Measurement of D-meson triggered correlations in proton+proton collisions at RHIC energies

Long Ma[(1)] (for the STAR collaboration)
1) Shanghai Institute of Applied Physics

Sept 23 –27 , 2016 , Wuhan , China

中国科学院上海应用物理研究所
Shanghai Institute of Applied Physics, Chinese Academy of Sciences

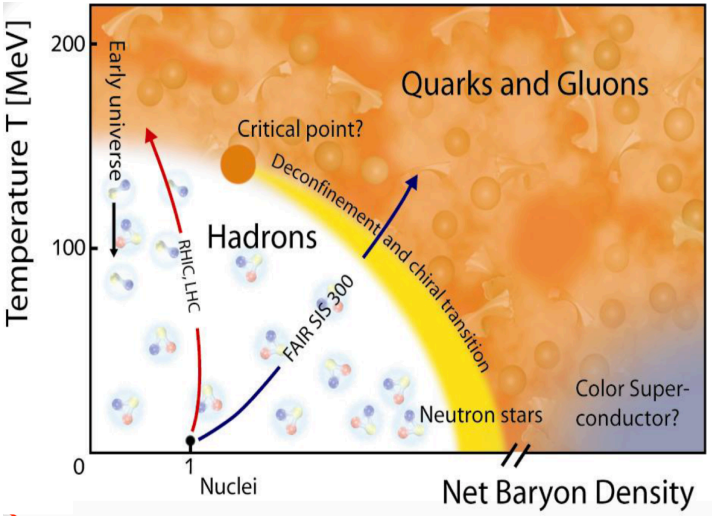
Outline

- Research motivations
- STAR detector and D meson reconstruction
- Results and discussions
  - ➢ D*- hadron azimuthal correlation
  - ➢ D - $\bar{D}$ azimuthal correlation
- Summary

Motivation

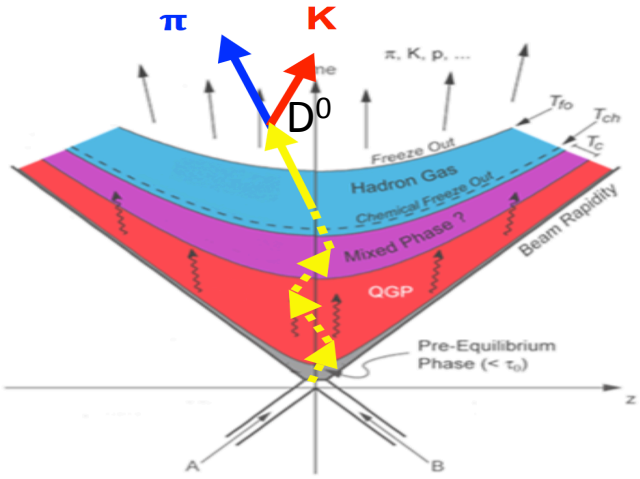
A new state of hot, dense QCD matter (Quark-Gluon Plasma) is created in high energy heavy-ion collisions

Its properties can be studied through interactions of energetic partons with the medium



Heavy quarks produced in hard scatterings at the early stage of collisions experience the entire evolution of the QGP matter

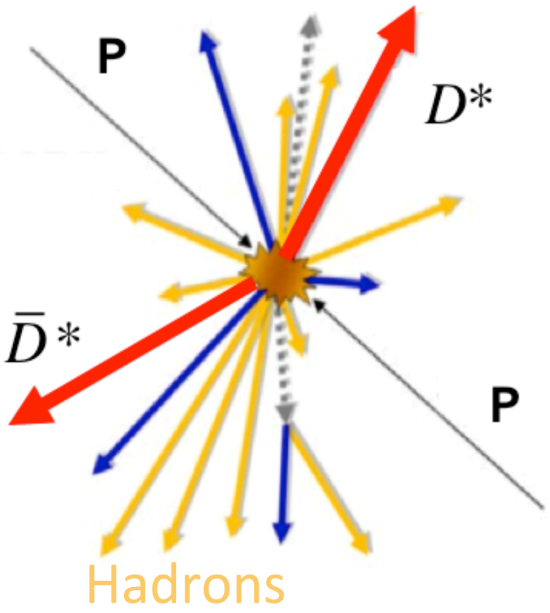
- Excellent probes of QGP properties



Study of D-hadron angular correlation

In A+A collisions

- Study medium-induced modifications to charm fragmentation
- Provide insight into the energy loss mechanism for charm quarks inside the medium



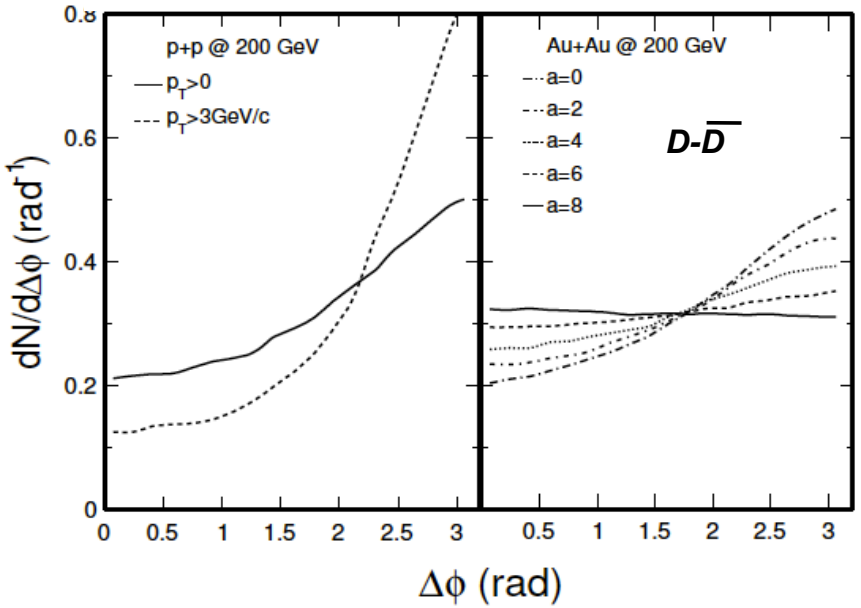
In p+p collisions

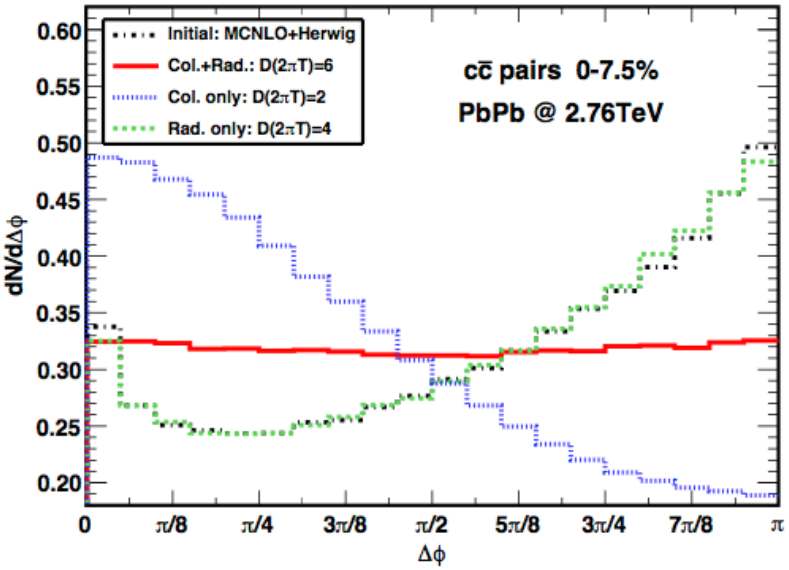
- Test perturbative QCD calculations
- Reference measurements for p+A and A+A collisions

