Prospect of Measuring $D_s^+ \to \pi^+\pi^+\pi^- X$ @ BESIII

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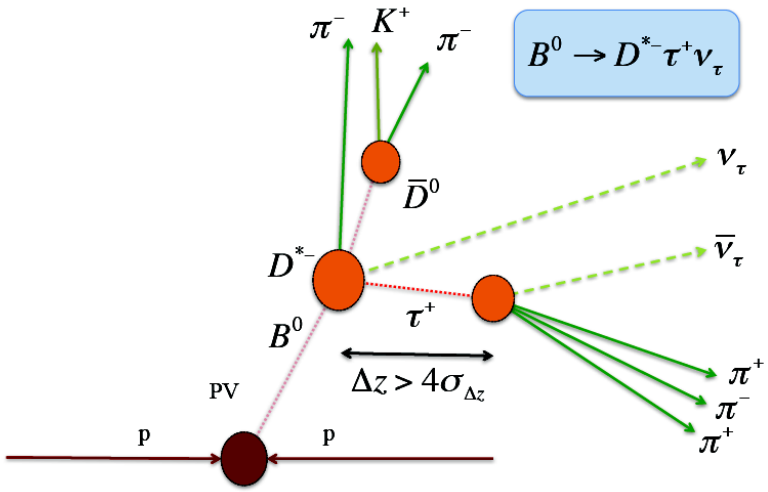
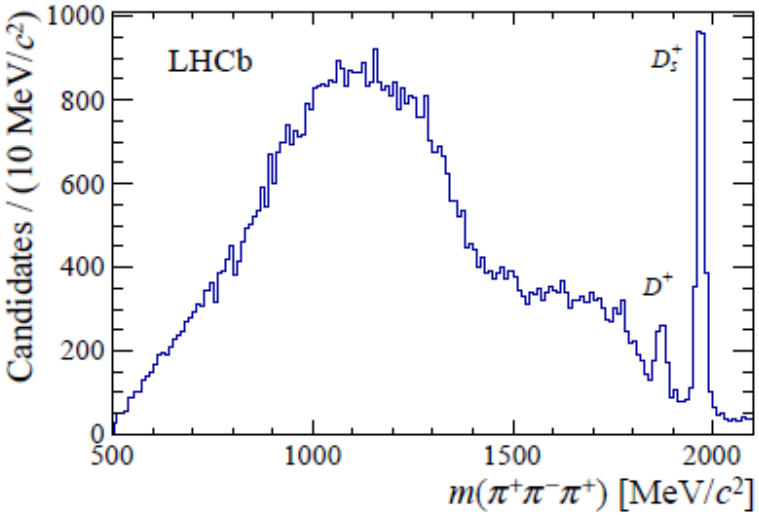
Motivation

