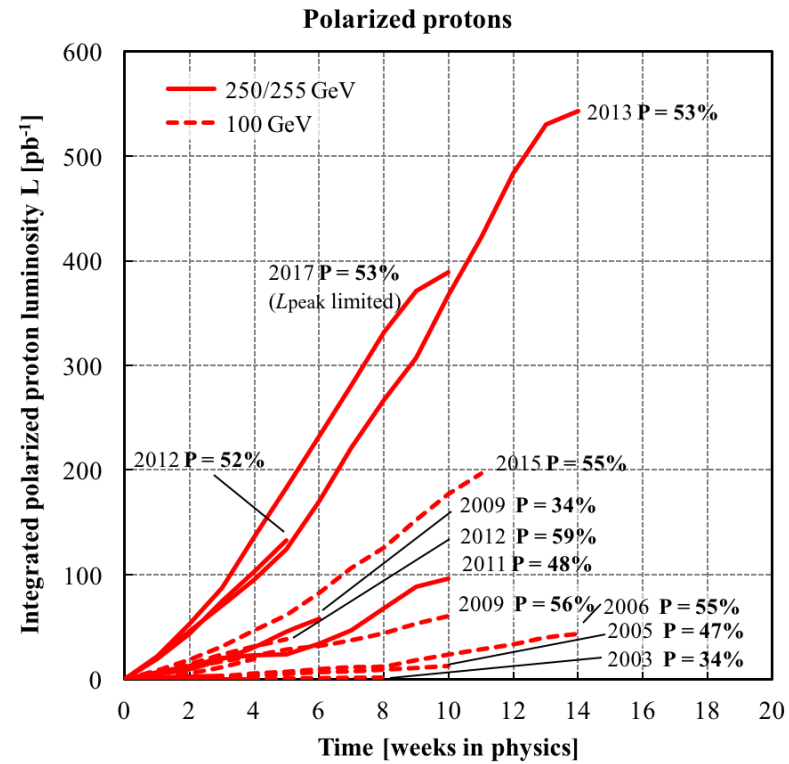
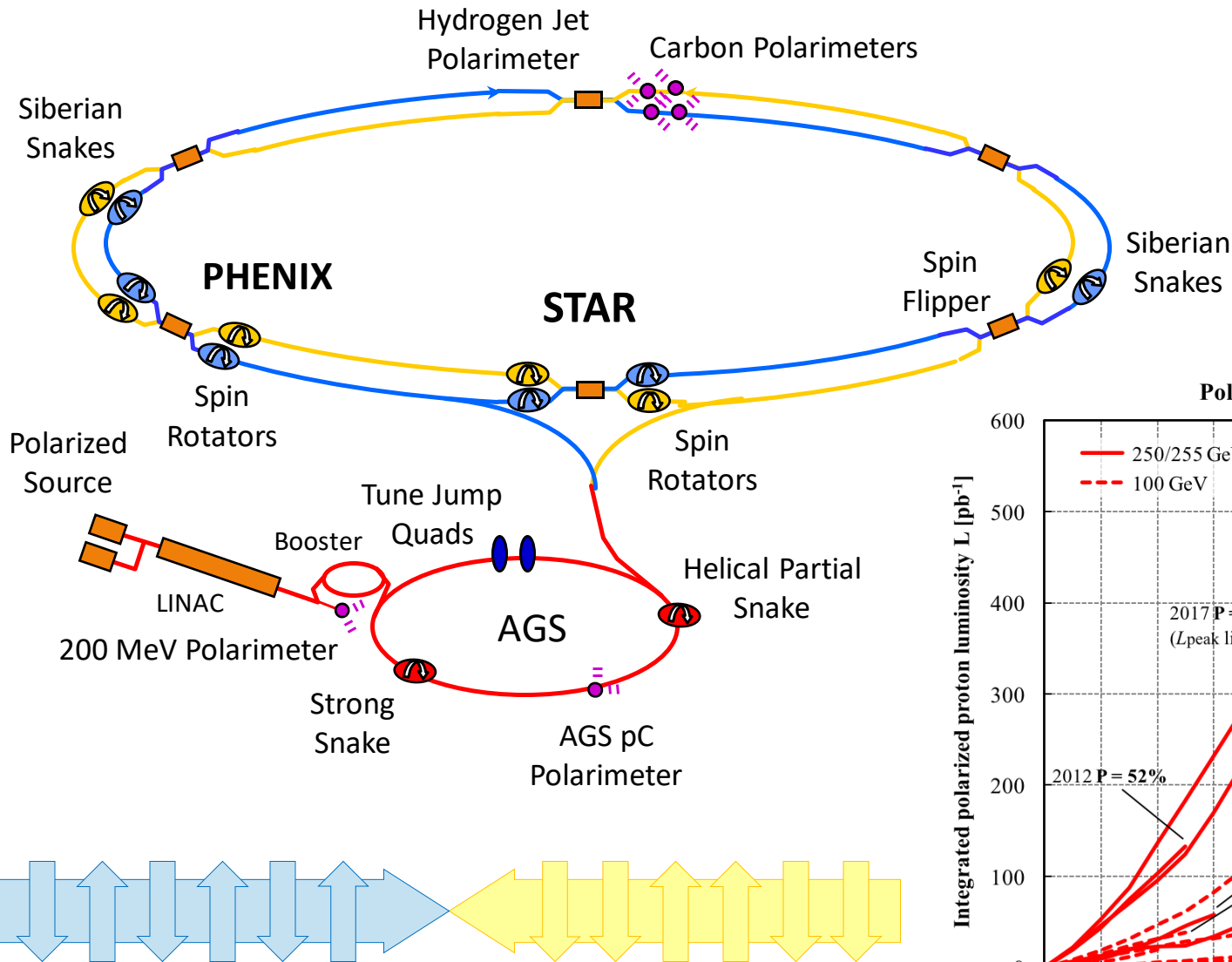
Initial / final state effects