Study of D-$\bar{D}$ angular correlation

X.Zhu, N. Xu, P.F Zhuang, PRL 100 (2008) ,152301

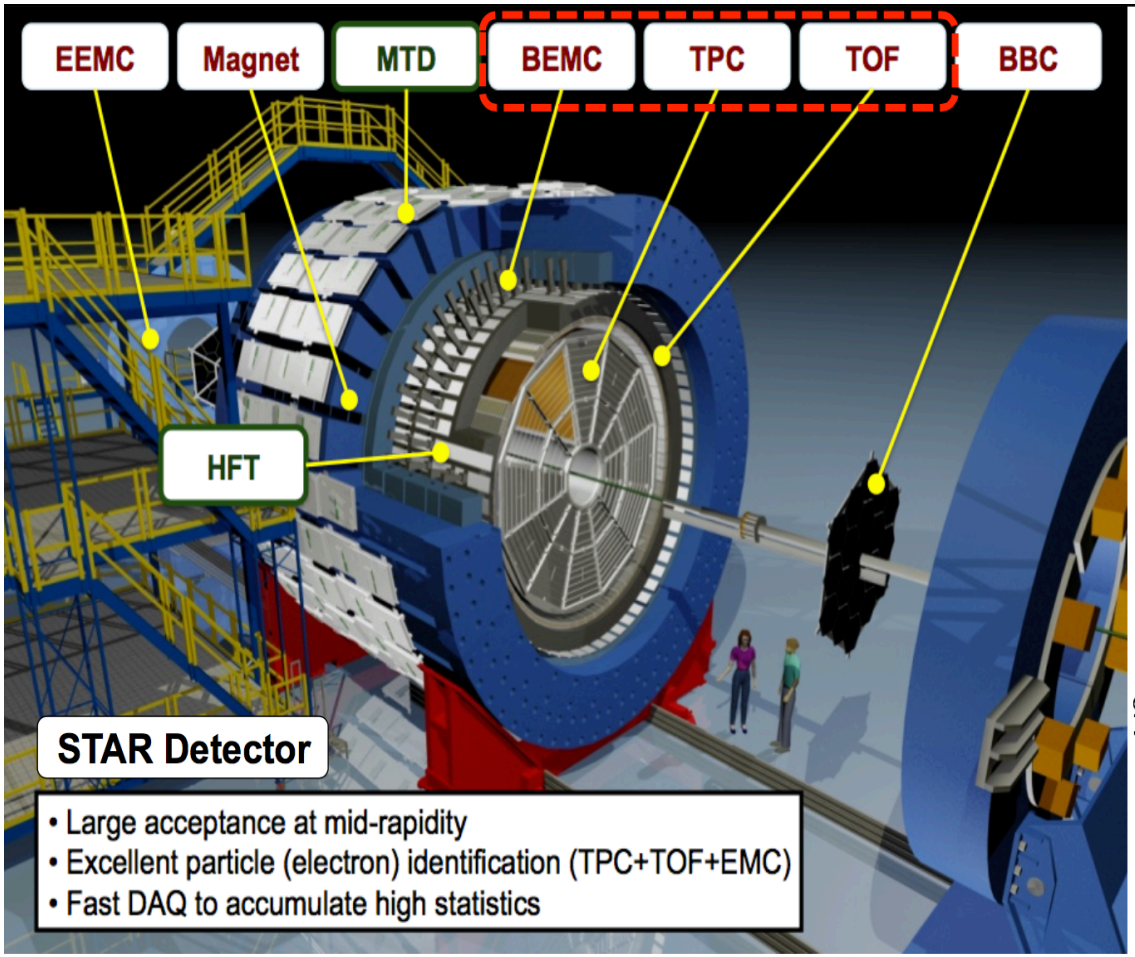
S.S.Cao, G.Y.Qin, S.A.Bass, Nucl. Phys. A 932 (2014) 38

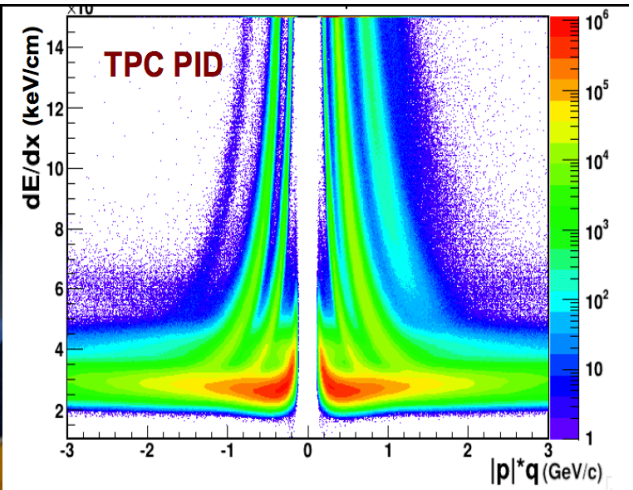


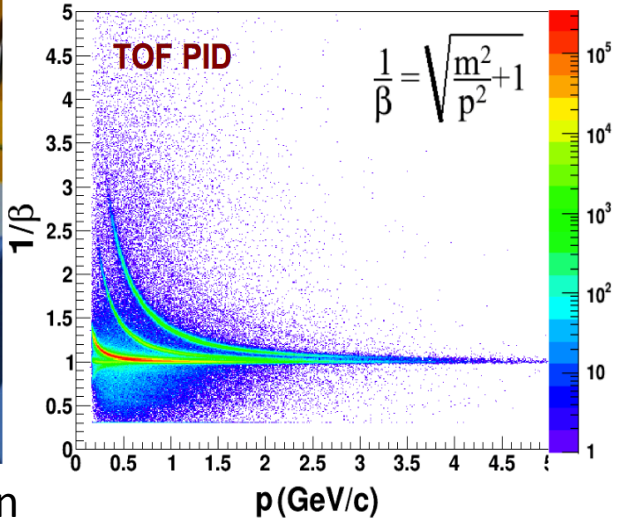


- Heavy quark correlation – sensitive probe to the medium thermalization
- Potential for distinguishing different energy loss mechanisms in the medium
- Clean probe at RHIC energies – much smaller feed-down contribution and background from uncorrelated D and $\bar{D}$ pairs compared to LHC energies

Experimental setup – the STAR detector



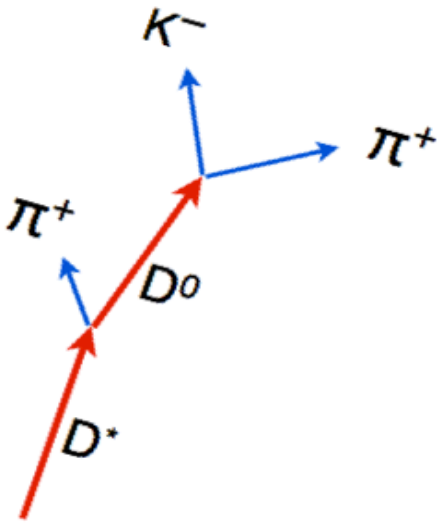


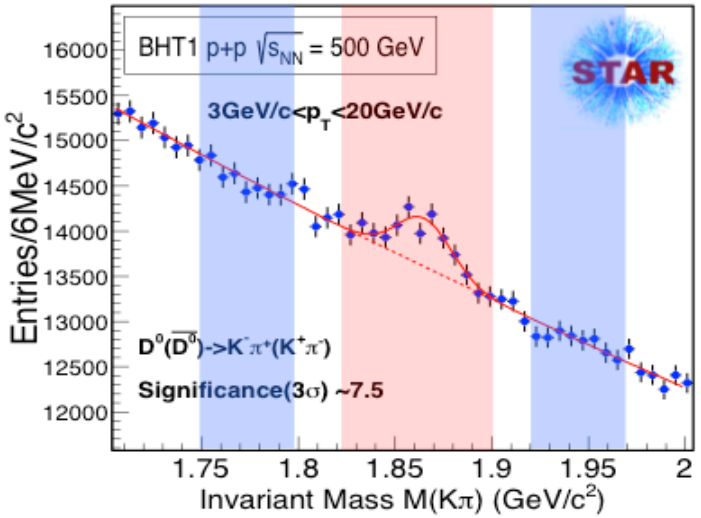


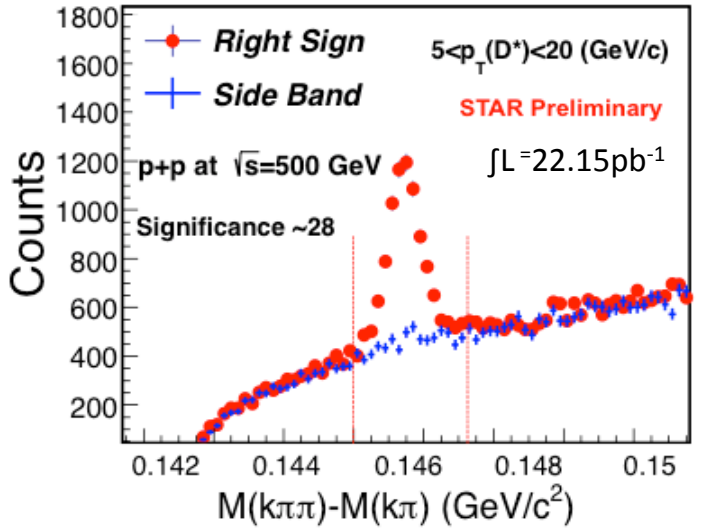
- Detectors highlighted in the red dashed box are used in this analysis

D meson reconstruction in p+p collisions

Decay Channel	Branching Ratio
$D^0 -> K^- \pi^+$	~3.89%
$D^{*+} -> D^0 + \pi^+$	~67.7%

