Research on inclusive decay at BESIII

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BESIII NP. Meeting @ WHU

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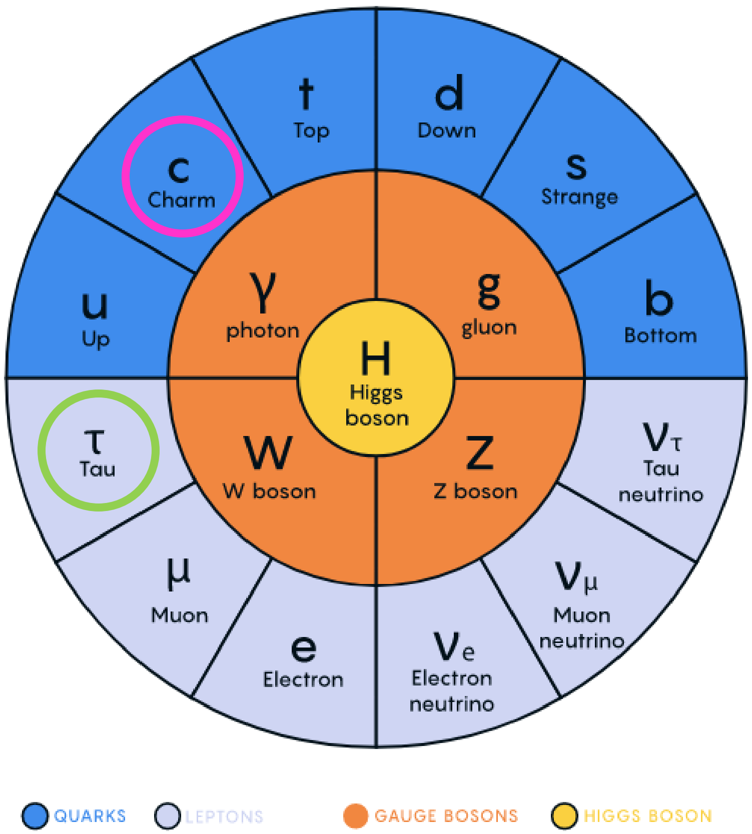
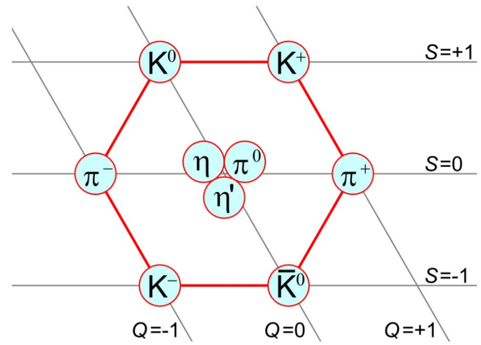
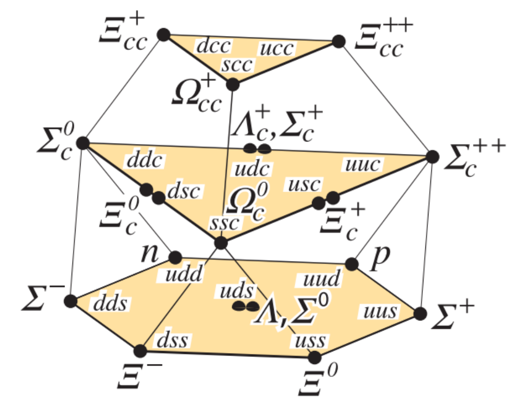
Standard model

- **Standard model(SM):**







Success and shortage of SM:

✓ A good framework of particle physics based on 3 interactions and 61 basic particles；

✓ Agreement well with most experiments；

✓ Successful predictions.

