Physics of heavy flavors and strangeness with time-of-flight PID upgrade at CMS

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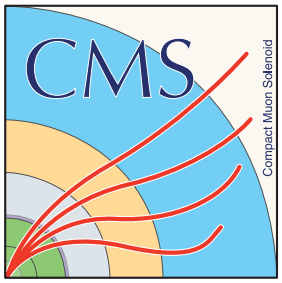
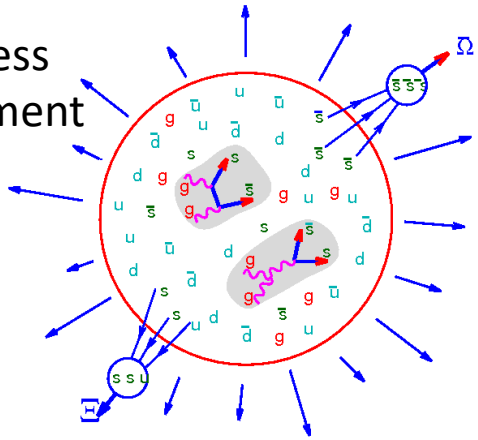
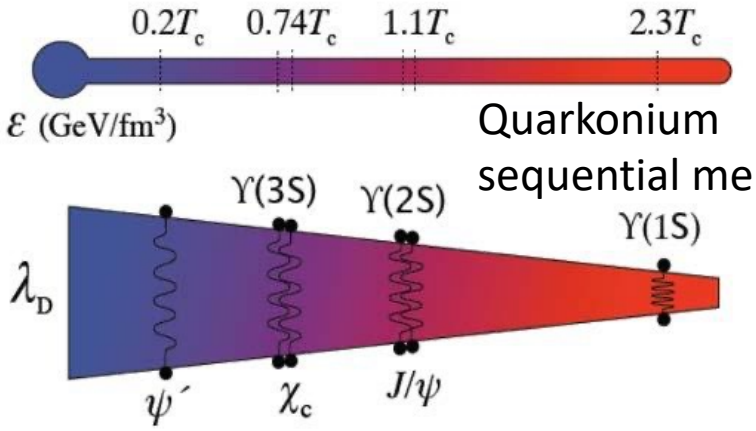


Strangeness in Quark Matter, Strasbourg
3-7 June 2024

Strangeness and heavy flavor in HI

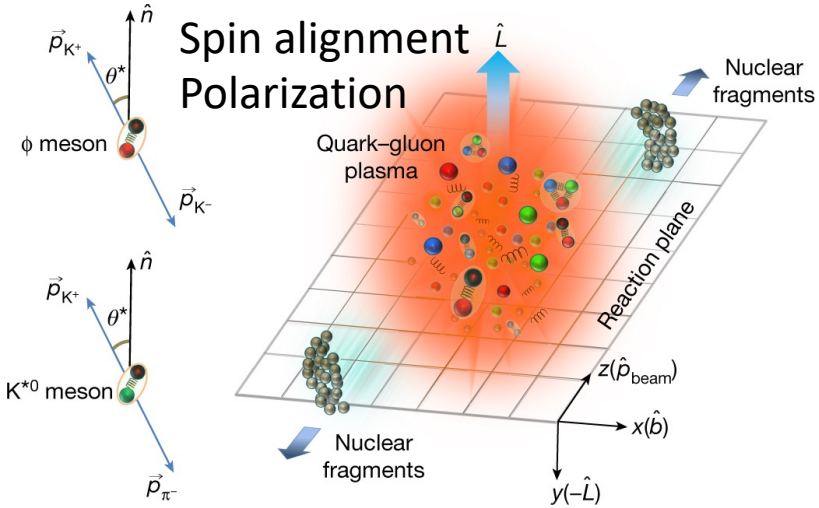
Strangeness enhancement



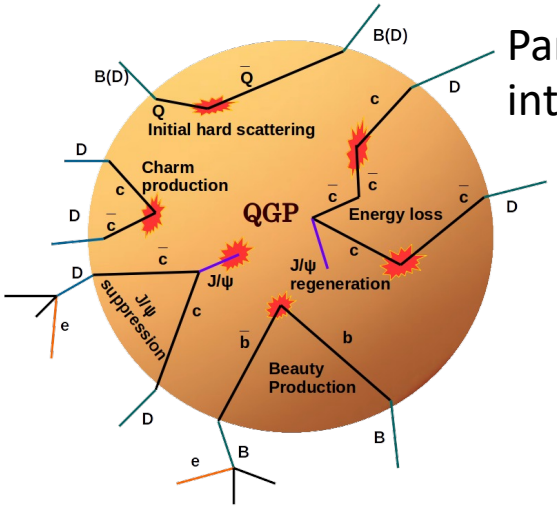


Quarkonium sequential melting

Spin alignment
Polarization

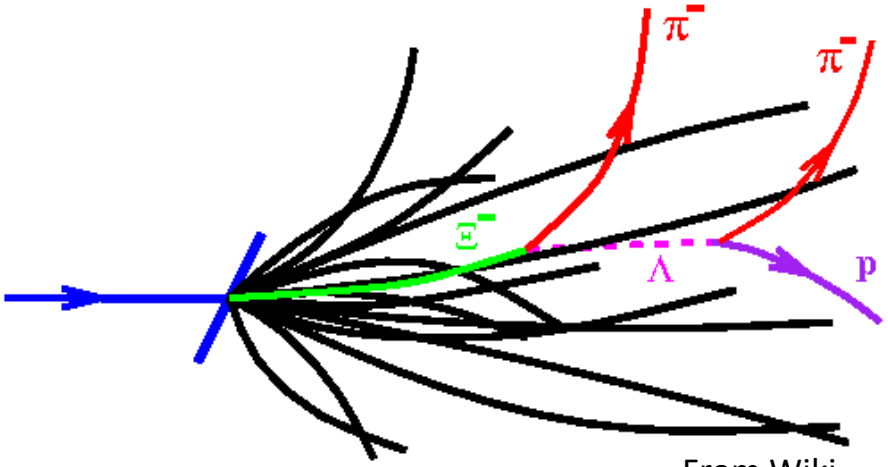


Parton-medium interaction

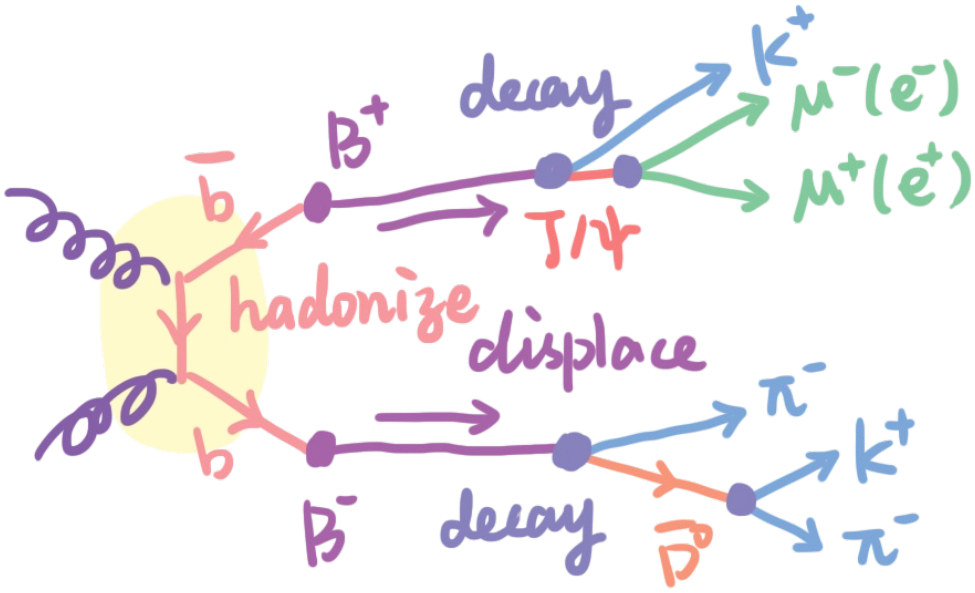


Strangeness and heavy flavor are key probes to understand heavy-ion collisions

Strangeness and heavy flavor reconstruction



From Wiki



From Jing Wang

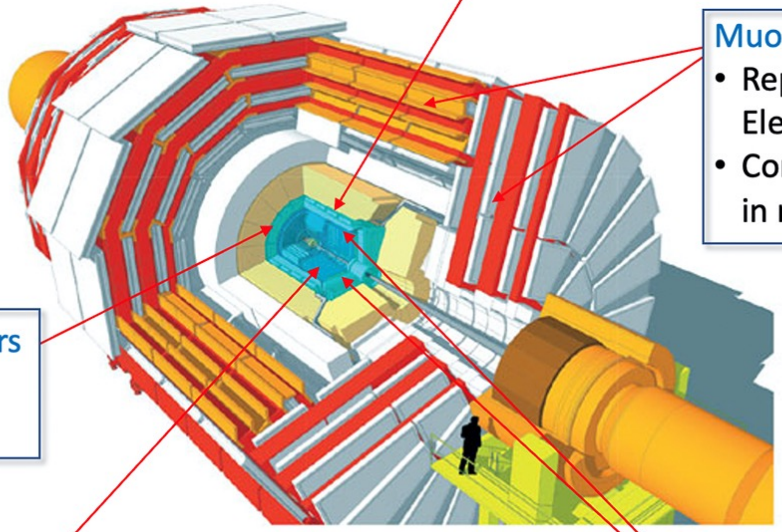
Particle identification largely enhance the ability to reconstruct strange and heavy flavor hadrons