- TMD factorization: two characteristic scales Q^2 and Q_T^2
- Collinear factorization: twist-3 with one hard scale
- Both are closely related

Direct photons, PRL 110, 232301

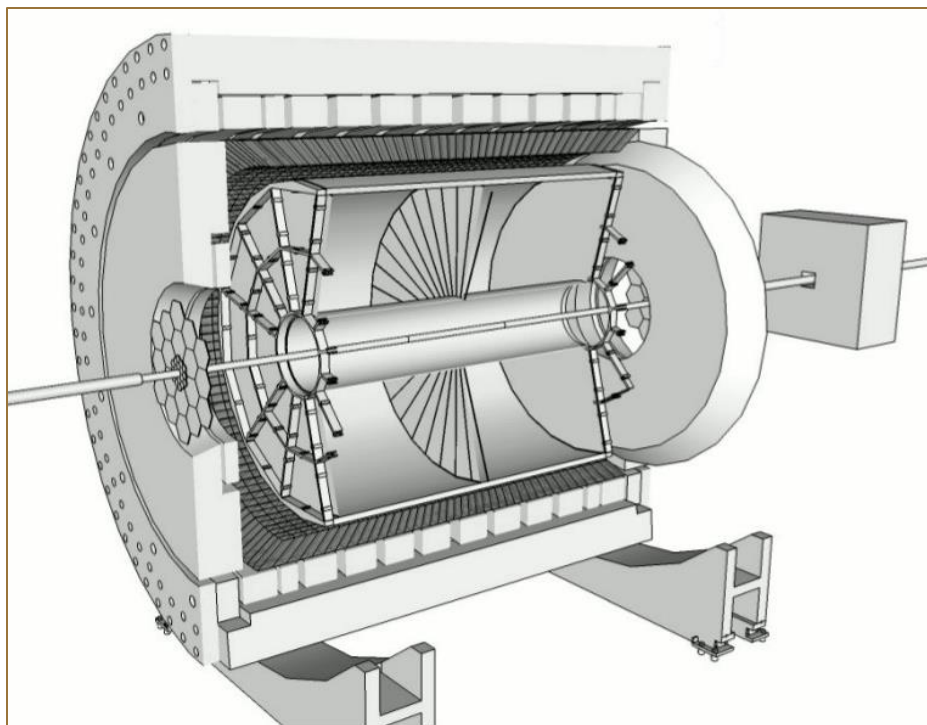


Polarized Proton Collider: RHIC



The STAR Experiment

5



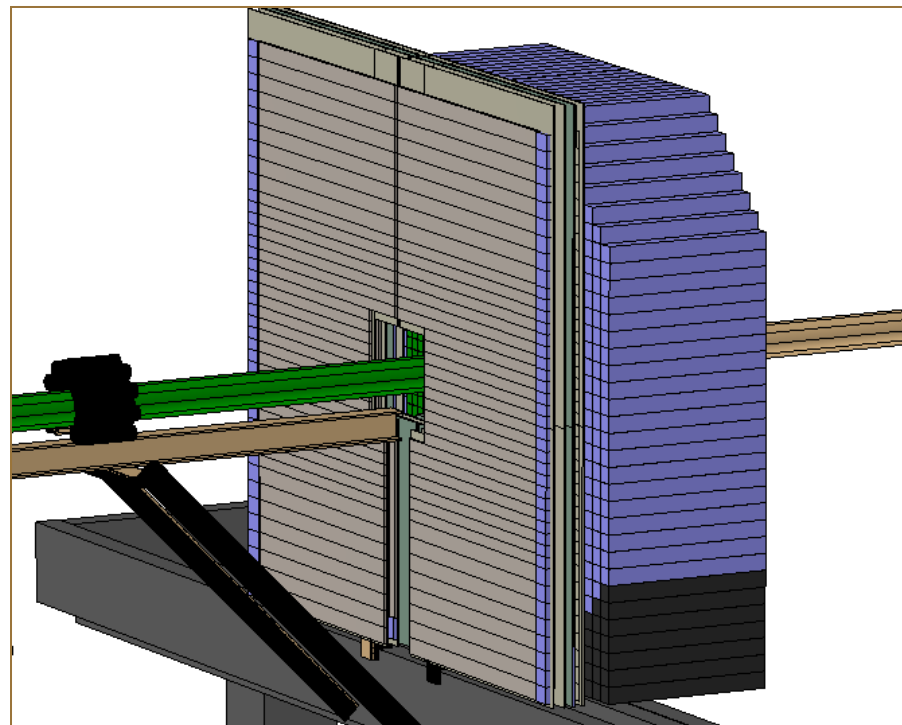
Large acceptance

$-1 < \eta < 2$, full azimuth

TPC+TOF

EMCal

other dedicated subsystems



Forward EMCAL

$2.5 < \eta < 4$

preshower detector in 2015

postshower detector in 2017

→ D. Kapukchyan (session KF, 2pm today)