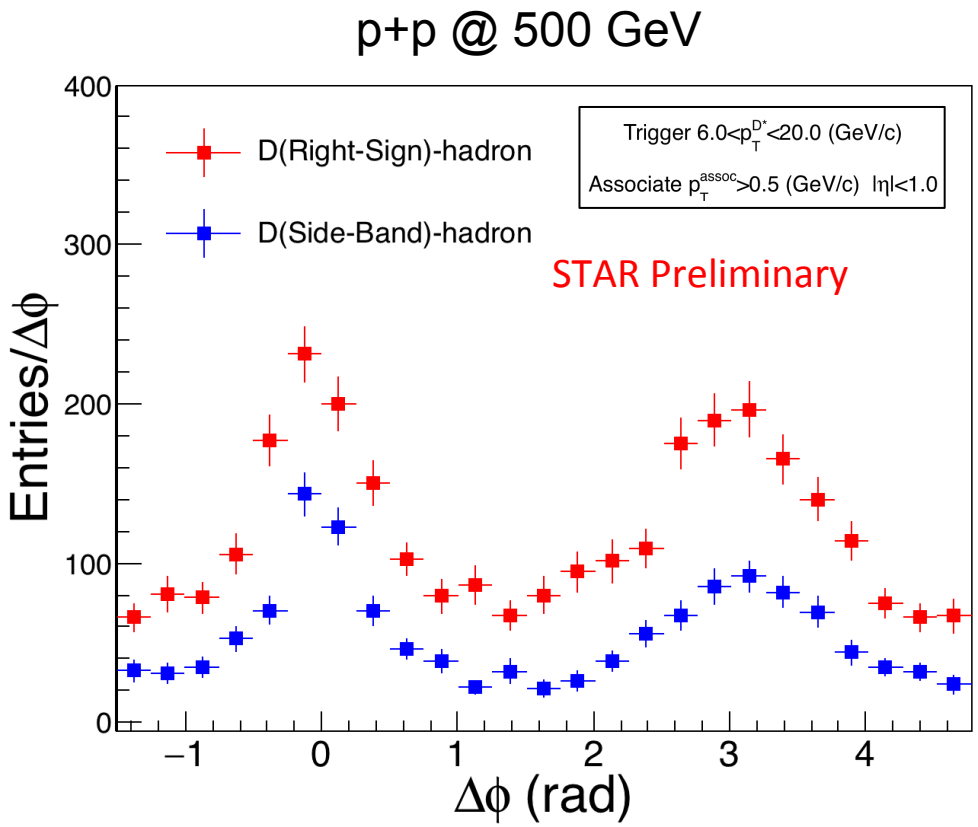






- ✓ D^0 / D* reconstruction using invariant mass method
- ✓ Background subtraction via side-band method

Raw signals of D*-h azimuthal correlation



✓ Foreground- and background- triggered correlations show similar shapes

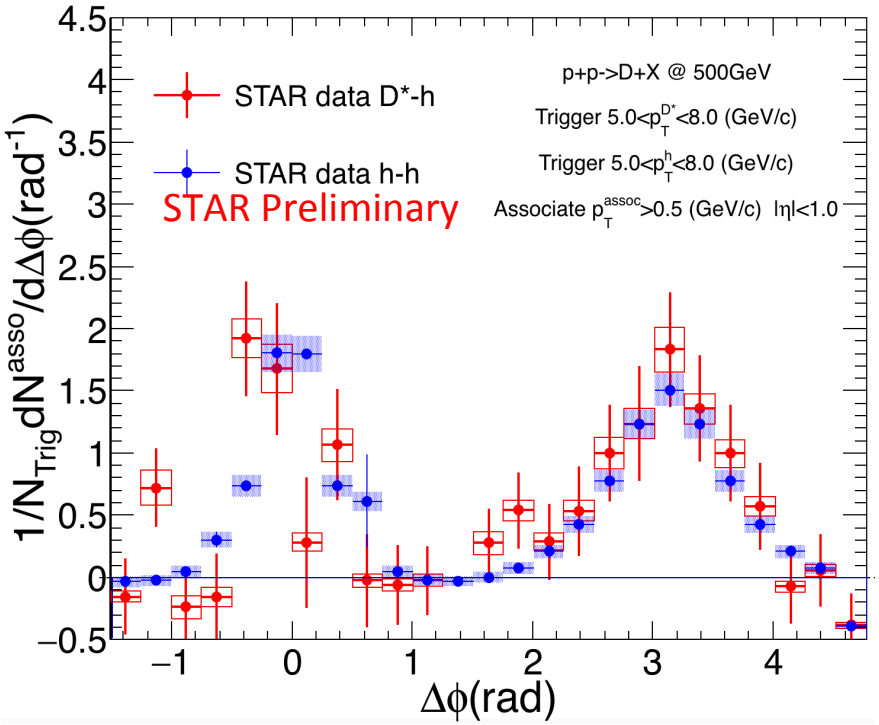
$$C_{signal}(\Delta\varphi,|\eta|<1.0) = C(\Delta\varphi,|\eta|<1.0)_{right-sign} - \frac{BG_{right-sign}}{BG_{side-band}} C(\Delta\varphi,|\eta|<1.0)_{side-band}$$

D*-hadron azimuthal correlation in 500 GeV p+p collisions

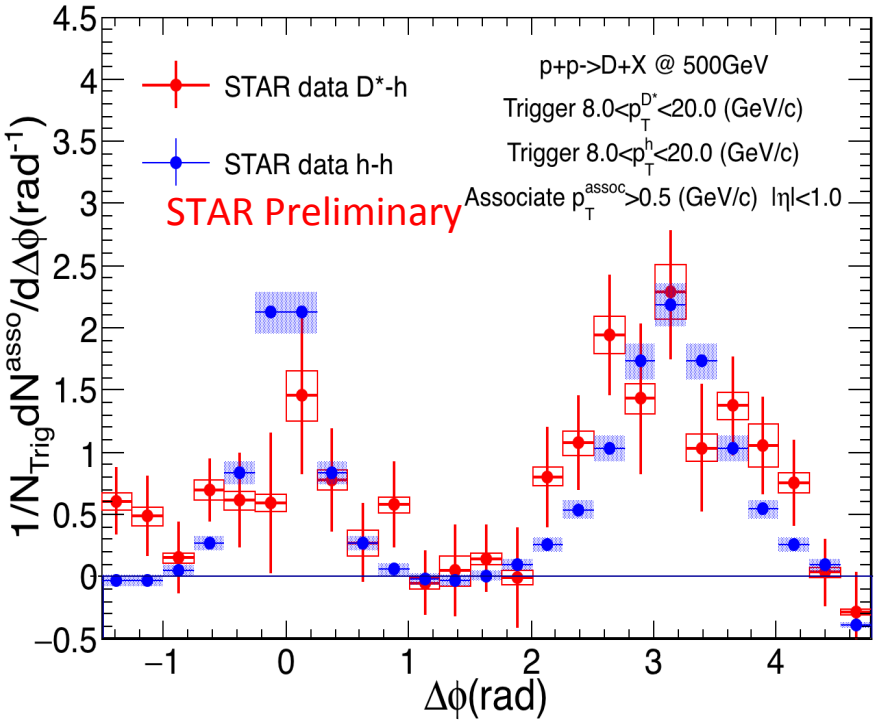
- Comparison of D*-hadron and di-hadron correlations

Compatible within uncertainties between D*-hadron and di-hadron azimuthal correlations

$5.0< p_T^{Trig}(D^*) <8.0$ GeV/c



$8.0< p_T^{Trig}(D^*) <20.0$ GeV/c



D*-hadron azimuthal correlation in 500 GeV p+p collisions

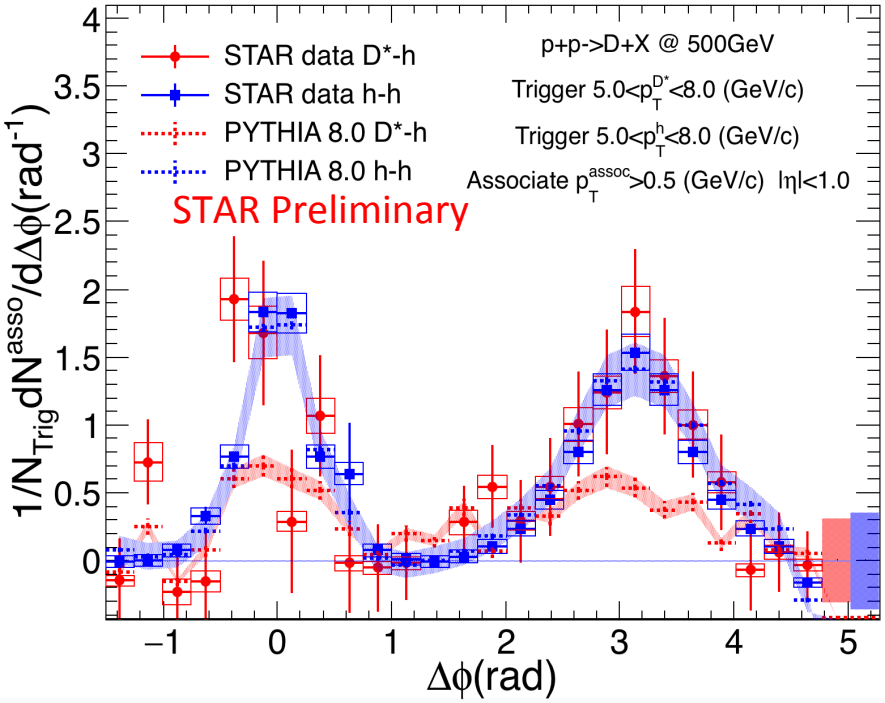
- **Comparison of D*-hadron and di-hadron correlations**