The current CMS detector has limited PID for π/K/p 😐

CMS Phase II upgrade for HL-LHC

Trigger/HLT/DAQ
- Track information in L1-Trigger
- L1-Trigger: 12.5 μs latency – output 750 kHz
- HLT output 7.5 kHz

Barrel ECAL/HCAL
- Replace FE/BE electronics
- Lower ECAL operating temp. (8 °C)



Muon Systems
- Replace DT & CSC FE/BE Electronics
- Complete Muon coverage in region $1.5<|\eta|<2.4$

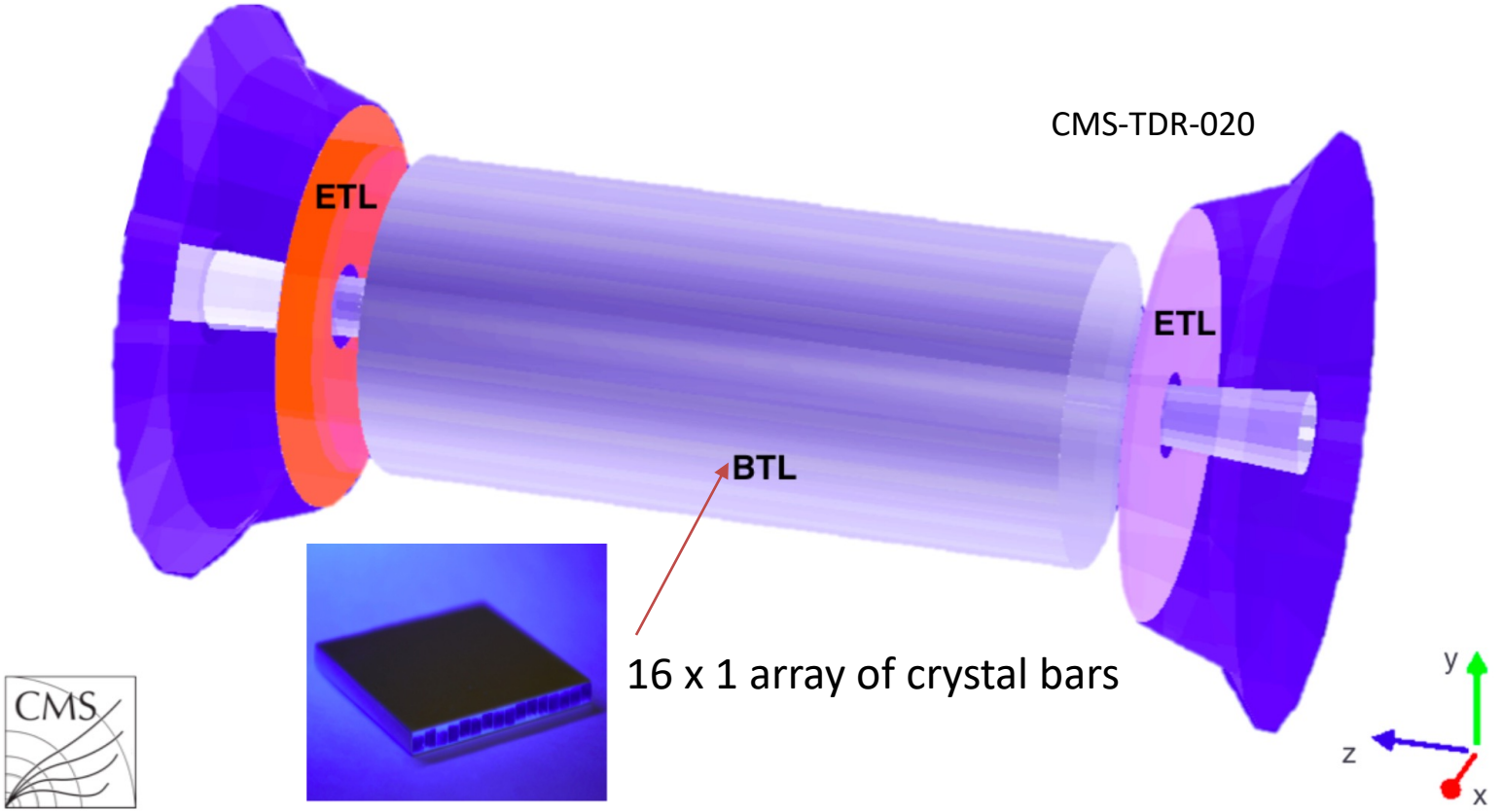
New Endcap Calorimeters
- High granularity
- 3D capable

New Tracker
- Rad. tolerant – high granularity – significant less material
- 40 MHz selective readout (p_T>2 GeV) in Outer Tracker for L1 -Trigger
- Extended coverage to η=4

New Precision Timing Detector
- Barrel: Crystal +SiPM
- Endcap: Low Gain Avalanche Diodes

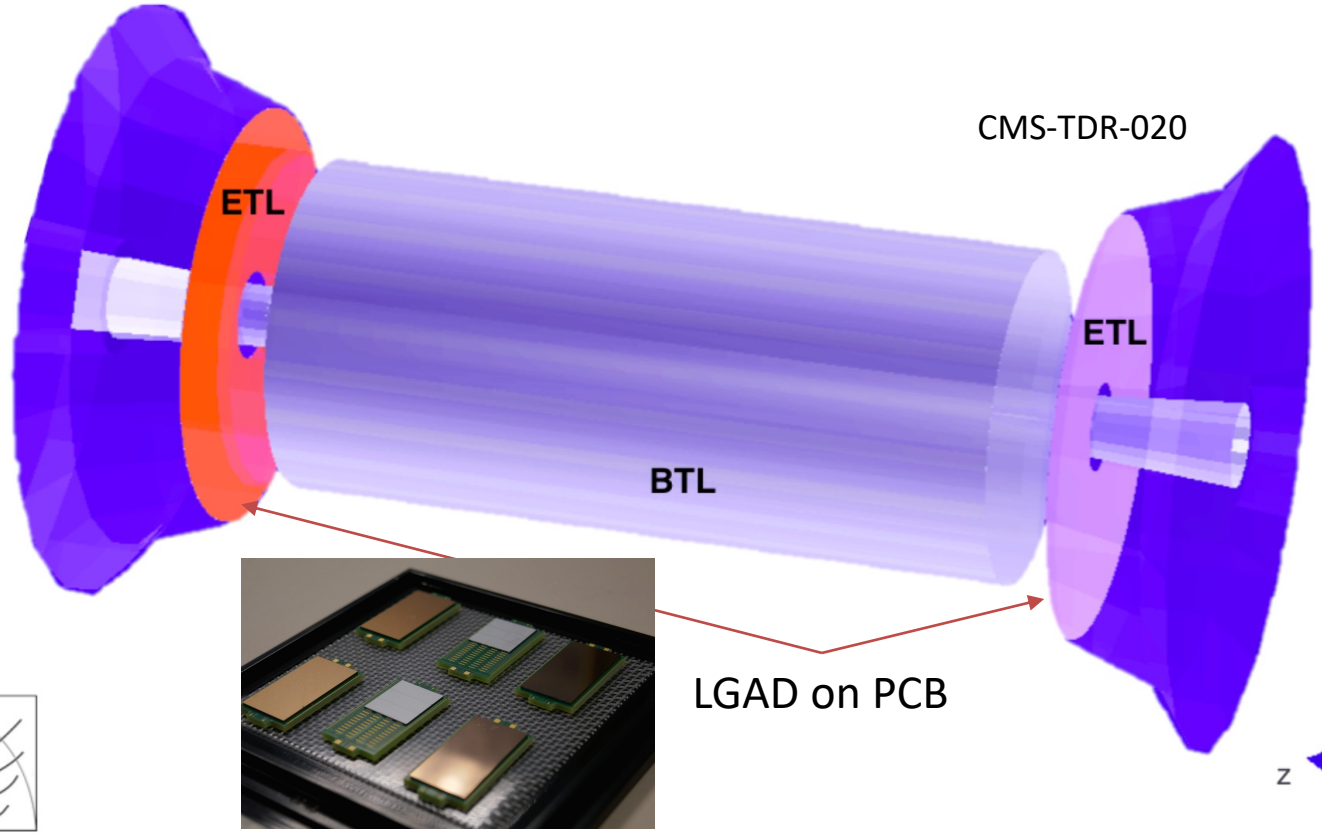
MIP Timing Detector → Time of Flight → PID 😀

Barrel timing layers



LYSO bars + SiPM readout
Length: +/- 2.6 m along z → |η| < 1.45
Inner radius 1148 mm (40 mm thick)
Surface ~38m² with 332k channels