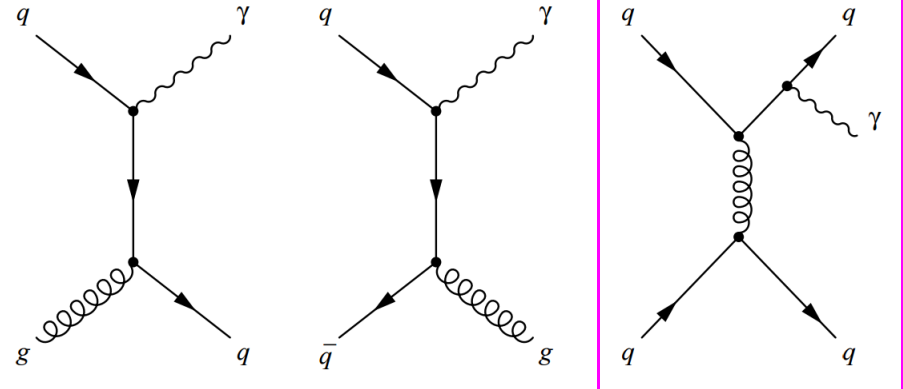
Direct Photons

Real photon from QCD hard scattering

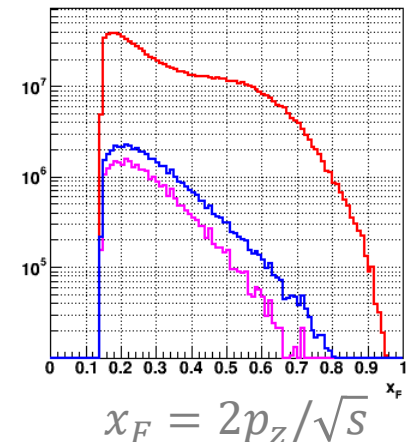
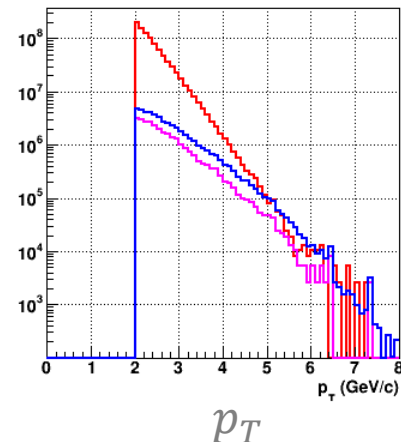
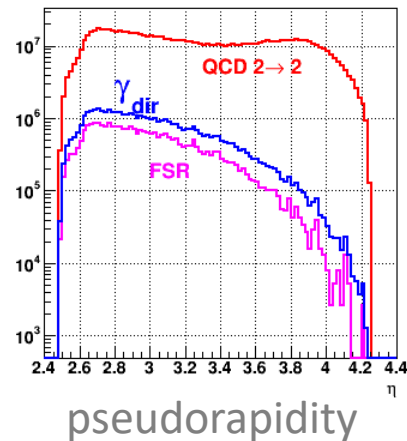
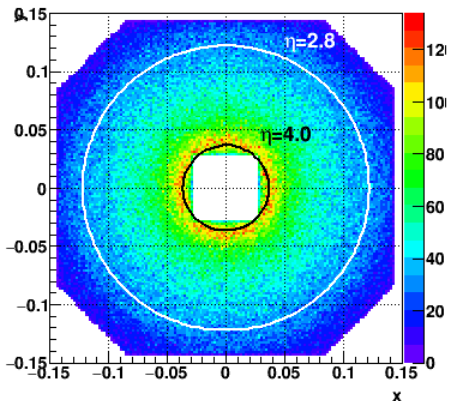
- Compton process
- Annihilation
- No fragmentation

$p + p$ collisions, $\sqrt{s} = 200$ GeV

- Small cross section $11 \mu\text{b}$
- Simulation: event generator PYTHIA 6.4.28
- With preshower selection for photon candidate