- No gravity;
- Parameters;
- CP violation;
- Neutrino oscillation;
- Non-perturbative;
- …

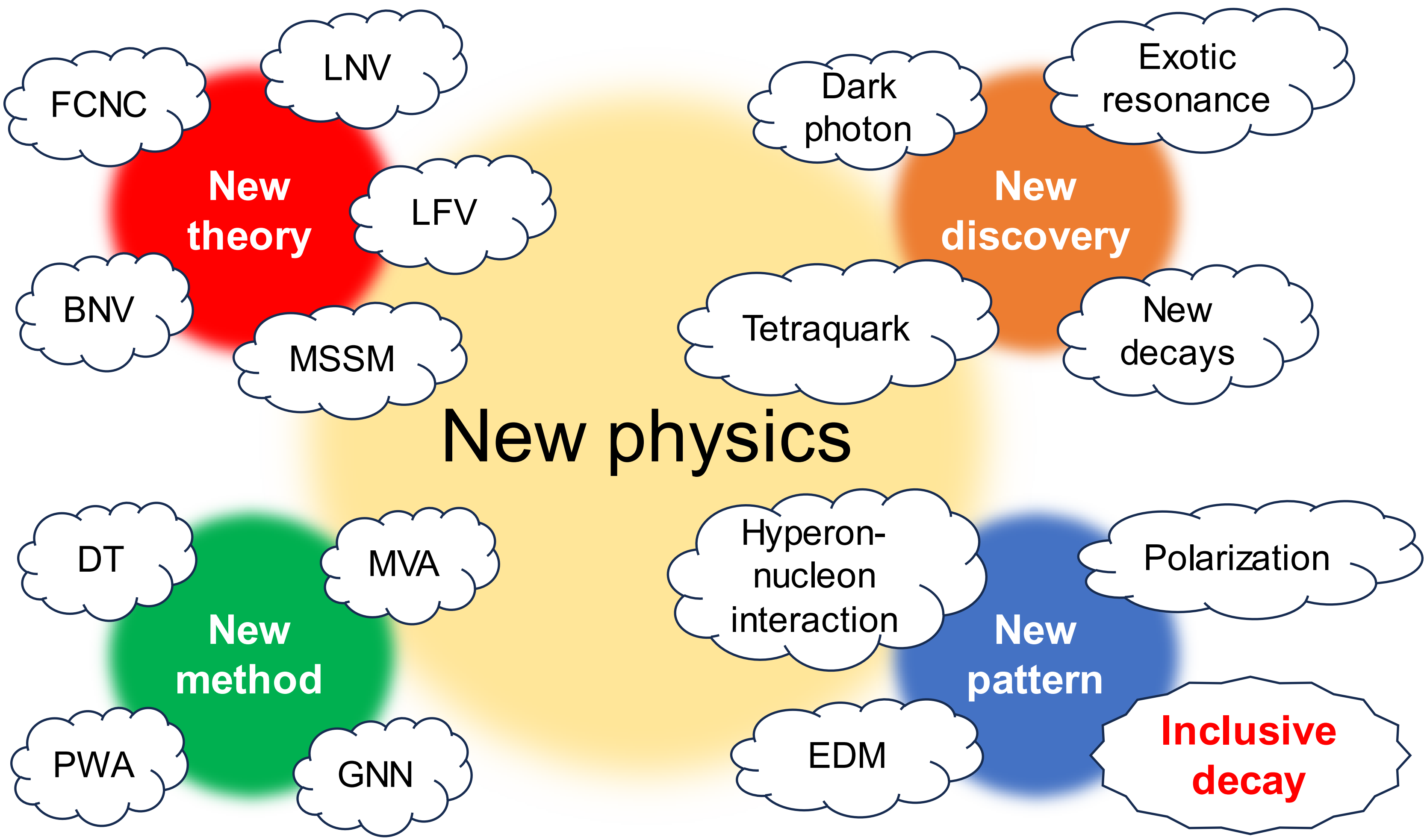
Higher precision!

More situations!

New physics!