Endcap timing layers



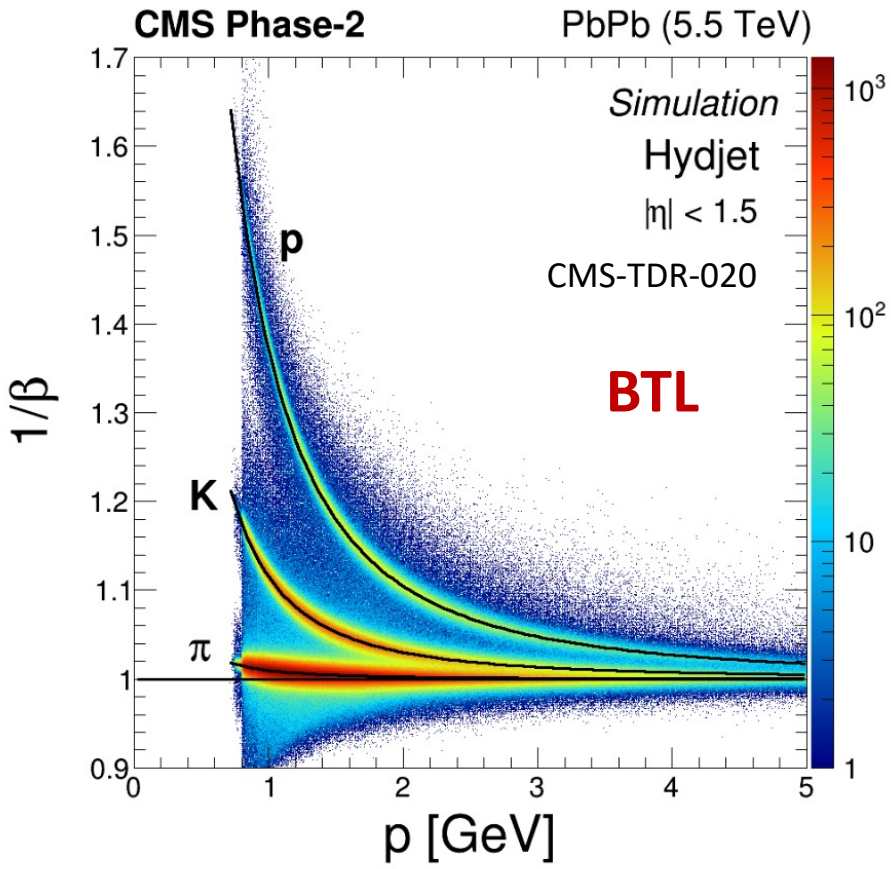
Si with internal gain (LGAD)

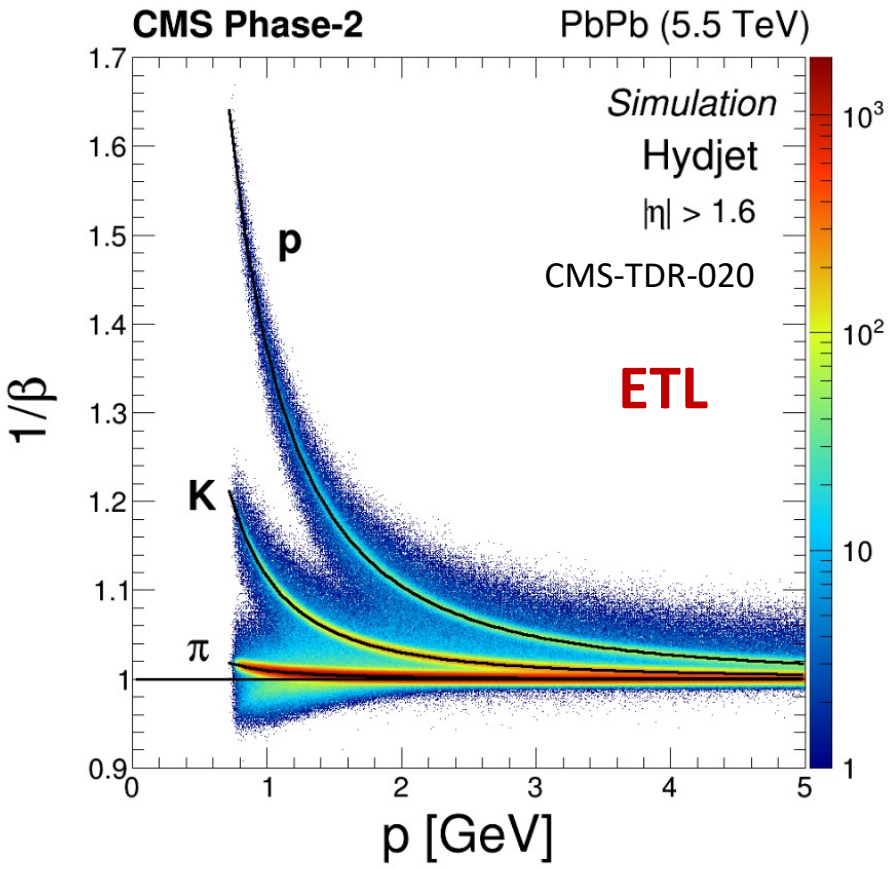
Radius: 315 < R < 1200 mm → 1.6 < |η| < 3.0

Position: +/- 3.0m in z (45 mm thick)