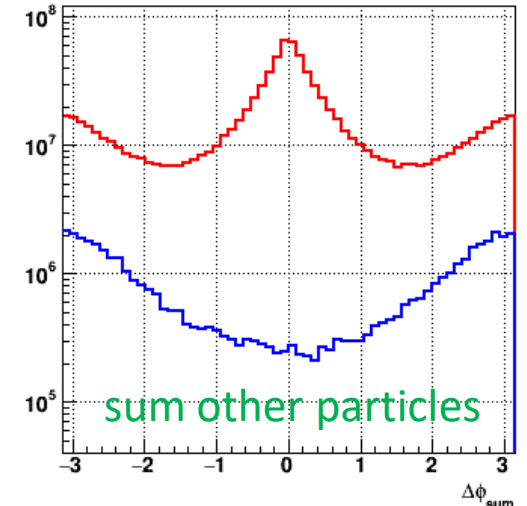
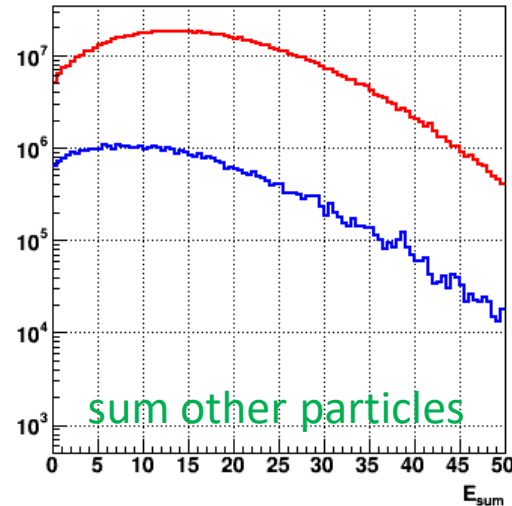
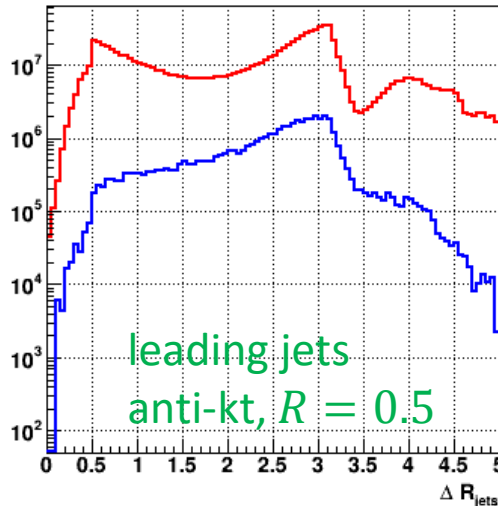
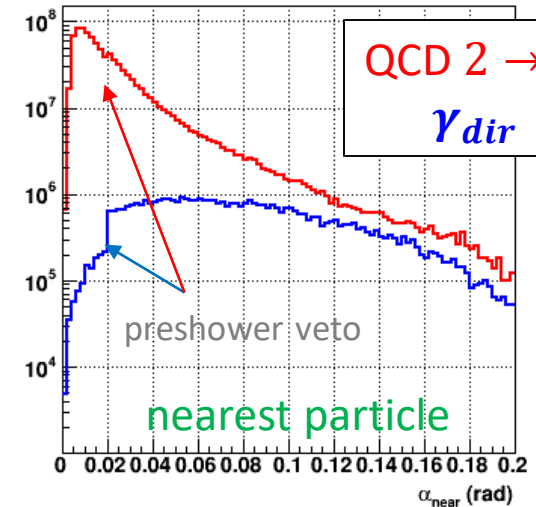
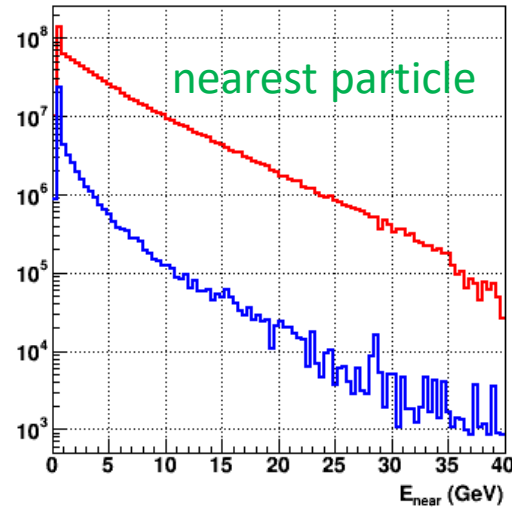
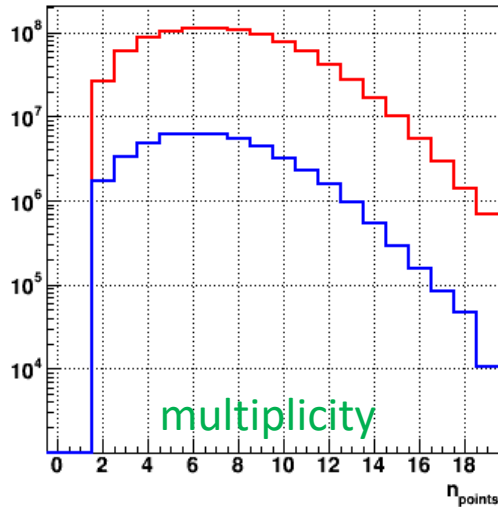
Trigger $p_T > 2.0$ GeV/c
 Photon candidate with highest energy
 Background $\times 10$ larger than signal



QCD 2 → 2 Background

Characteristics of decay photons and other event activity
(incl. hadronic response in em. calorimeter)