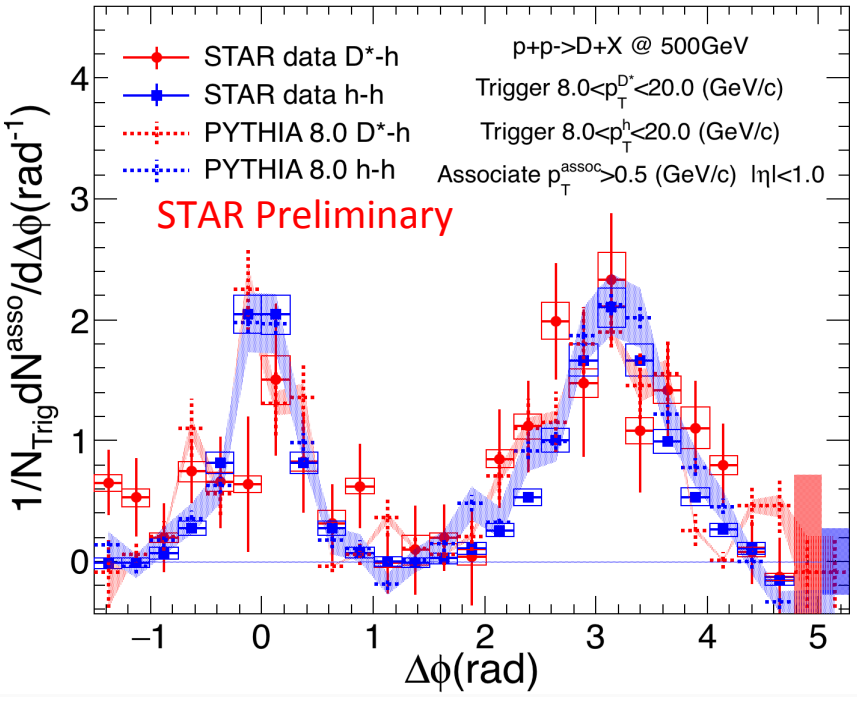
Compatible within uncertainties between D*-hadron and di-hadron azimuthal correlations

- **Comparison of data and PYTHIA simulation**

PYTHIA well reproduces di-hadron correlations

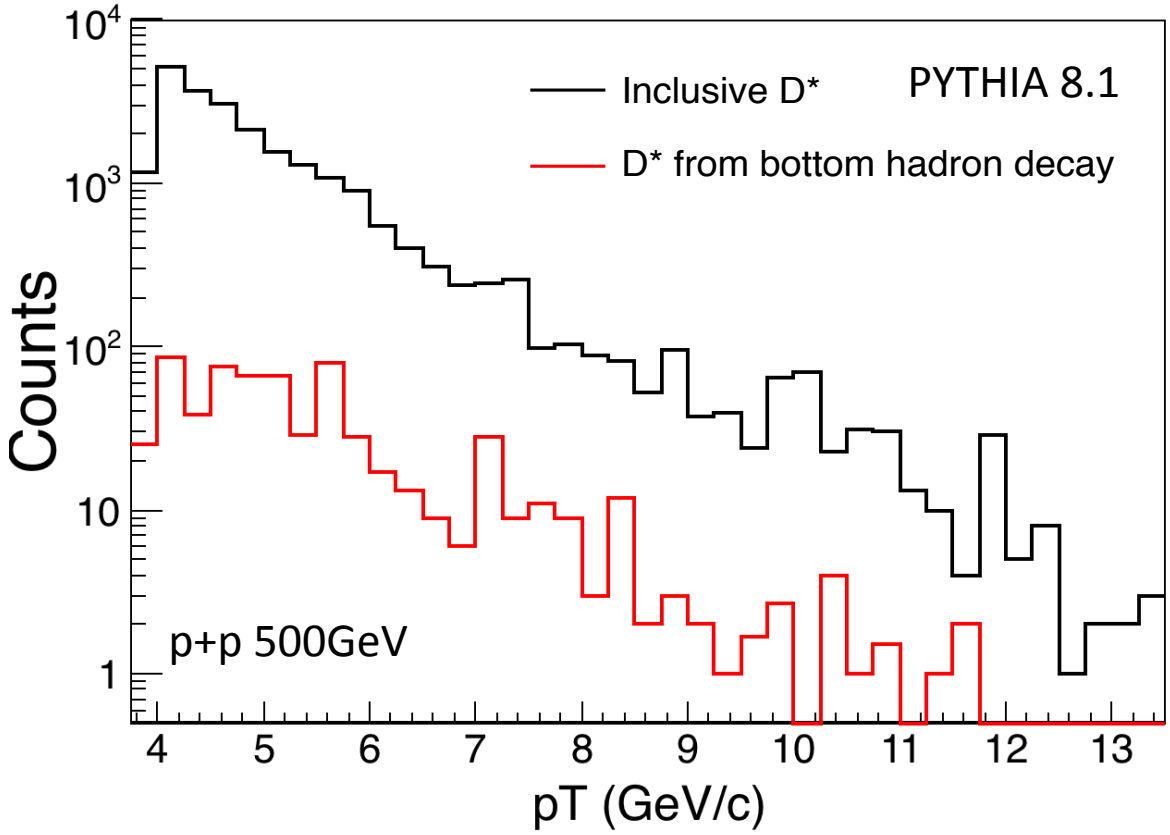
PYTHIA well describes D*-hadron correlation at high pT $8< p_T^{Trig}(D^*) <20$ GeV/c





The feed-down contribution (PYTHIA study)

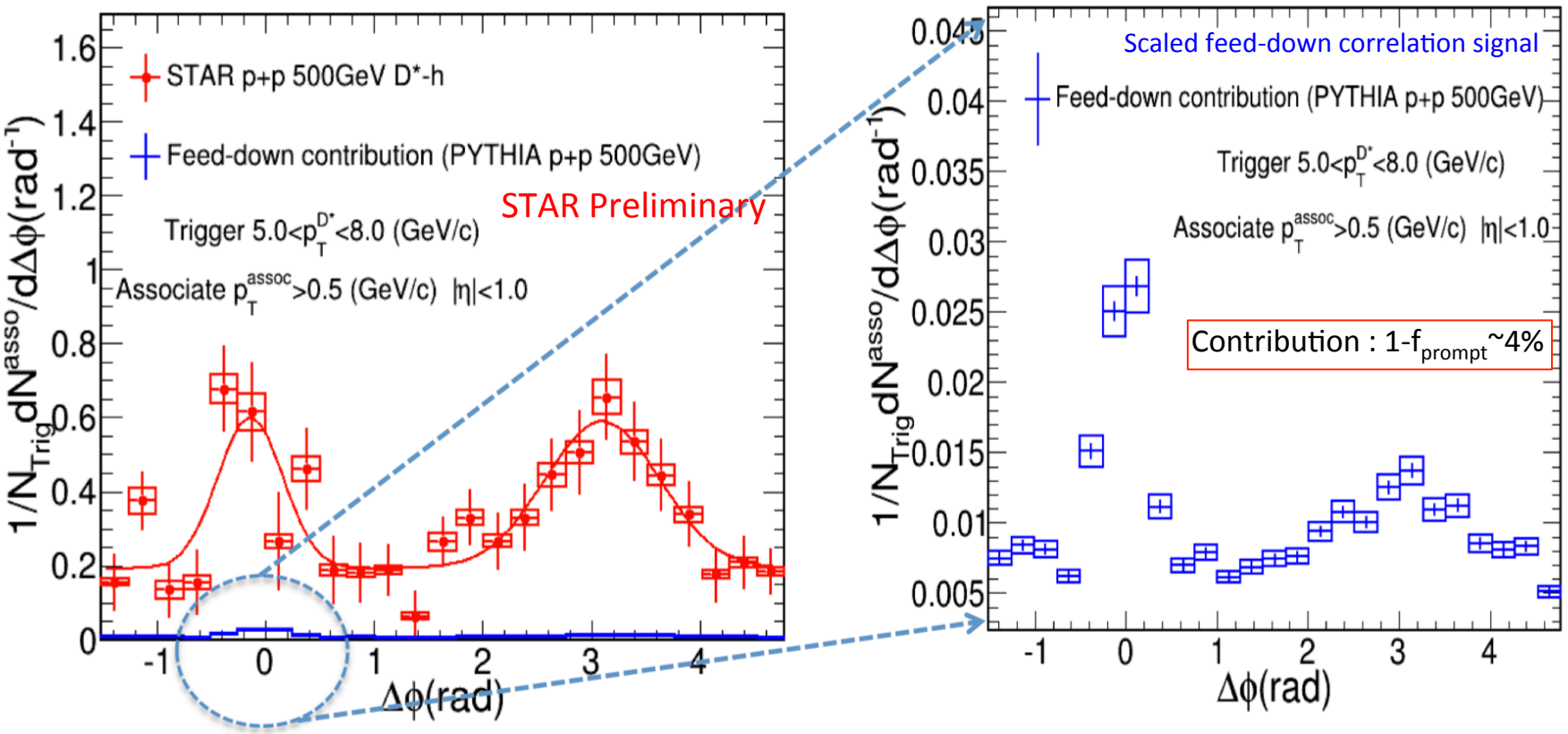
Feed-down contribution from b-quark decay (PYTHIA 8.1 simulation) :