New physics

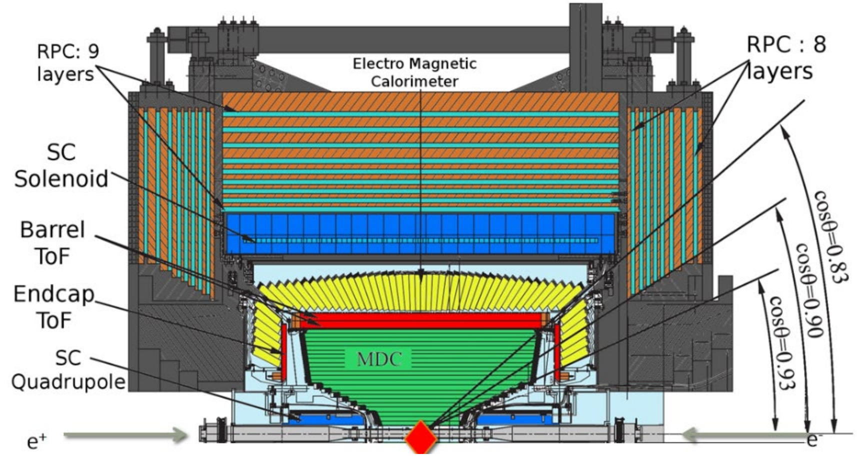
- **Why inclusive decay presented here?**

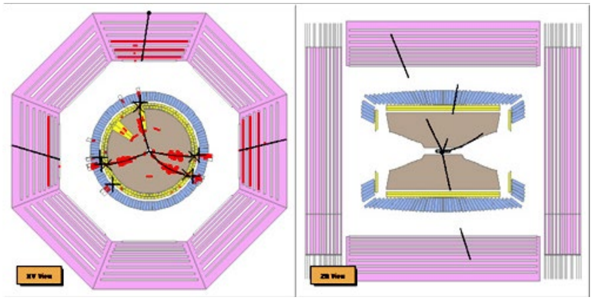


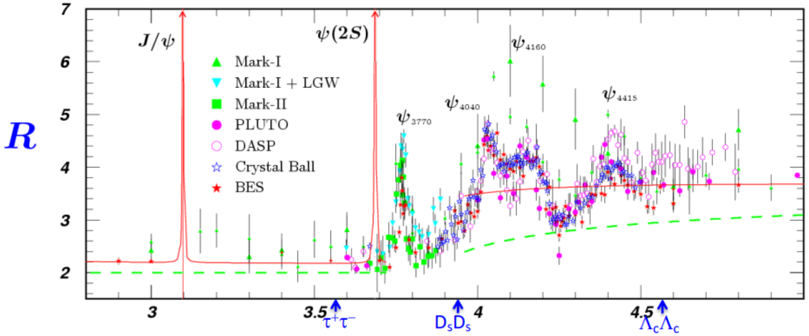
BEPCII

- BEPCII

BESIII







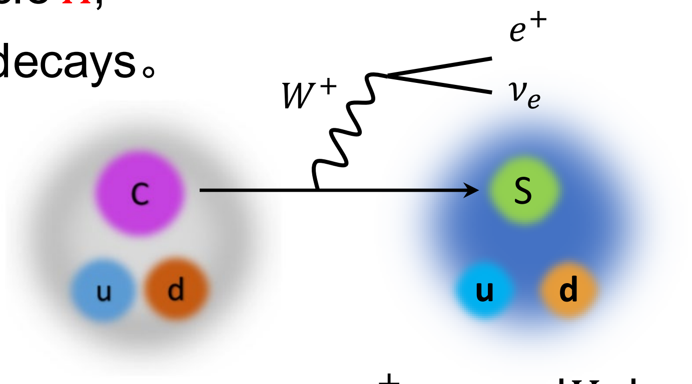
First HEP collider in China (1988)
CMS energy: 2 ~ 5 GeV
Max luminosity: $1\times10^{33}cm^{-2}s^{-1}$

Non-perturbative
$\tau - charm$ region
$\tau^{\pm}$ 、D/D_s、$\Lambda_c^+ \ldots$

J/ψ : 2.97 fb^{-1}(10B)
$\psi(3686)$: 4.07 fb^{-1}(2.7B)
$\psi(3770)$: 8 fb^{-1}
4.6~4.7GeV: 4.48 fb^{-1}