$$\sqrt{s} = 200 \text{ GeV}$$
$$L_{int} = 40 \text{ pb}^{-1}$$

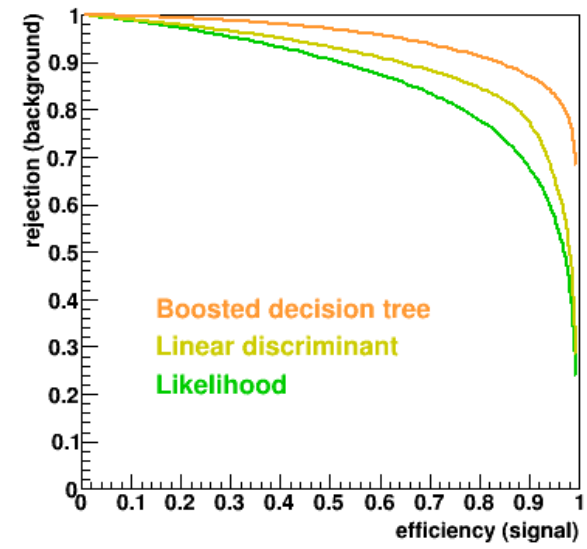
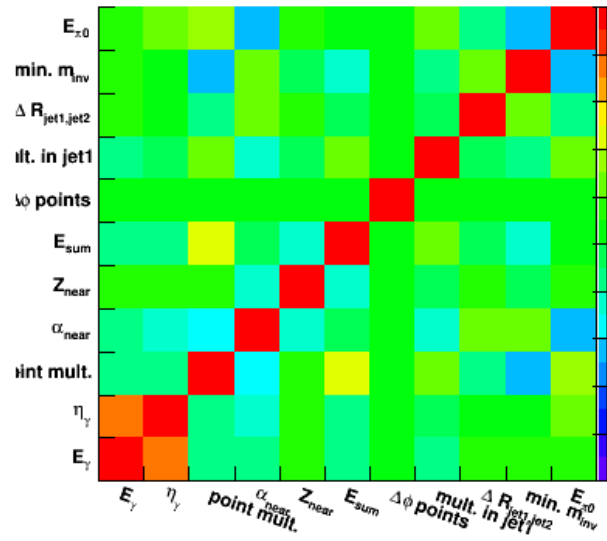


Direct Photon Identification

Multi-variate analysis

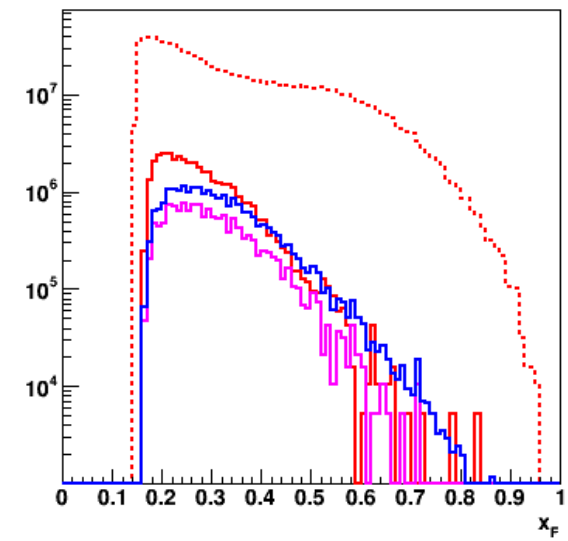
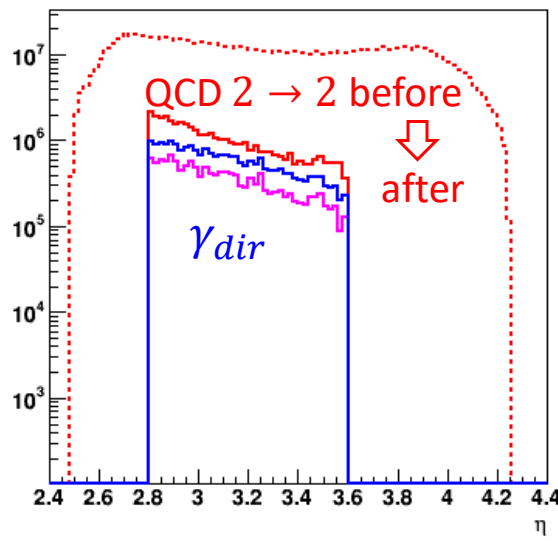
- Selection of uncorrelated variables
- Best results for boosted decision trees
- Signal efficiency $\approx 80\%$

$$\sqrt{s} = 200 \text{ GeV}$$



Remaining background

- Asymmetric η decays
- Low energy, $E < 25 \text{ GeV}$
- Near edge of acceptance

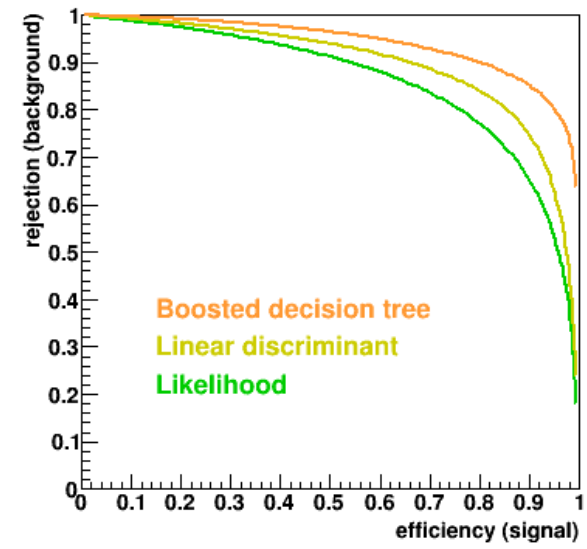
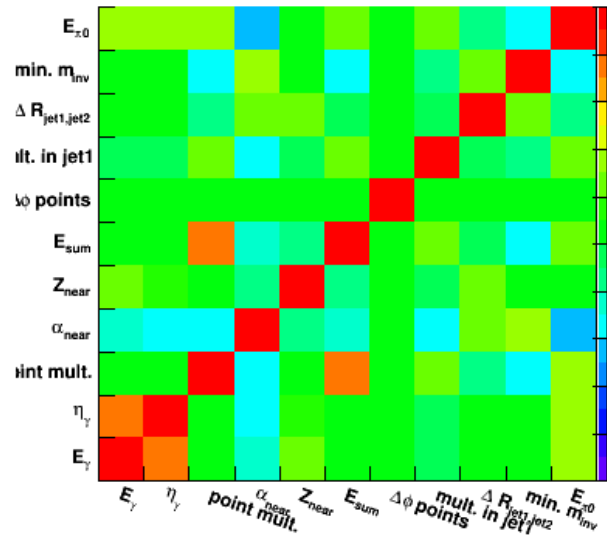