Surface ~14m^2 with 8.5M channels

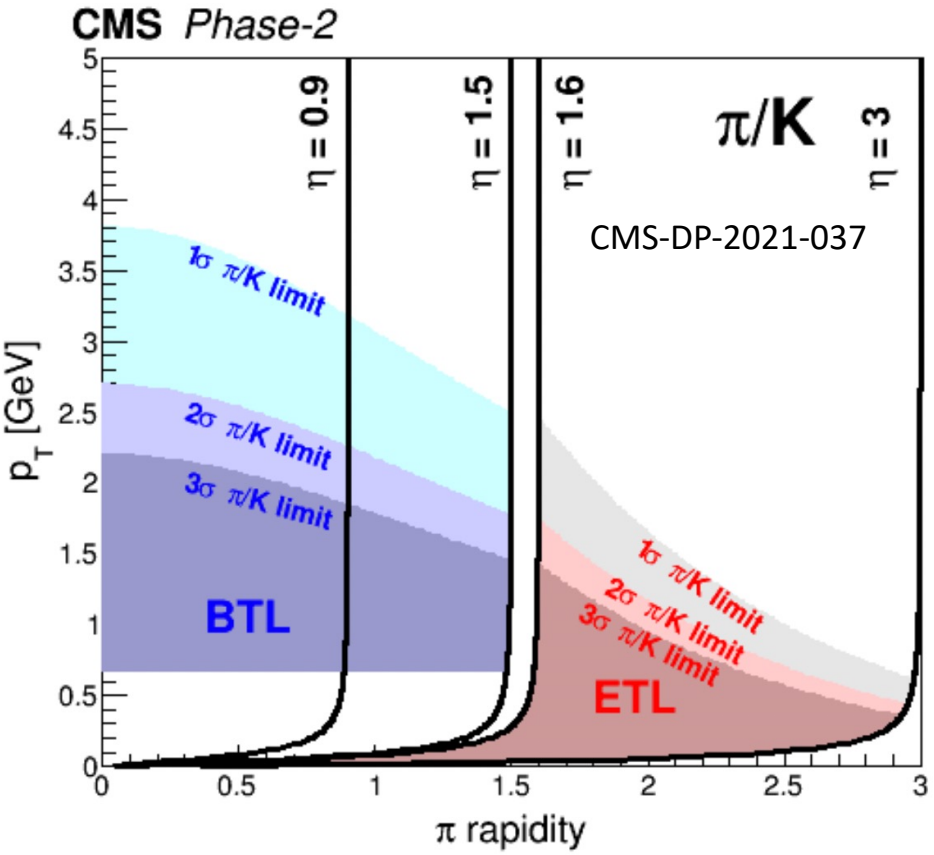
Time-of-flight PID capability

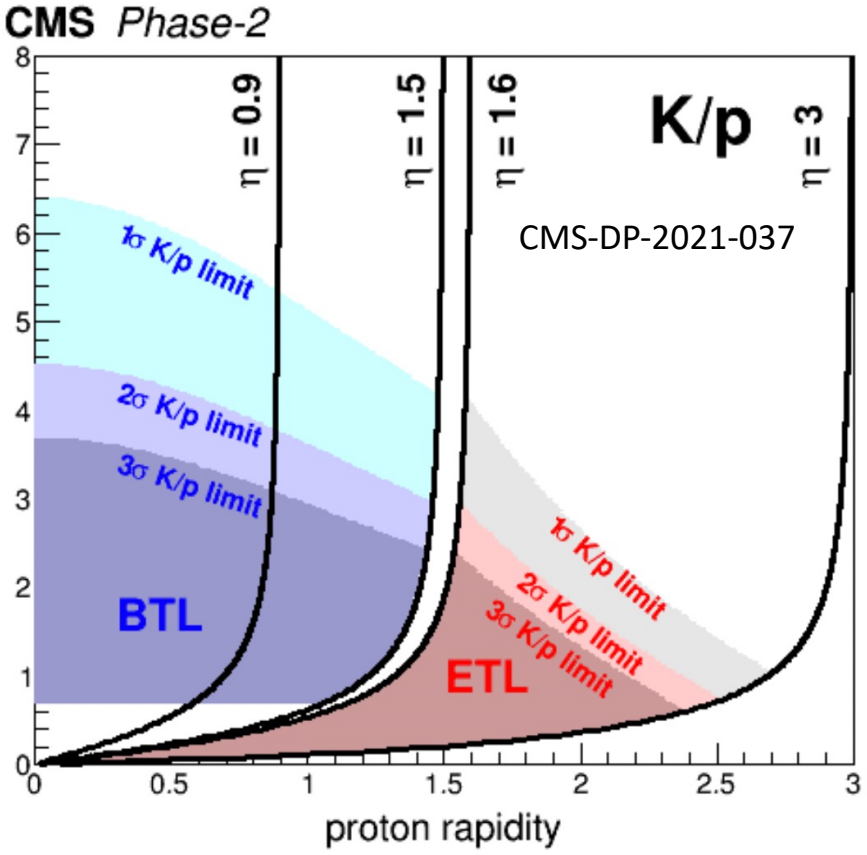




π/K separation up to 3 GeV, K/p up to 5 GeV

Time-of-flight PID capability



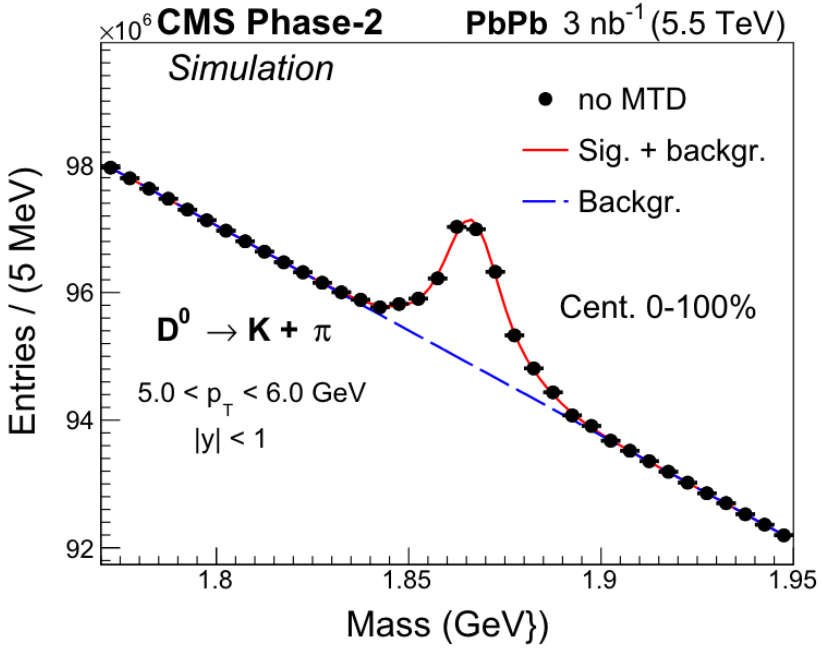


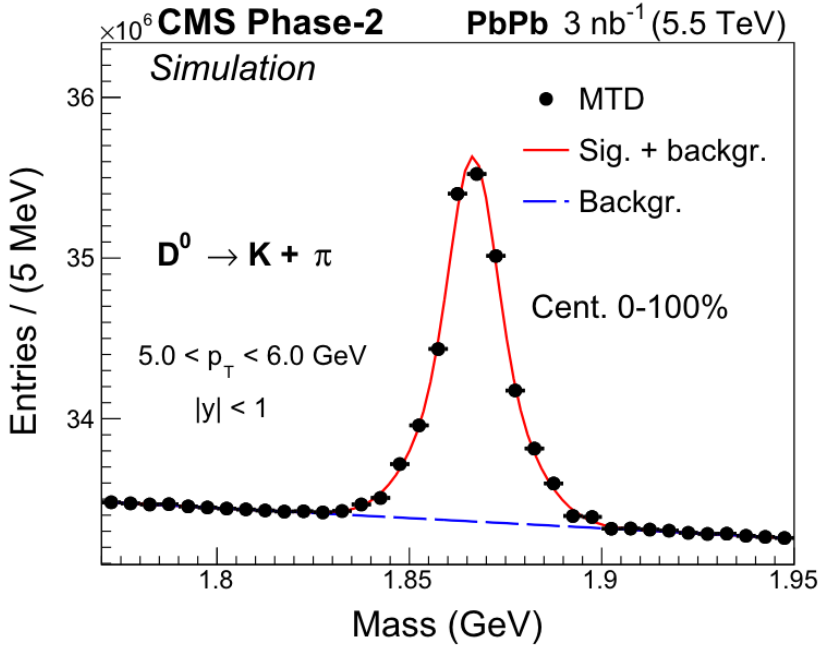
π/K separation up to 3 GeV, K/p up to 5 GeV
Momentum coverage competitive to ALICE and STAR
Unique hermetic coverage up to |η| = 3

What we can do with it?

Heavy quark production

CMS-TDR-020

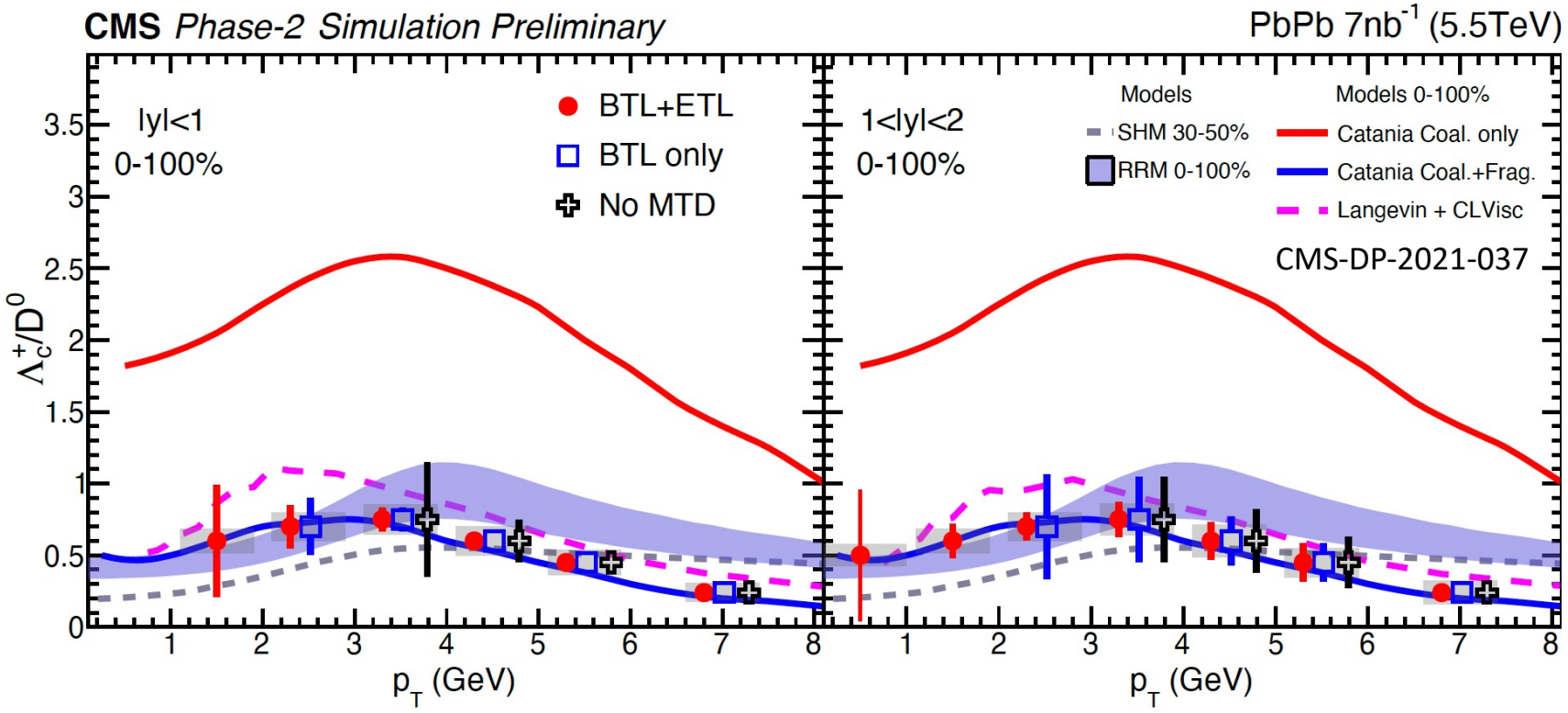




Large improvements in heavy flavor reconstruction

$D^0 \rightarrow K\pi$, $B^+ \rightarrow D^0\pi^+$, $\Lambda_c^+ \rightarrow pK\pi$ …