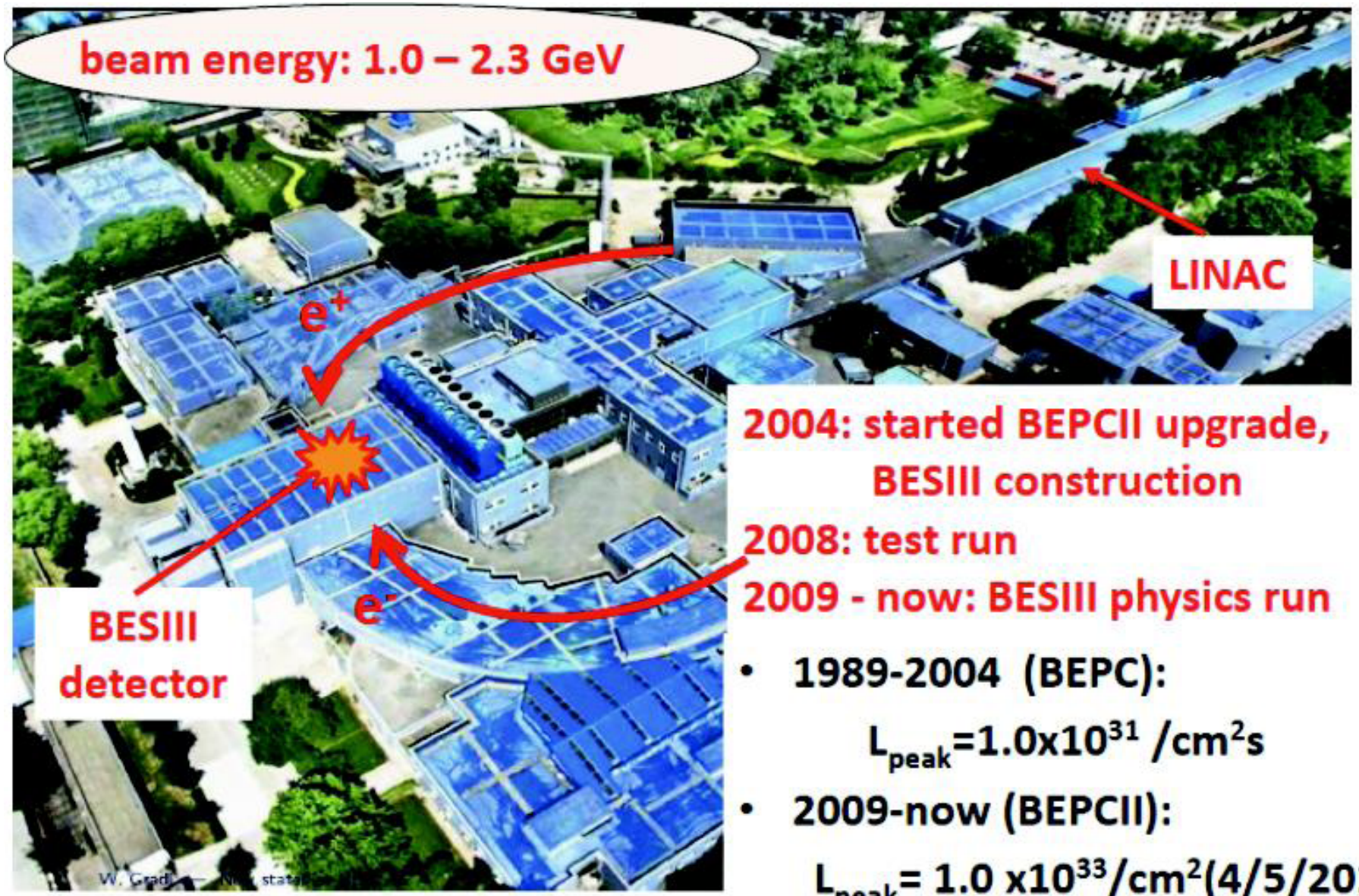
- Measuring R_{D^*} with decay $B^0 \to D^{*-}\tau^+\nu_\tau$ with τ lepton reconstructed from $\tau^+ \to \pi^+\pi^+\pi^-(\pi^0)\bar{\nu}_\tau$ in LHCb [arXiv:1708.08856, arXiv:1711.02505]
- Dominant double charm background: $B \to D^{*-} D_s(X)$ with 3 charged pions from D_s
  - Br ($D_s \to 3\pi+X$) expected to be 25%, never measured directly
- The resonant structure of the 3π system from D_s is dominated by $\eta^{(\prime)}$, different from that in the $\tau^+ \to 3\pi X$ final states
- LHCb uses D_s enriched data to measure the inclusive $D_s \to 3\pi X$ decays
- These decays can be better understood using independent datasets from a different experiment



arXiv:1711.02505



Beijing Electron Positron Collider (BEPCII)