Direct Photon Identification

Multi-variate analysis

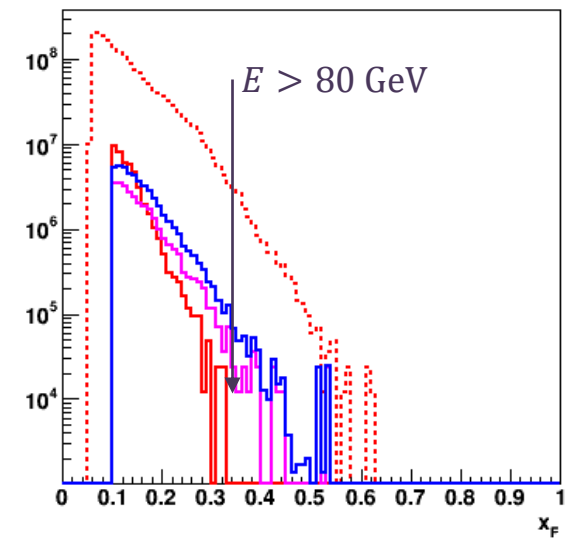
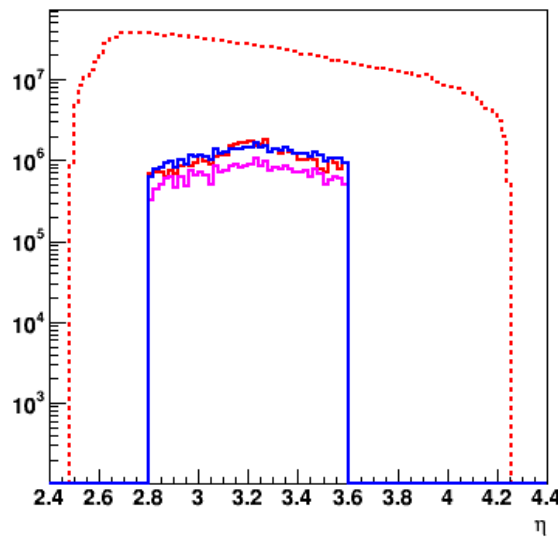
- Selection of uncorrelated variables
- Best results for boosted decision trees
- Signal efficiency $\approx 90\%$

$$\sqrt{s} = 500 \text{ GeV}$$



Remaining background

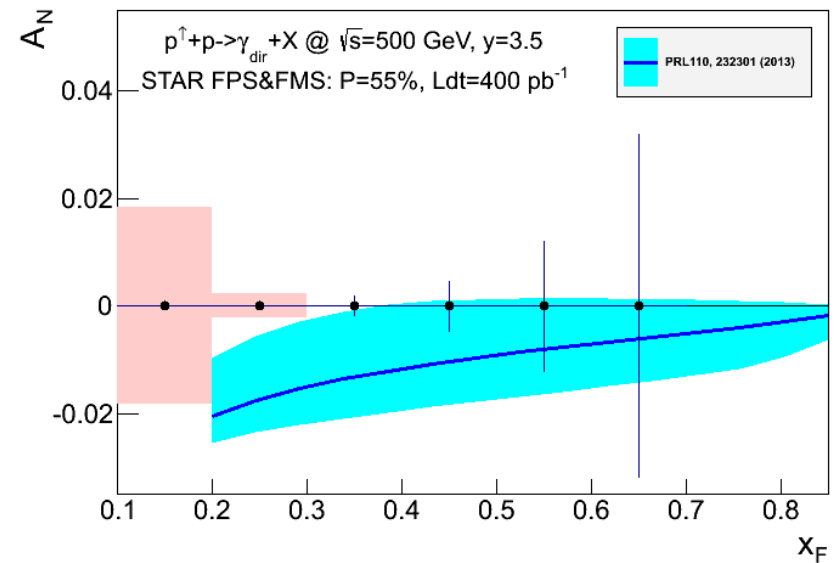
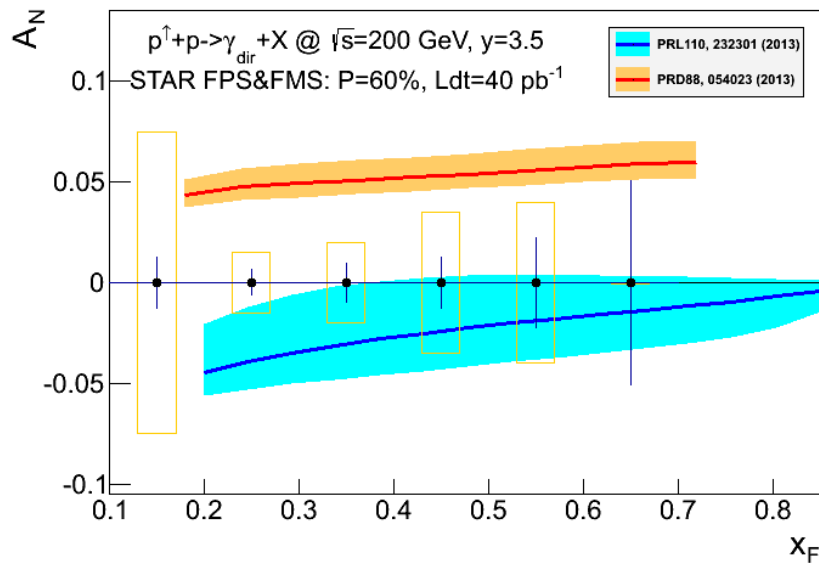
- Better rejection
- More luminosity, $\mathcal{L}_{rec} = 240 \text{ pb}^{-1}$ (2017)
- Merged π^0 showers at high energies, $E > 80 \text{ GeV}$