B->D* / Inclusive D*	5-8 (GeV/c)	8-20 (GeV/c)
p+p @ 500 GeV	~0.04	~0.05

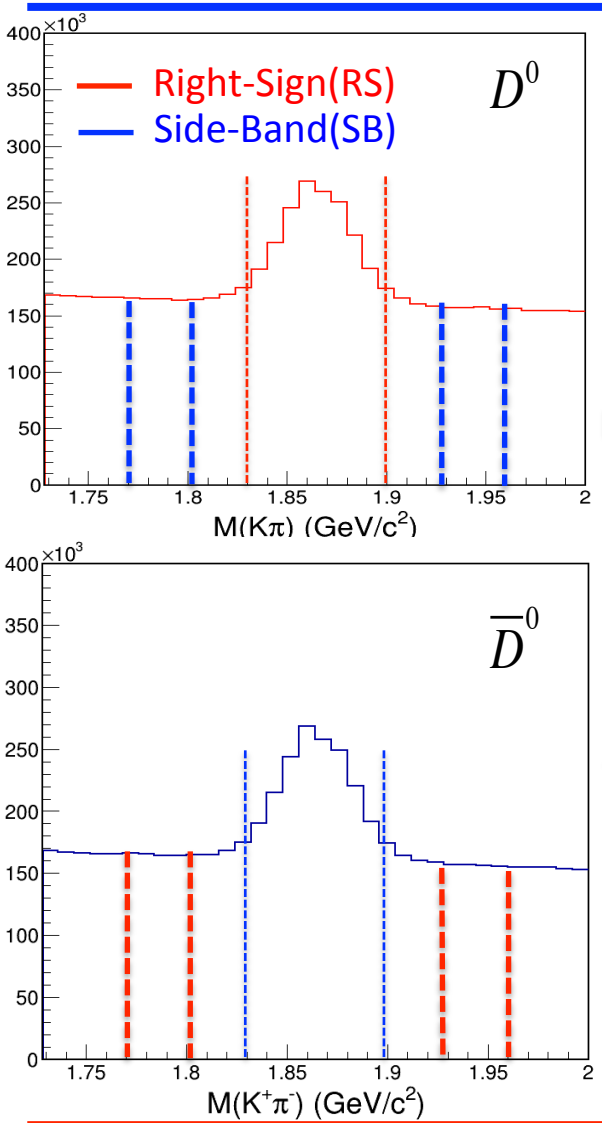
The feed-down contribution (PYTHIA study)

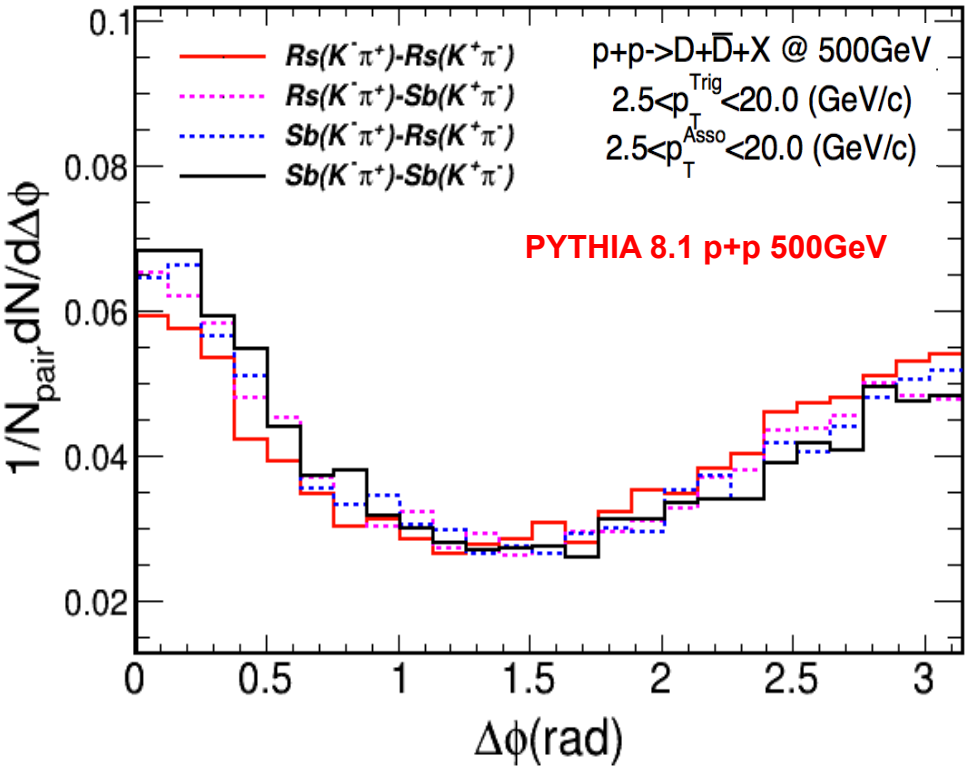
b-quark contributions→Near-side dominated



$$C_{\text{prompt}}(\Delta\varphi) = \frac{1}{f_{\text{prompt}}}\Big[\; C_{\text{inclusive}}(\Delta\varphi) - (1 - f_{\text{prompt}})C^{\text{MC}}_{\text{feed-down}}(\Delta\varphi)\Big]$$

Simulation study of D-$\bar{D}$ correlation

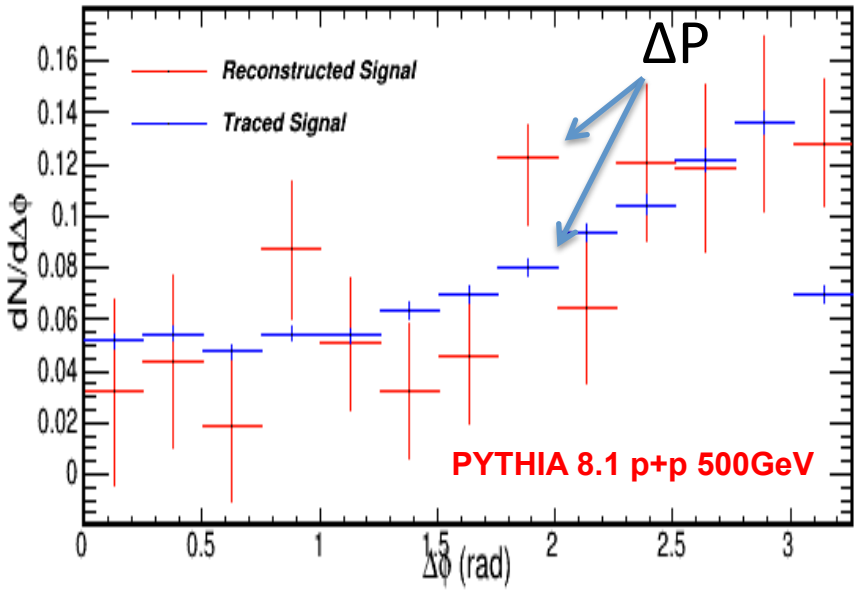


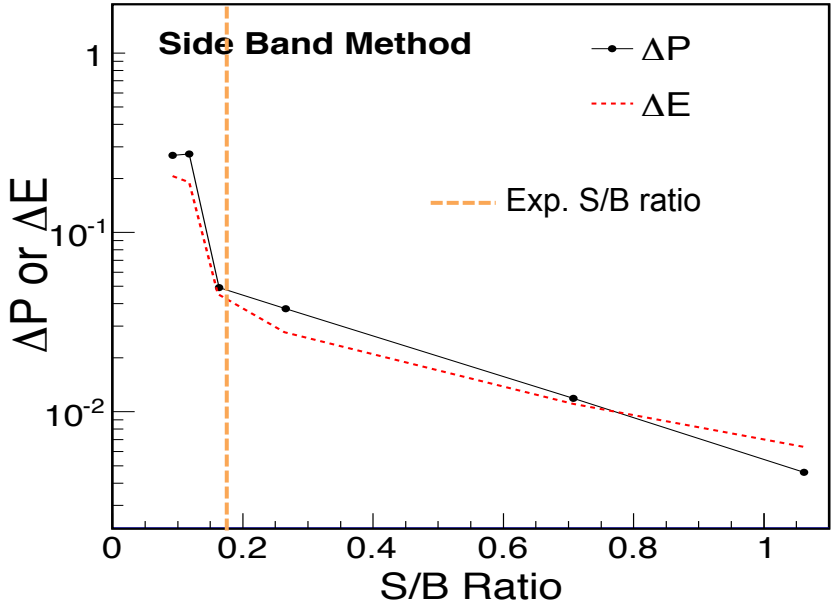


Correlation Method

$$Signal(D^0)\bullet Signal(\bar{D}^0)$$
$$= RS(D^0)\bullet RS(\bar{D}^0) - SB(D^0)\bullet RS(\bar{D}^0)$$
$$- SB(\bar{D}^0)\bullet RS(D^0) + SB(D^0)\bullet SB(\bar{D}^0)$$