2004: started BEPCII upgrade, BESIII construction

2008: test run

2009 - now: BESIII physics run

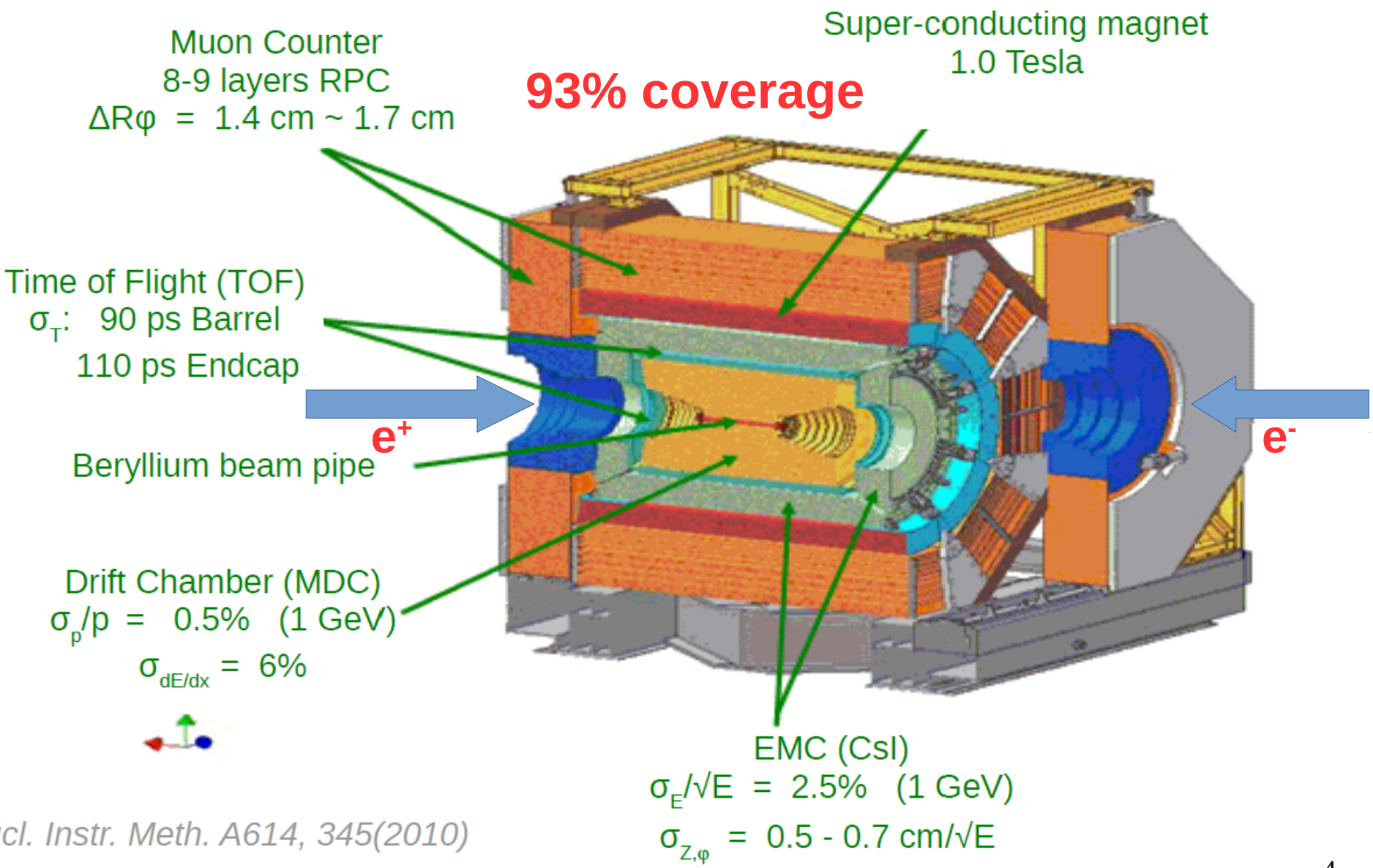
- 1989-2004 (BEPC):

  L_{peak}=1.0x10^{31} /cm^{2}s

- 2009-now (BEPCII):

  L_{peak}= 1.0 x10^{33}/cm^2(4/5/2016)

BESIII detector



Nucl. Instr. Meth. A614, 345(2010)