Heavy quark production



Large improvements in heavy flavor reconstruction

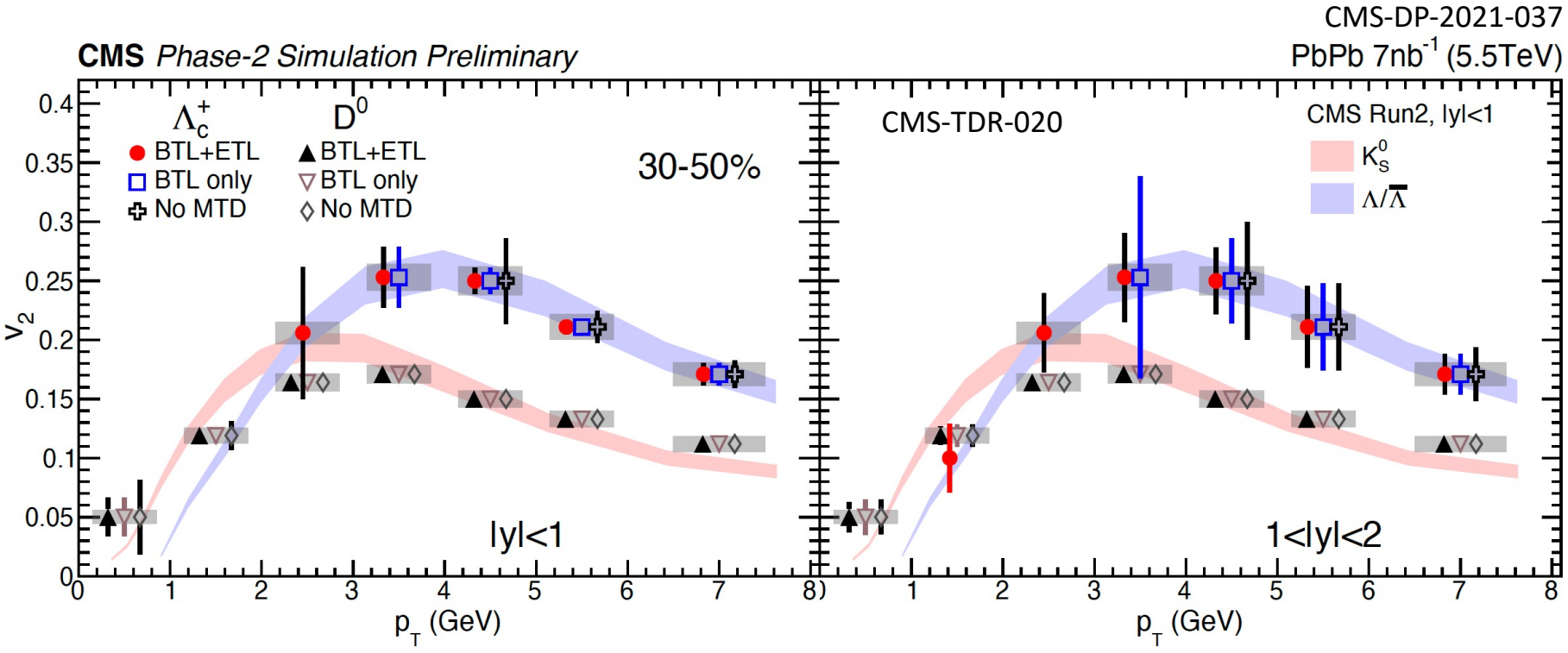
$D^0 \rightarrow K\pi$, $B^+ \rightarrow D^0\pi^+$, $\Lambda_c^+ \rightarrow pK\pi$ …

High precision Λ_c^+/D^0 ratio over wide rapidity range down to 0 p_T

Precise measurements of B_c, B_s, D_s; observation of Λ_b

Strong constraints on Heavy Quark hadronization

Heavy quark collective flow



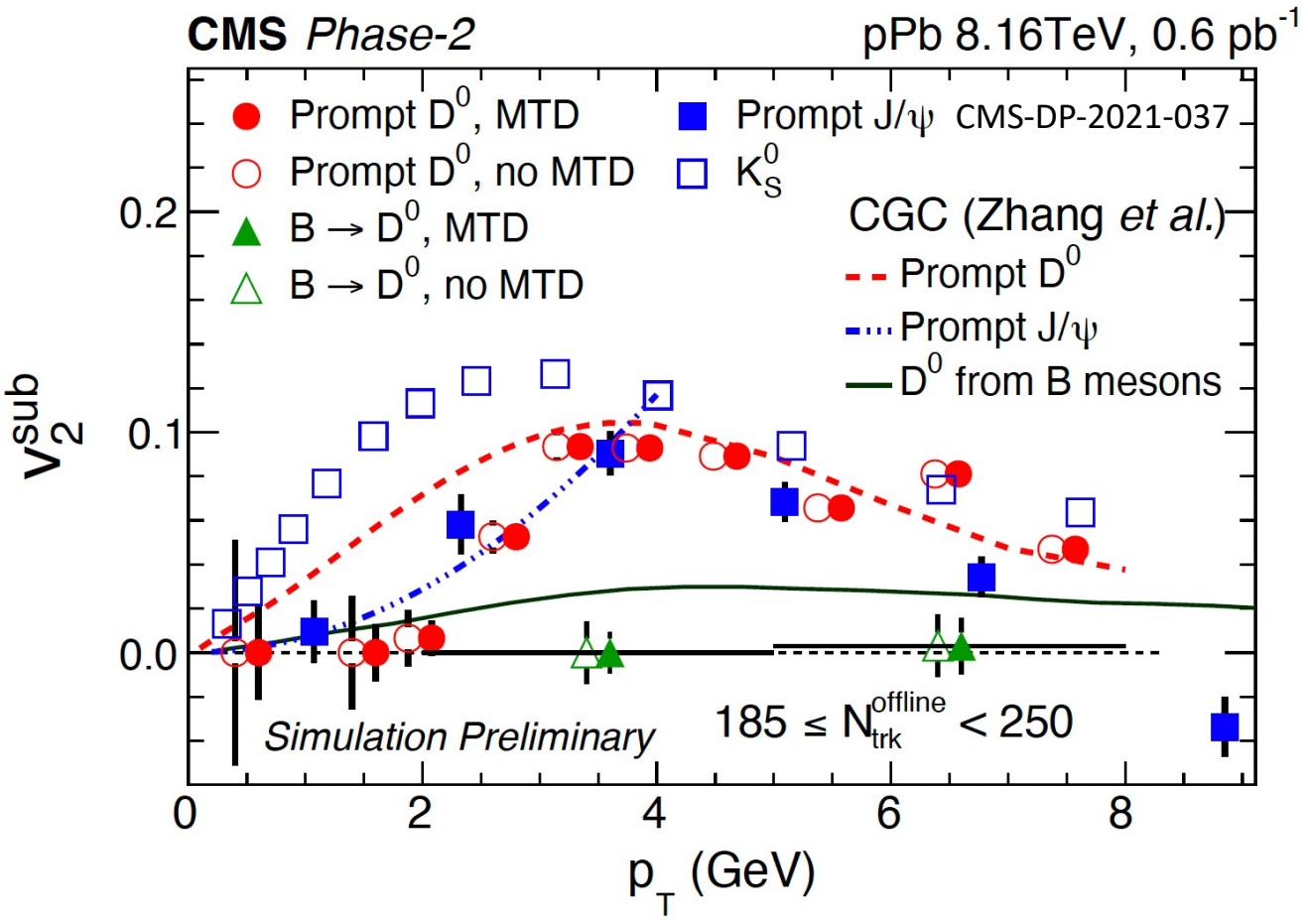
Precision measurements of v_2 down to low p_T

Straight forward test of charm quark flow via NCQ scaling

$v_2(\Lambda_c^+)/v_2(D^0) = 3/2$?