Simulation study of D-$\bar{D}$ correlation





Reconstructed signal
- Reconstructed D^0-D^0(bar) correlation

Traced signal
- Real D^0-D^0(bar) correlation

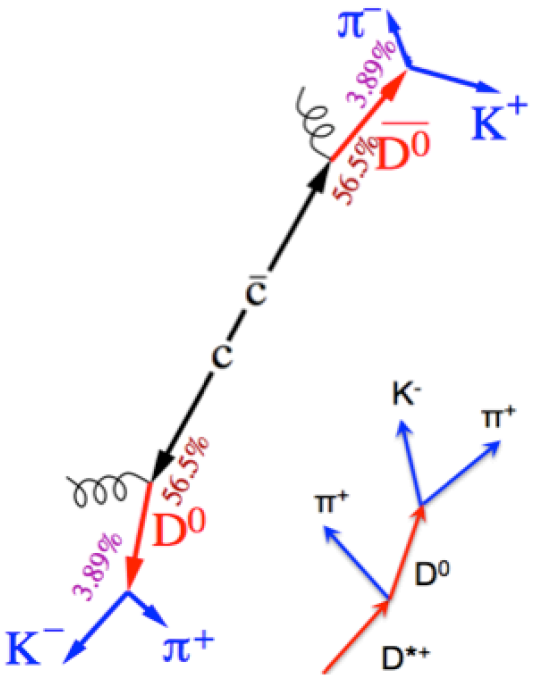
Consistency check -
Relative differences of central values and combined statistical errors

$$u_i = \left(\frac{1}{N_{trig}}\frac{dN}{d\Delta\phi_i}\right)_{reco}, \qquad v_i = \left(\frac{1}{N_{trig}}\frac{dN}{d\Delta\phi_i}\right)_{real}$$

$$\Delta P = \frac{1}{N}\sum_{i=1}^{k}\left|\frac{u_i - v_i}{v_i}\right|, \qquad \Delta E = \frac{1}{N}\sum_{i=1}^{k}\left|\frac{\sqrt{\sigma_{u_i}^2 + \sigma_{v_i}^2}}{v_i}\right|$$

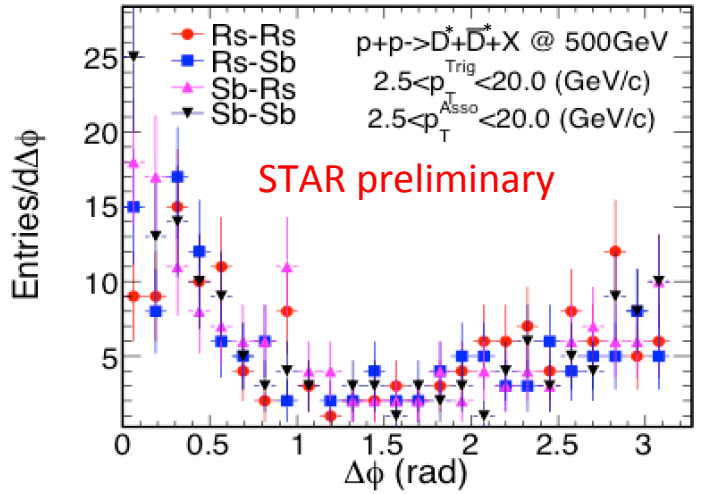
✓ Side-band method shows good performance down to low S/B

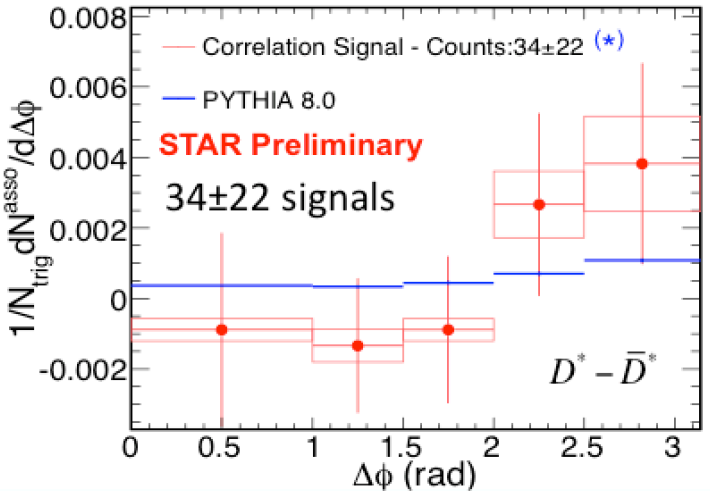
D*- $\bar{D}$* azimuthal correlation in 500 GeV p+p collisions



Correlation Method

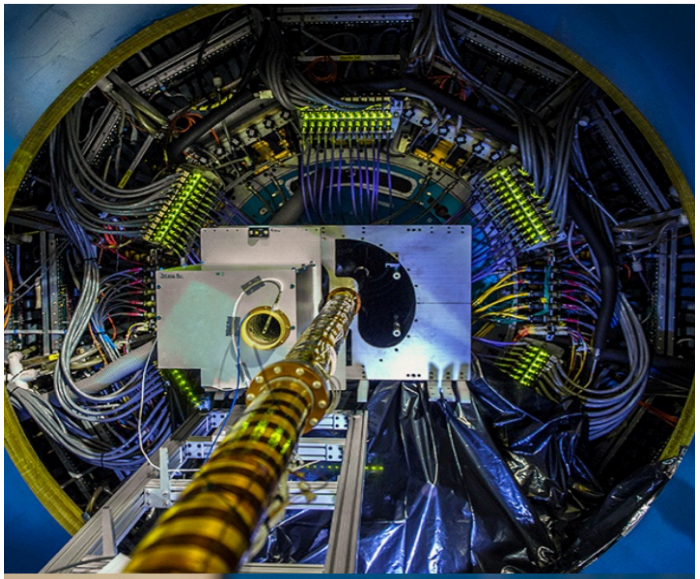
$$Signal(D^*)\bullet Signal(\bar{D}^*)$$
$$= RS(D^*)\bullet RS(\bar{D}^*) - SB(D^*)\bullet RS(\bar{D}^*)$$
$$-SB(\bar{D}^*)\bullet RS(D^*) + SB(D^*)\bullet SB(\bar{D}^*)$$

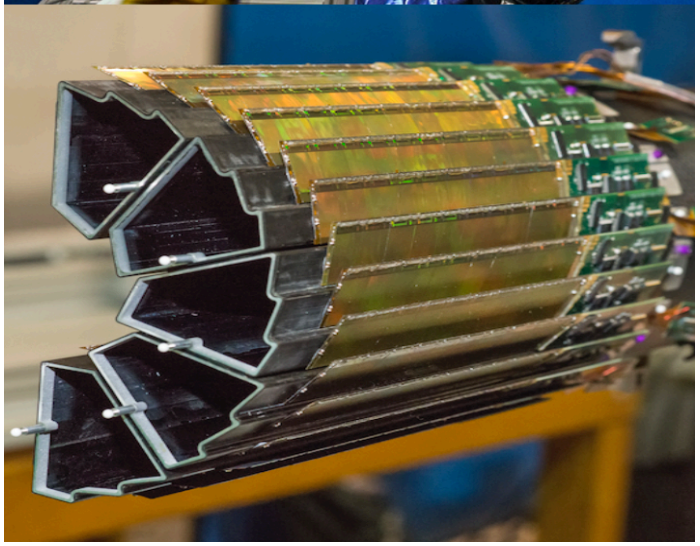


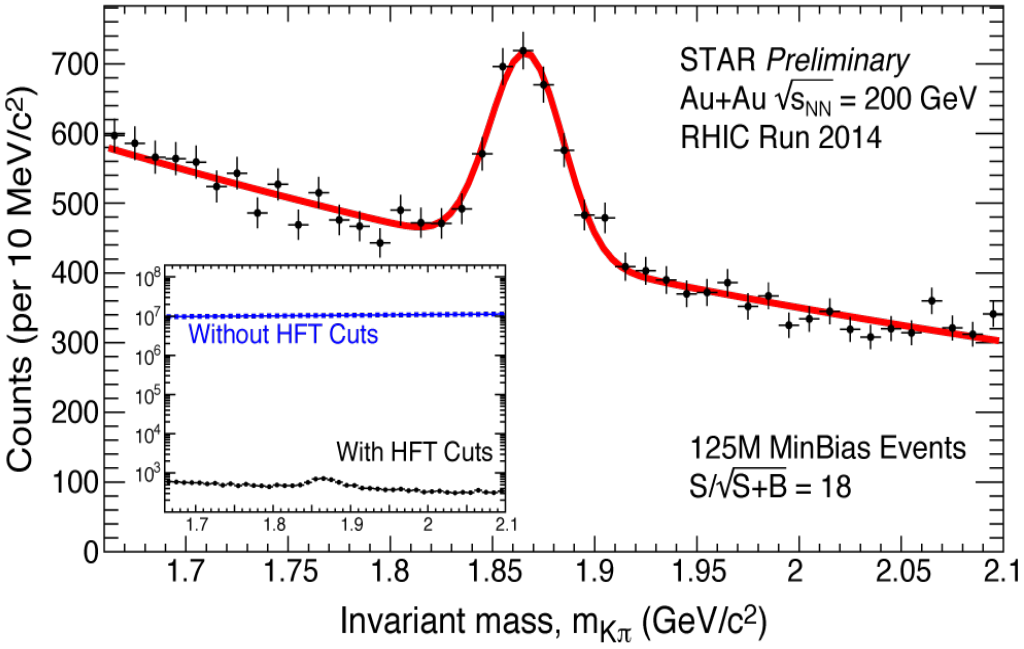


Correlation signal with 34±22 associated D*-D* pairs

D-meson triggered correlation study in Au+Au collisions by HFT







Year	2014	2014+2016
Events (AuAu MB)	1.2 B	>3 B
Significance / billion events	51	>100