BESIII detector

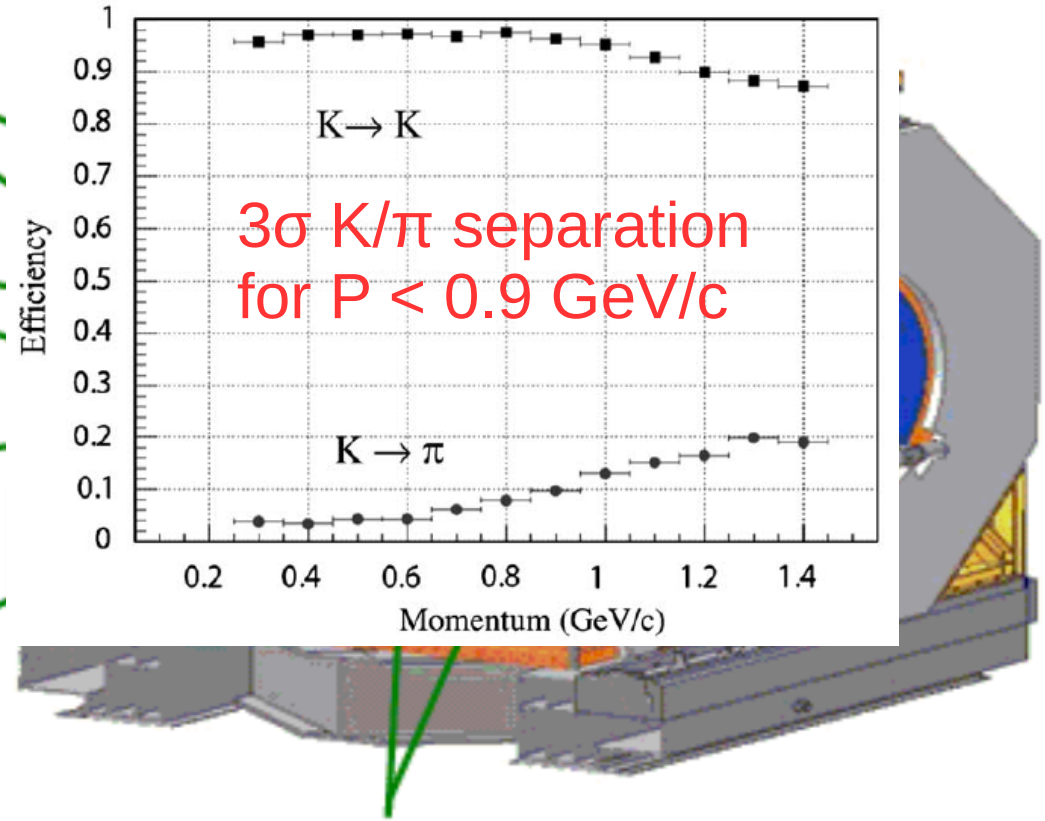
Muon Counter
8-9 layers RPC
$\Delta R\varphi$ = 1.4 cm ~ 1.7 cm

Super-conducting magnet
1.0 Tesla

Time of Flight (TOF)
σ_T: 90 ps Barrel
110 ps Endcap

Beryllium beam pipe

Drift Chamber (MDC)
σ_p/p = 0.5% (1 GeV)
$\sigma_{dE/dx}$ = 6%



EMC (CsI)
$\sigma_E/\sqrt{E}$ = 2.5% (1 GeV)
$\sigma_{Z,\varphi}$ = 0.5 - 0.7 cm/√E

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Charm data sets at BESIII

- $D^{0(+)}$ data
  - Taken @ E_{cm} = 3.773 GeV, L_{int} = 2.93 fb^{-1}
  - $e^+e^- \rightarrow D^0\bar{D}^0/D^+D^-$: 21 M D^0 and 16 M D^+ produced
- D_s^+ data
  - Taken @ E_{cm} = 4.009 GeV, L_{int} = 0.482 fb^{-1}
    - $e^+e^- \rightarrow D_s^+D_s^-$: 0.3 M D_s^+ produced
  - Taken @ E_{cm} = 4.178 GeV, L_{int} = 3.19 fb^{-1}
    - $e^+e^- \rightarrow D_s^*D_s$: 6 M D_s^+ produced
    - Accumulated in 2016

Most relevant for this study

- Λ_c data
  - Taken @ E_{cm} = 4.599 GeV, L_{int} = 0.567 fb^{-1}
  - $e^+e^- \rightarrow \Lambda_c^+\bar{\Lambda}_c^-$: 0.2 M Λ_c produced