Probe the (3+1)D dynamics of Heavy Flavor in QGP

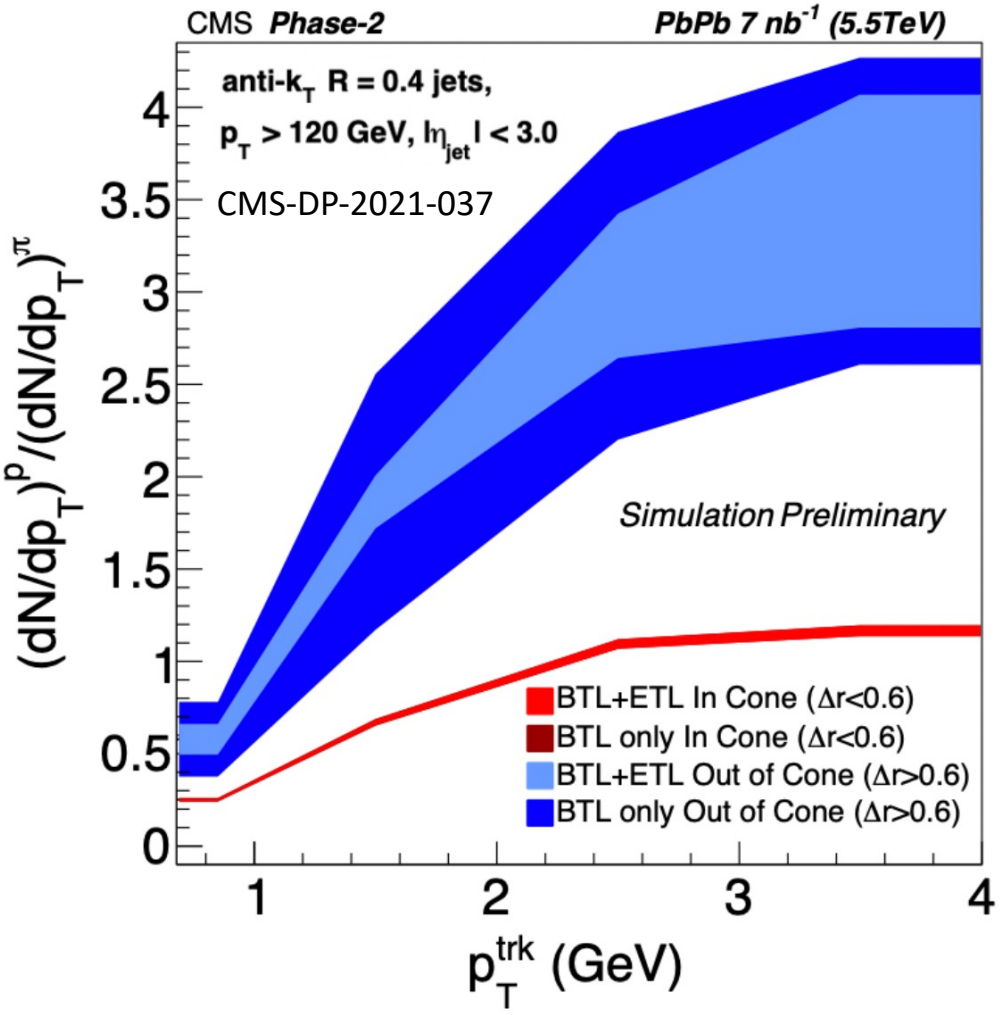
Heavy quark collective flow



Extend v_2 of HF hadrons down to very low p_T in small systems

Probe the origin of collectivity in small systems

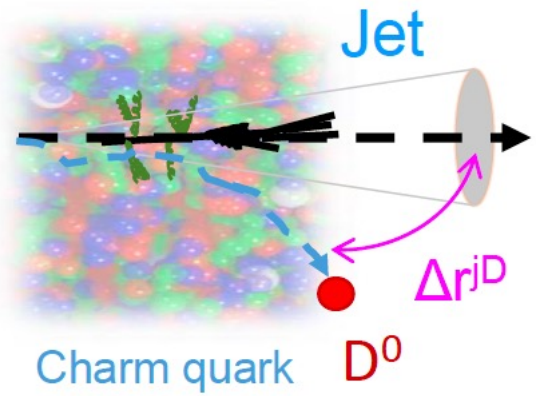
Jet properties and medium response

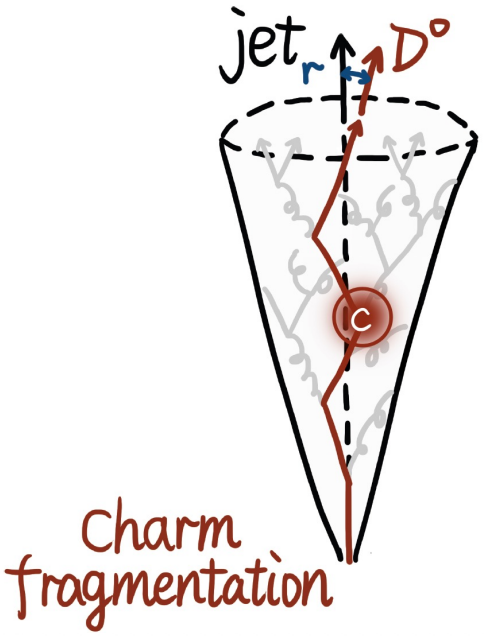


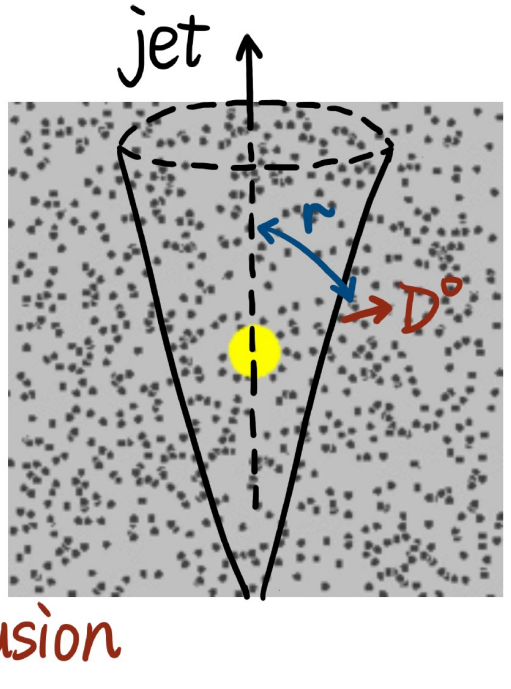
Unique opportunity for baryon-to-meson ratio inside & outside jets