Summary and outlook

- First measurement of D*- hadron azimuthal correlations in p+p collisions at center-of-mass energy of 500 GeV

- PYTHIA simulation describes D*-h correlations at high p_T (8-20 GeV/c)
- Results are compatible within uncertainties between D*- hadron and di-hadron correlations for p_T (5-20 GeV/c)

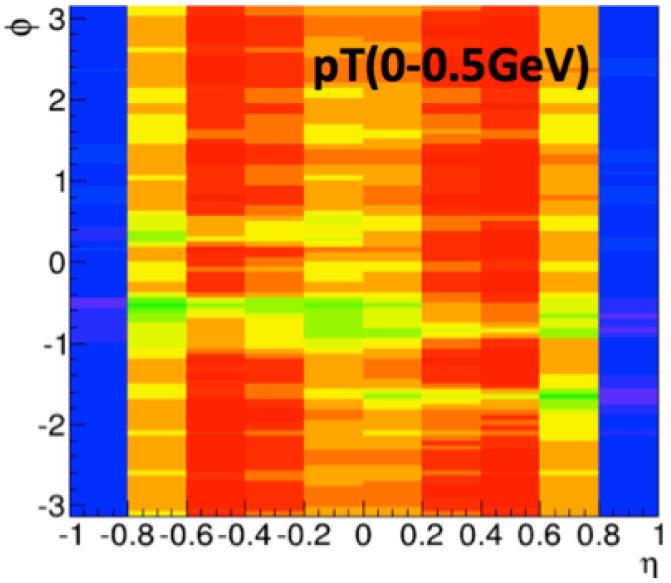
- First measurement of D*- D*(bar) correlations in 500 GeV p+p collisions

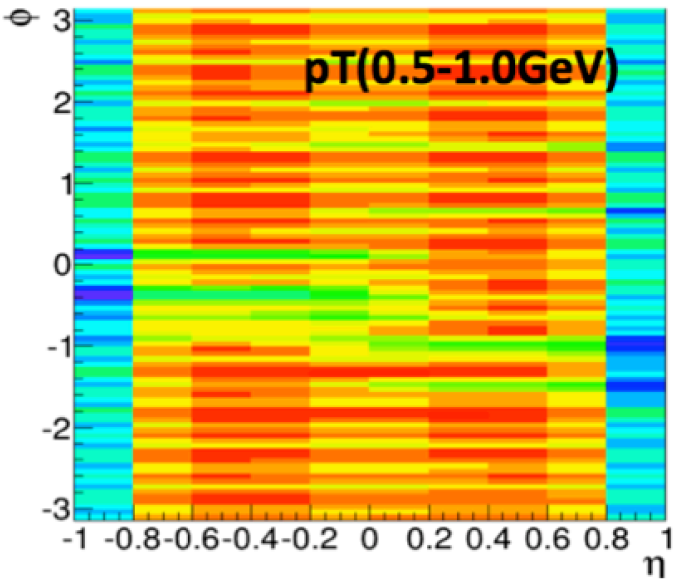
- Results are consistent with PYTHIA predictions within large uncertainties

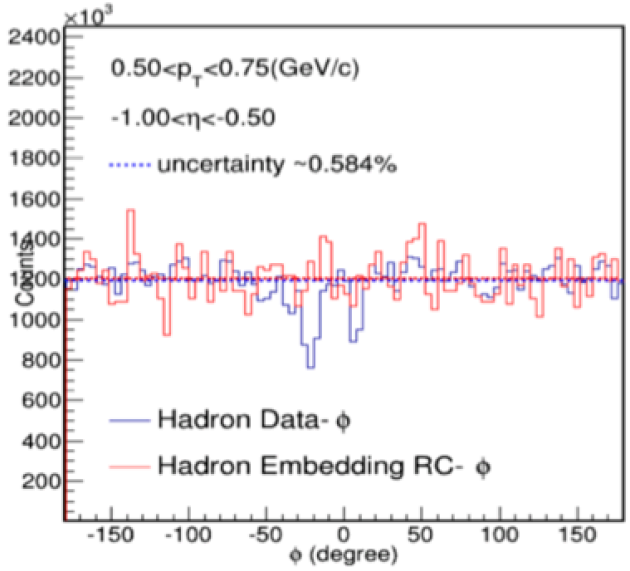
- High statistics data taken with STAR Heavy Flavor Tracker will allow the measurements of D-hadron and D-D(bar) correlations in Au+Au collisions in the future

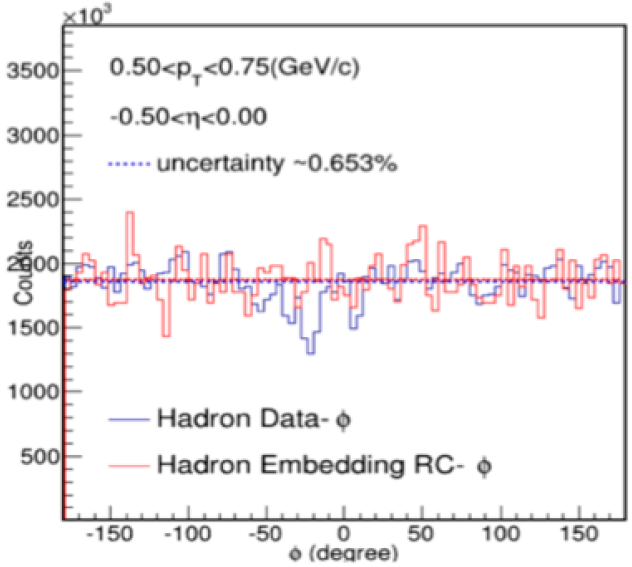
Thank You!