Tagging method

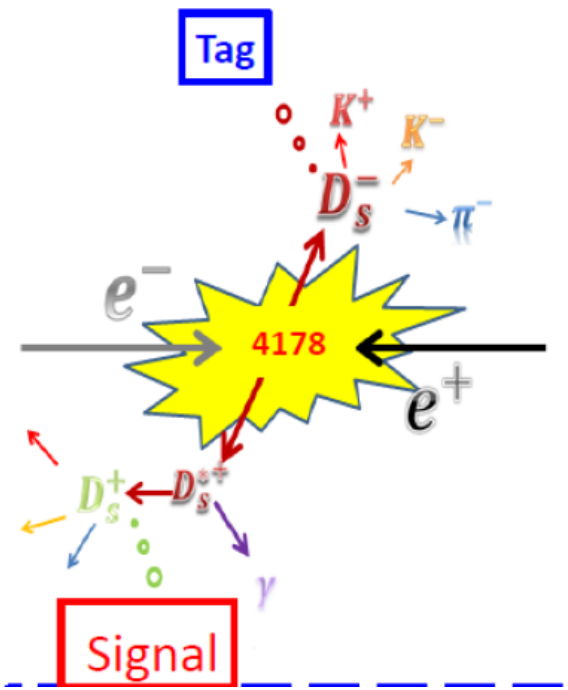
$e^+ e^- \rightarrow D_s^{*+} D_s^-$

3.19 fb^{-1} @4.178 GeV

Tag side: we have a fully reconstructed D_s decay, $D_s^- \rightarrow K^+K^-\pi^-$ for example

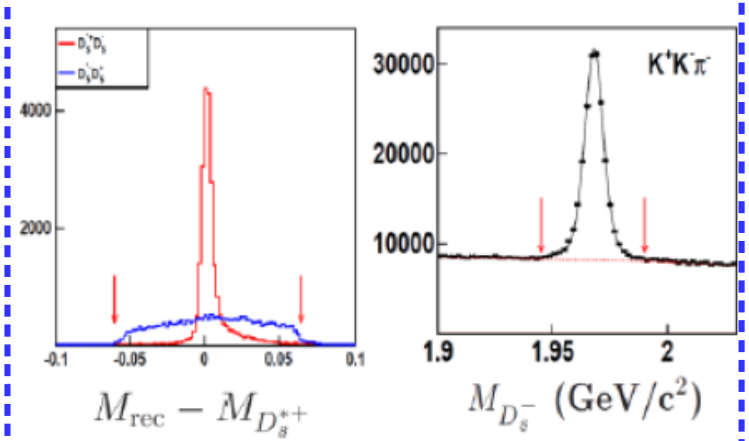
Signal side: requiring three charged pion tracks $D_s^+ \rightarrow \pi^+\pi^+\pi^-X$

Photon emitted from D_s^* could be either in the tag side or signal side



For Tag side(reconstructed from $K^+K^-\pi^-$):

$$M_{\rm rec} = \sqrt{(E_{\rm cm} - \sqrt{|\vec{p}_{D_s^-}|^2 + m^2_{D_s^-}})^2 - |-\vec{p}_{D_s^-}|^2}$$



~130K $D_s^- \rightarrow K^+K^-\pi^-$ tag events collected

Major background: light $q\bar{q}$

Possible tagging modes: $KK\pi$, $KK\pi\pi^0$, $\pi\pi\pi$, K_sK, $K_sK\pi^0$, $\eta^{(\prime)}\pi$, ...

Some thoughts on this study

- Based on BESIII $D_sD_s^*$ datasets, we expect to collect a few tens of thousands $D_s \to 3\pi(X)$ events with D_s tagged
- This could provide a unique opportunity for measuring the inclusive branching ratio, understanding the resonant structures, etc
- Challenges:
  - Efficiency determination
  - Backgrounds from K/π & μ/π misID
    - Can be evaluated using data-driven methods
  - $K_s \to \pi\pi$ background

Plans

- For $D_s D_s^*$ events, fully reconstruct a tagged D_s
- In the signal side, collect three pions with total charge equal to the signal D_s
- Identifying the photon from D_s^* helps to improve the background suppression, though not necessary
- Understanding background sources
- Efficiency determination from MC & validation
- Exploration of intermediate states in the 3π inclusive mode

Summary

- $D_s \to \pi\pi\pi X$ inclusive branching fraction and its 3π resonant structure important inputs for the LHCb $B \to D^*\tau\nu$ analysis
- Based on recently collected $3fb^{-1}$ $D_s^*D_s$ data, BESIII is able to provide unique information on $D_s \to \pi\pi\pi X$ inclusive mode
- A large range of physics topics are accessible @ BESIII: $D_s \to N3\pi$, $D_s \to \eta\pi X$, $D_s \to \eta'\pi X$, $D_s \to \pi\pi\pi\pi\pi X$, $D_s \to \tau(\to \pi\pi\pi X)\nu$, etc.
- Expecting first status report during the BES-LHCb Workshop in February