Distinguish QGP response from jet fragments

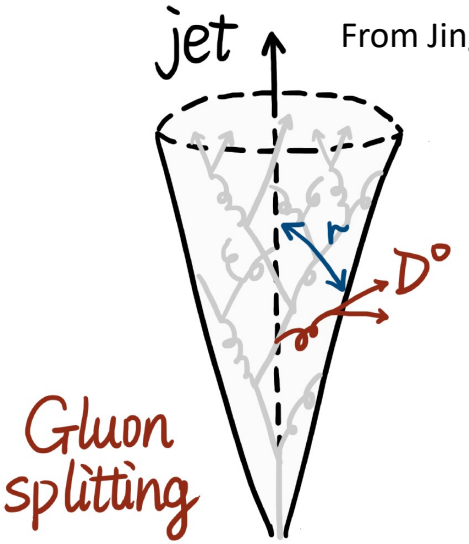
Jet properties and medium response

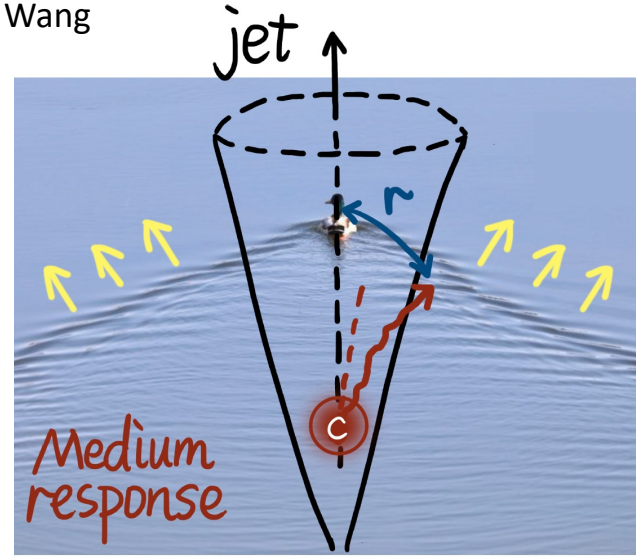




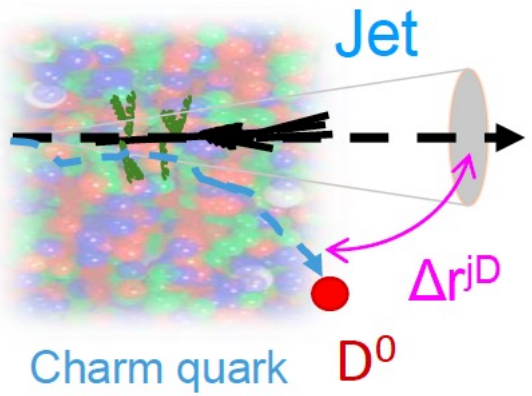


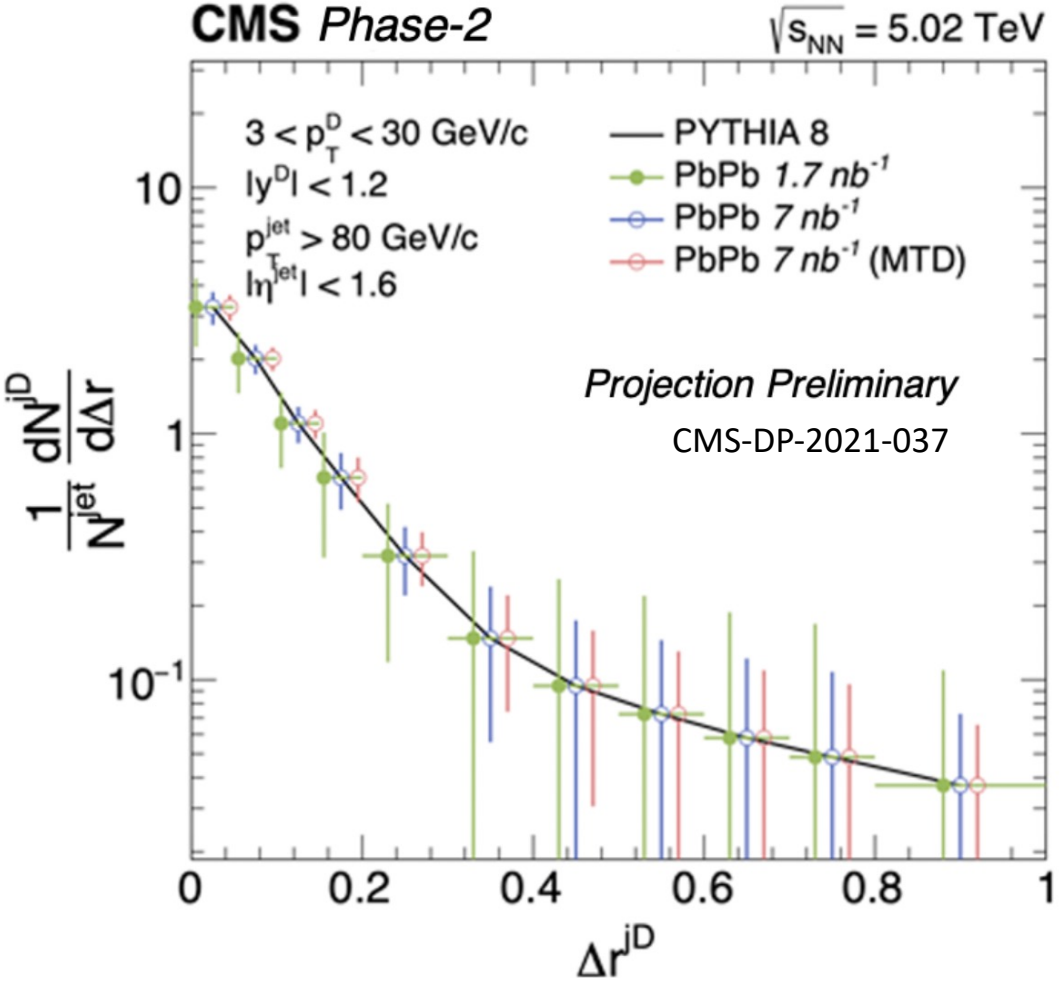
From Jing Wang





Jet properties and medium response

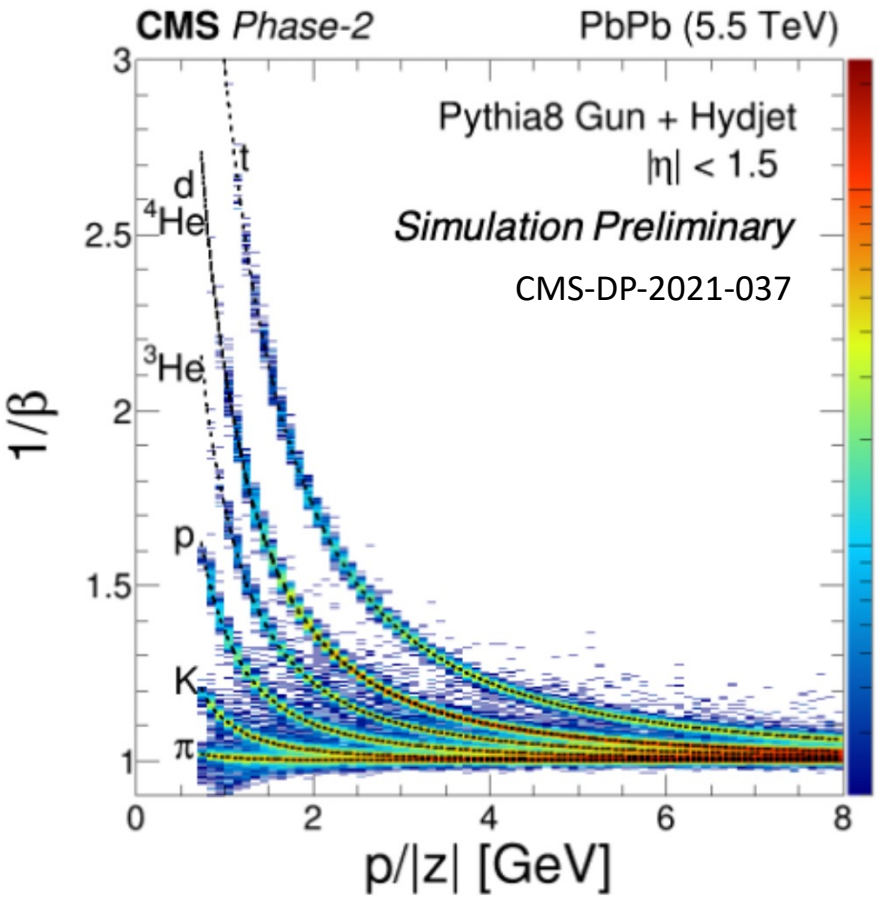


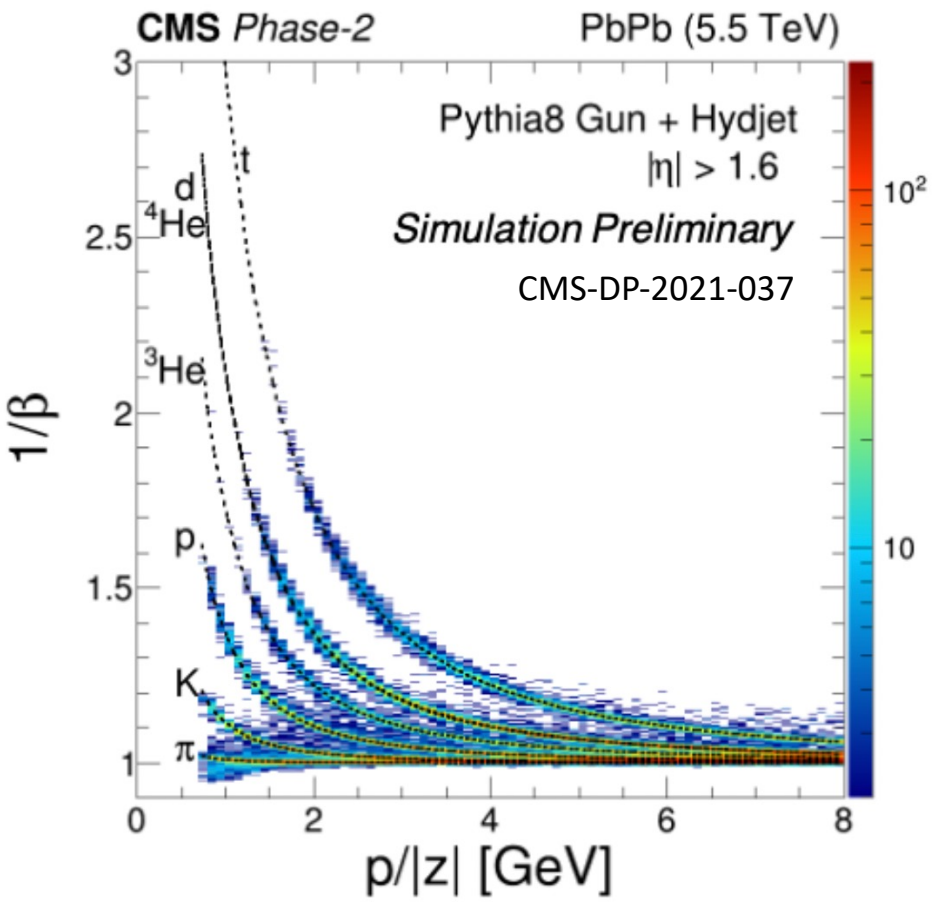


High precision measurement of D^0-jet correlation

Search for large angle scattering – size of quasi particle

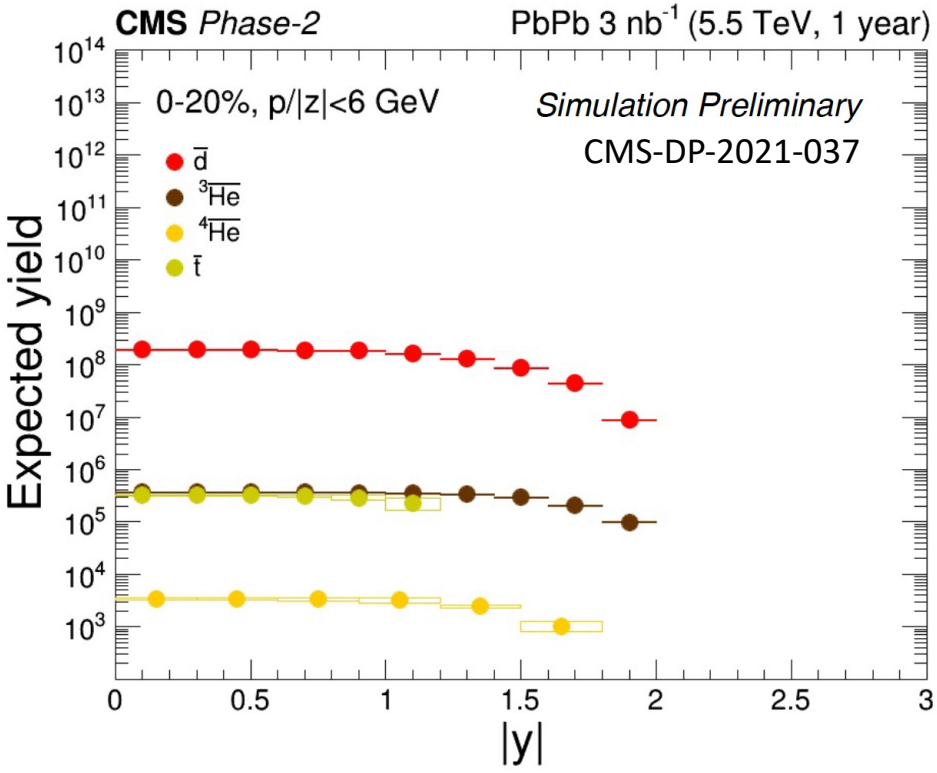
Identification of light nuclei

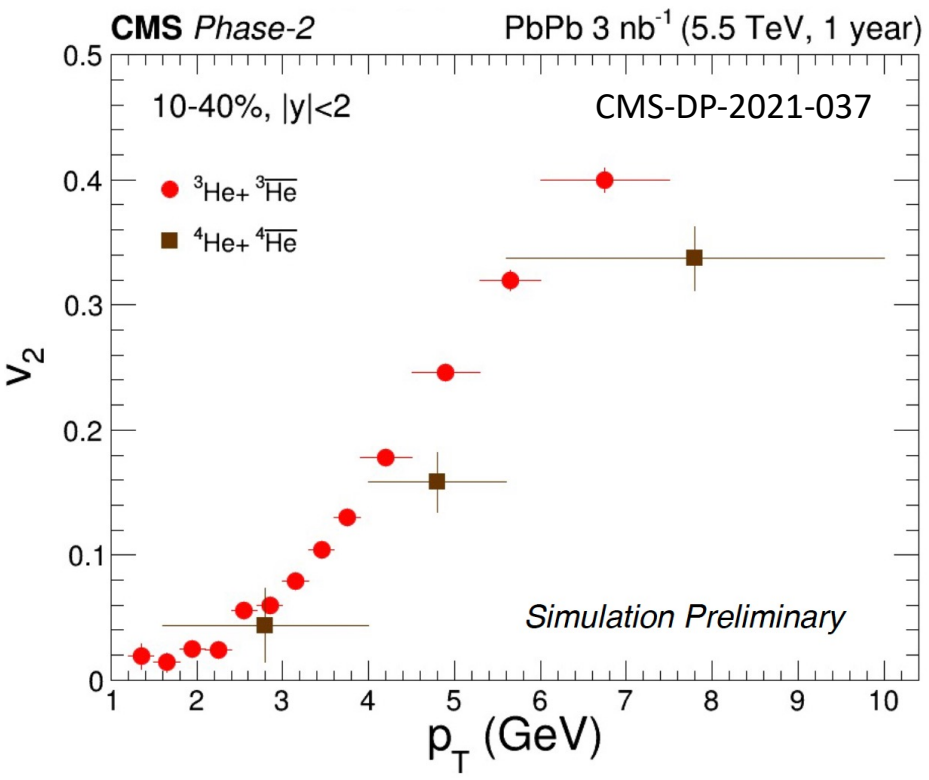




Time-of-flight allows identification of nucleus
Open the gate to light nuclei physics