Back-ups: Acceptance Correction

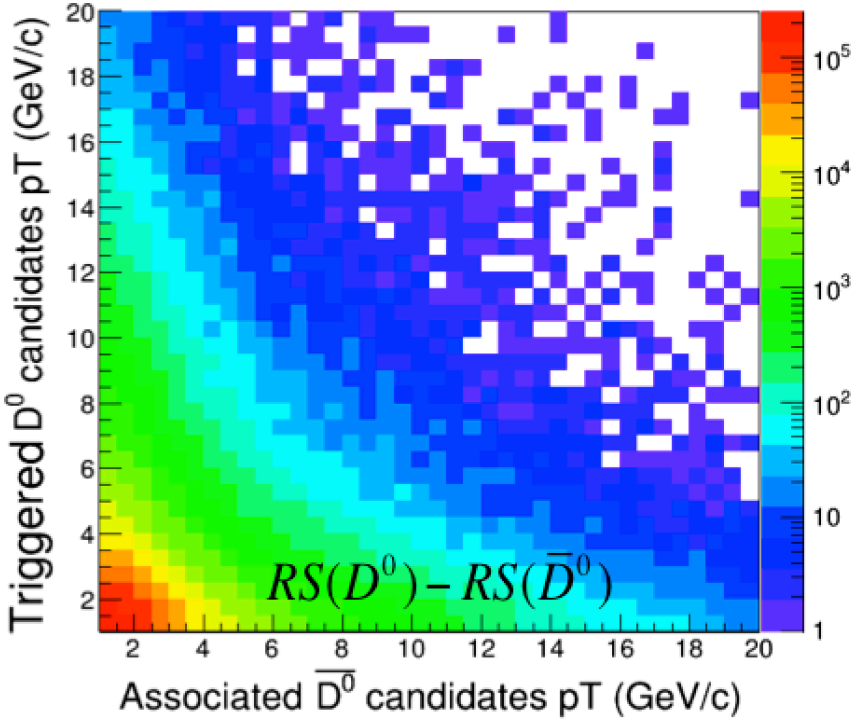


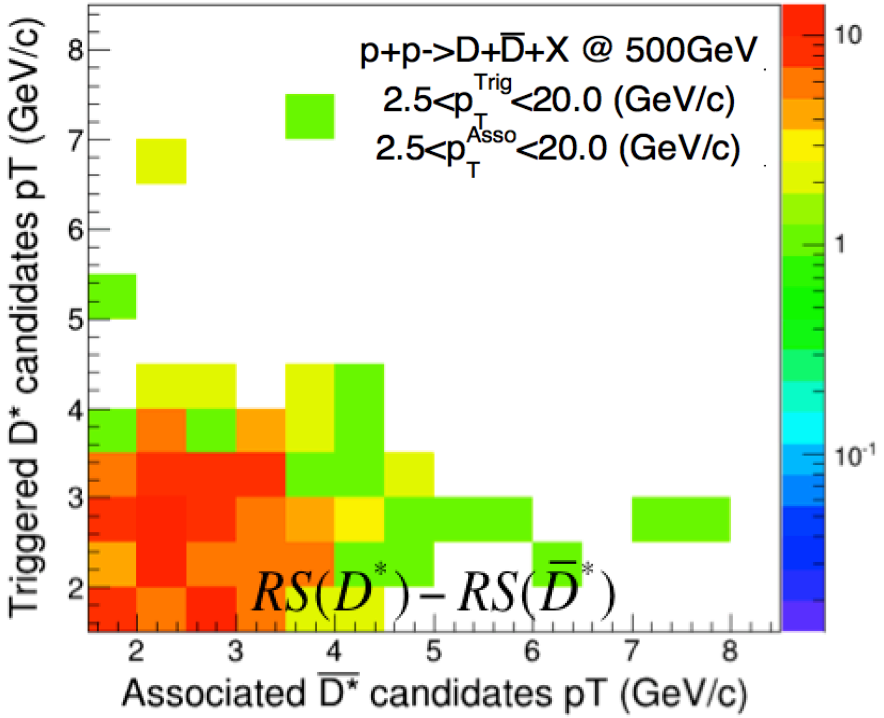






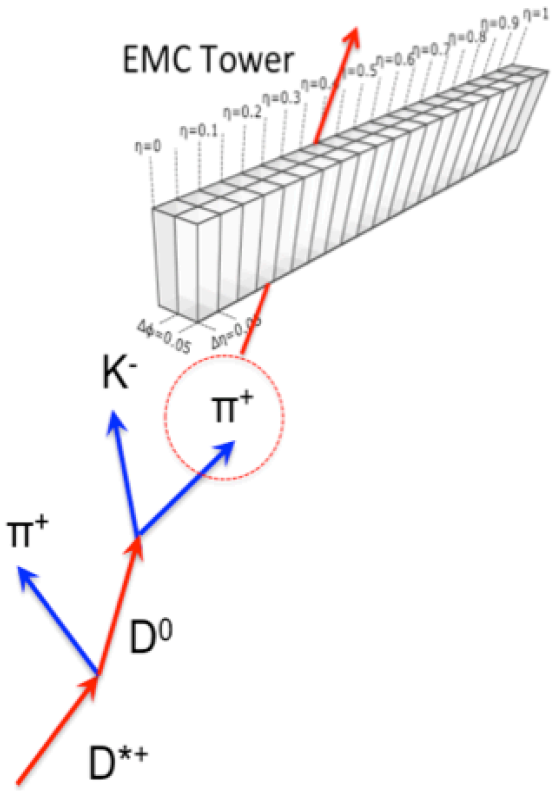
Back-ups: D-D(bar) correlation QA

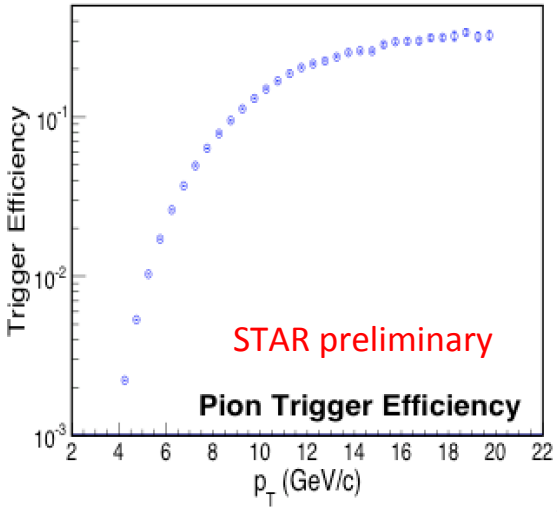


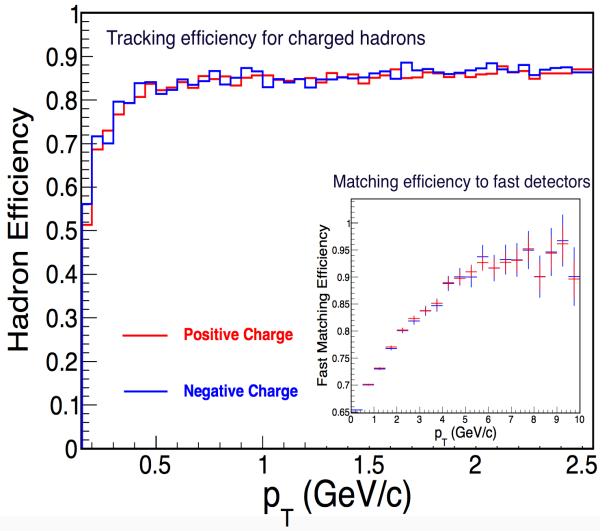


RS(D) - RS(Anti-D) correlation of foreground at peak region

Back-ups: Efficiency Correction





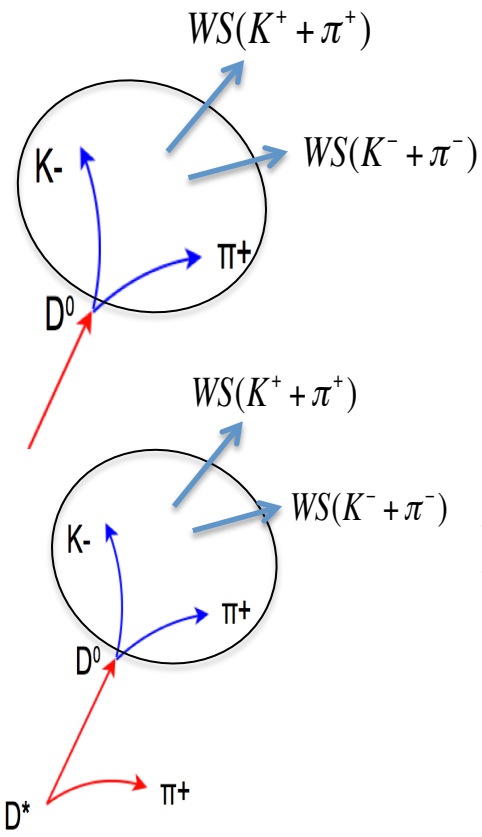


1) Associated charged hadrons are required to match fast detectors (TOF or BEMC) to reduce pile-up effect

2) Pion from D* decay is required to match the tower that fires the BEMC trigger to correct for trigger bias

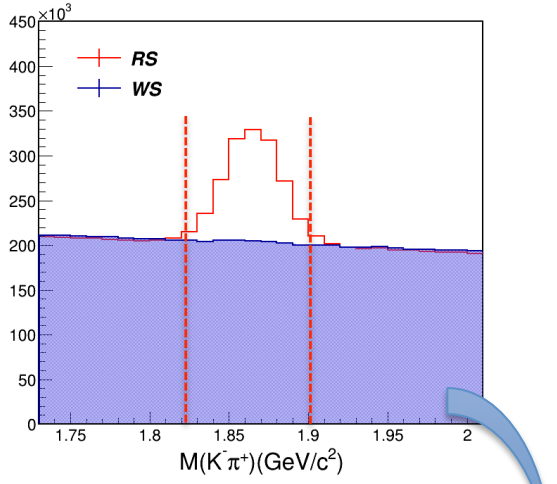
3) Tracking efficiency is derived from identified particles spectra and their efficiencies

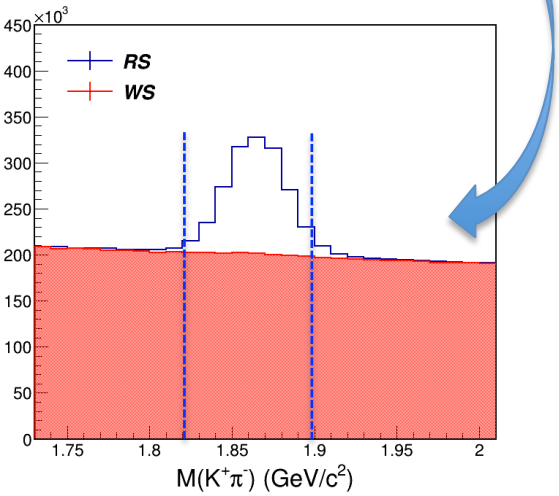
Back-ups: Wrong-sign correlation QA



$$WS(D) = \sqrt{WS(++)WS(--)}$$

$$WS(\bar{D}) = \sqrt{\overline{WS}(++)\overline{WS}(--)}$$





Cross term correlations