Next Steps

Comparison data / simulation

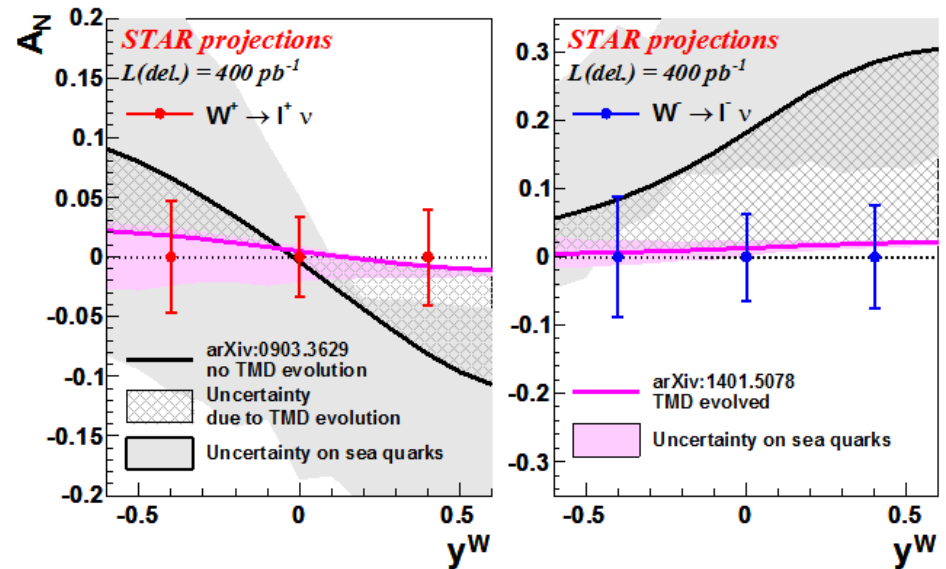
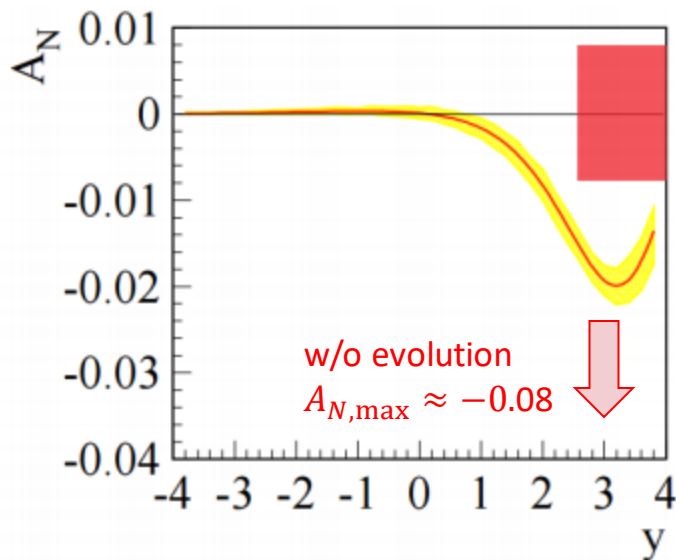
- Full detector simulation
- Possible beam related background
- Robust calibration
 - UV LED system for curing of radiation damage installed in 2017



Outlook

Direct photons are important to our understanding of QCD

- Universality
- Evolution
- Relation between higher twist collinear and TMD pictures
- In combination with measurements of Drell-Yan and W-Boson production