Light nuclei production & collective flow





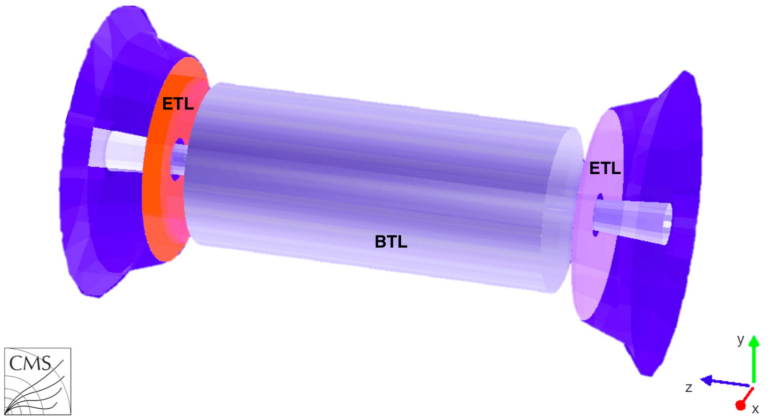
Precision measurements of light nuclei yields & collective flow

Probe the formation mechanism of light (anti-)nuclei

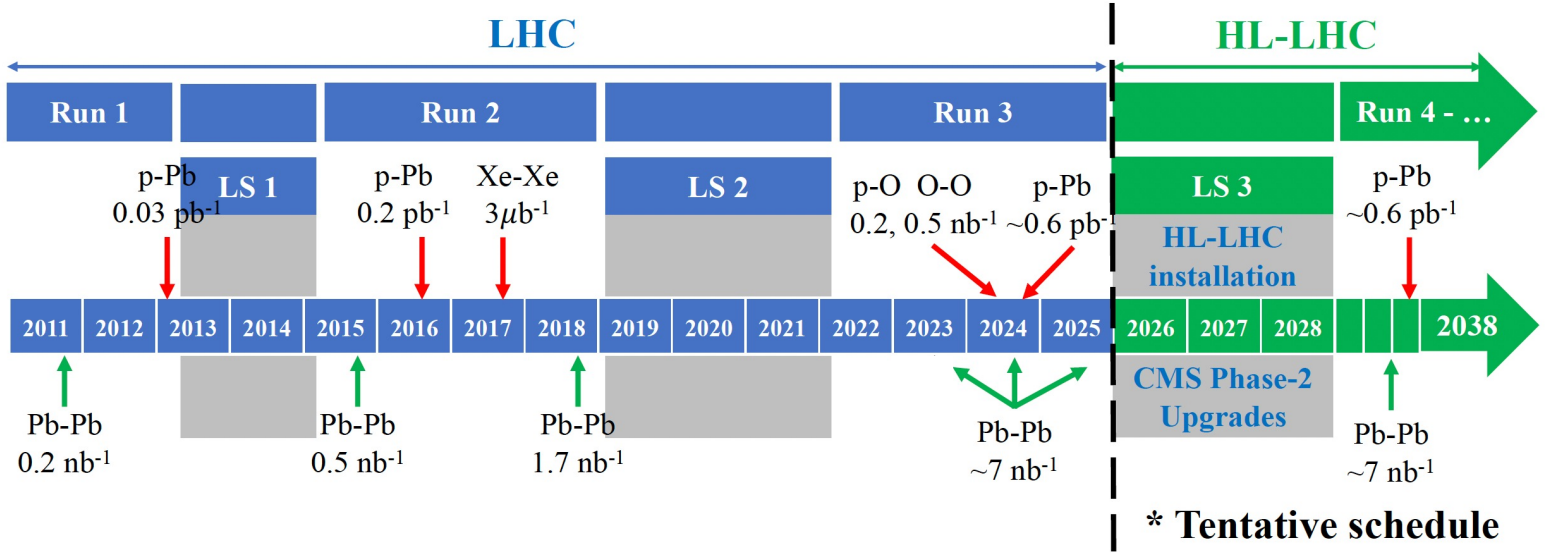
Summary

Many new physics opportunities with CMS time-of-flight upgrade

- (3+1)D dynamics of Heavy Flavor
- Origin of collectivity in small systems
- Jet medium response
- Light nuclei formation mechanism
- …

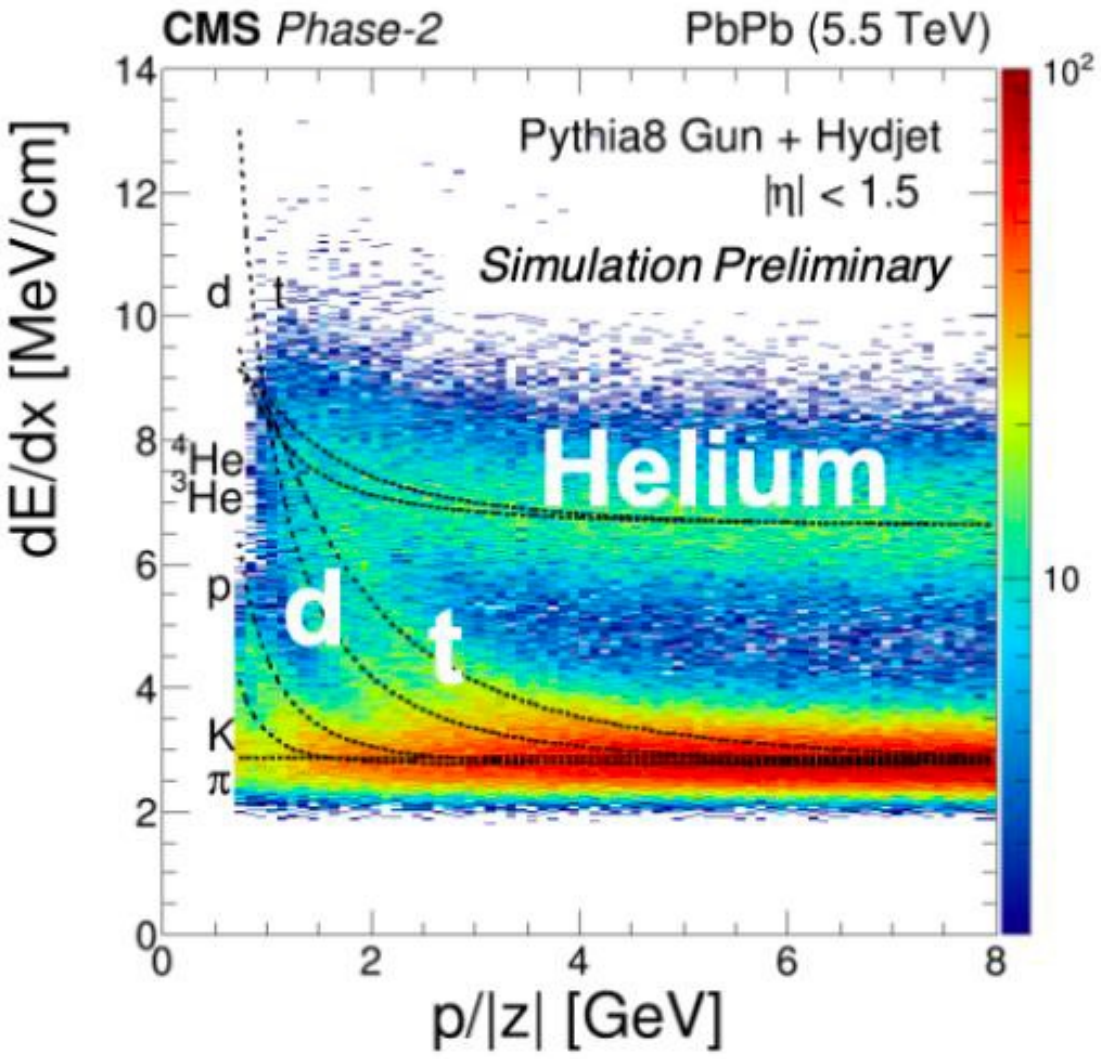


Do not go gentle into the HL-LHC era



Back up

Back up


CMS Phase-2
PbPb (5.5 TeV)
Pythia8 Gun + Hydjet
|η| < 1.5
Simulation Preliminary
dE/dx [MeV/cm]
p/|z| [GeV]
d
t
4He
3He
p
K
π
Helium
d
t
10²
10