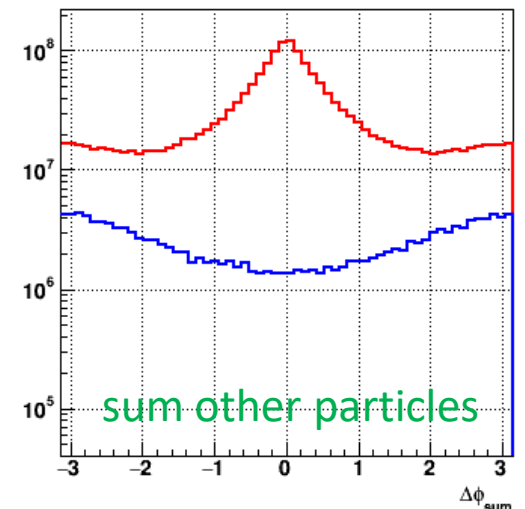
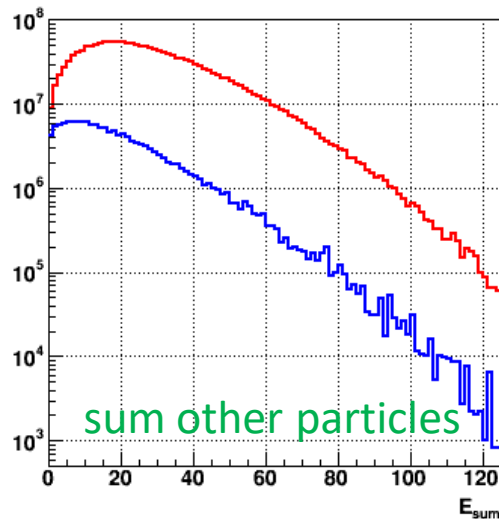
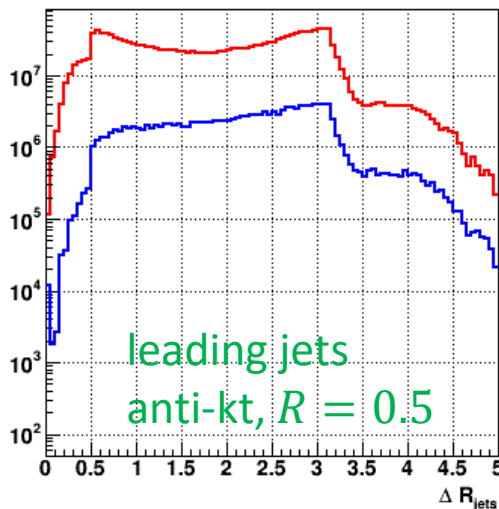
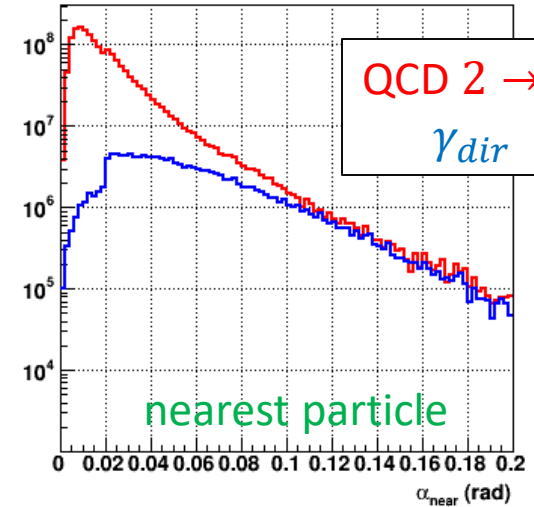
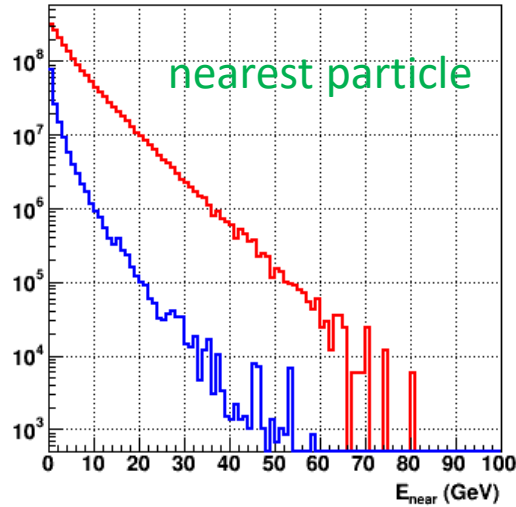
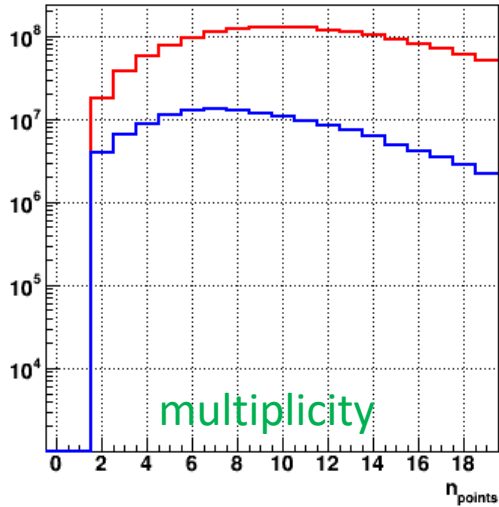


BACK UP

QCD $2 \rightarrow 2$ Background

Characteristics of decay photons and other event activity
(incl. hadronic response in em. calorimeter)

$$\sqrt{s} = 500 \text{ GeV}$$



Ideally...

Drell-Yan Production

$$p^\uparrow + p \rightarrow \gamma^* \rightarrow l^+ + l^-$$

$$\sqrt{s} = 500 \text{ GeV}$$

$$Q^2 = M^2 \gg p_T^2$$

Get rid of background

Scan x with rapidity

Accumulate a few fb^{-1}