Inclusive decay

- **Inclusive decay:**
- Decay as $A \to B + X$, B is a certain particle, X contains any possible particles, then this decay is called an inclusive decay of particle A;
- Inclusive decay is the sum of a series of exclusive decays。



$c \to s e^+ \nu_e$ $|V_{cs}|$

- **Motivation:**
- Provide verifications for SM parameters;
- Guide for undiscovered exclusive decays;
- Study the characteristics of a series of decays.

$$\Lambda_c^+ \to \Lambda X_{(exclusive)} \approx (30.1 \pm 1.2)\%$$

$$\Lambda_c^+ \to \Lambda X_{(inclusive)} = (38.2 \pm 2.6)\%$$

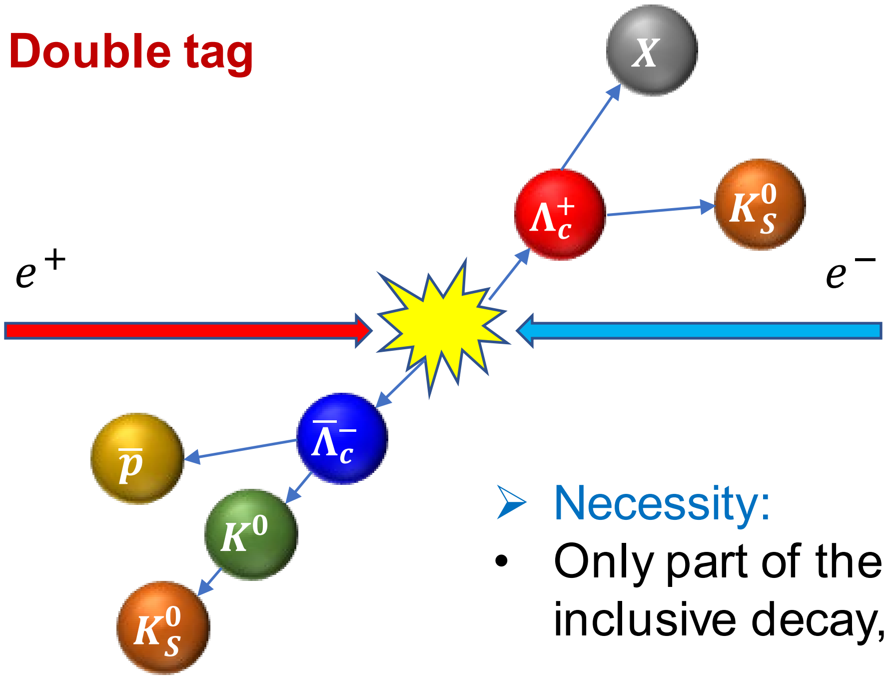
- **Research objects:**
- BF;
- Decay parameter;
- CPV
- …

$$\frac{\mathfrak{B}(\Lambda_c^+ \to \Lambda X)_{exclusive}}{\mathfrak{B}(\Lambda_c^+ \to \Lambda X)_{inclusive}} = (78.8 \pm 6.3)\%$$

=> Any other decay modes?

Methods for inclusive decay

- **Double tag**



➢ Necessity:

- Only part of the final states are reconstructed in inclusive decay, single-tag(ST) is not executable.

➢ Reasonability:

- The Λ_c are produced in pairs at threshold on BESIII, no other accompanied particles, 4-momentum conservation.

➢ Advantage:

- Absolute BF, decay parameter, CPV;
- Less background than ST;
- Cancel out some systematic uncertainties.

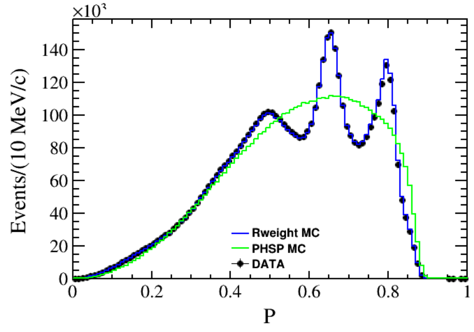
Methods for inclusive decay

- **Data driven** Using control sample from data to determine the efficiency of inclusive decay.

➢Necessity:

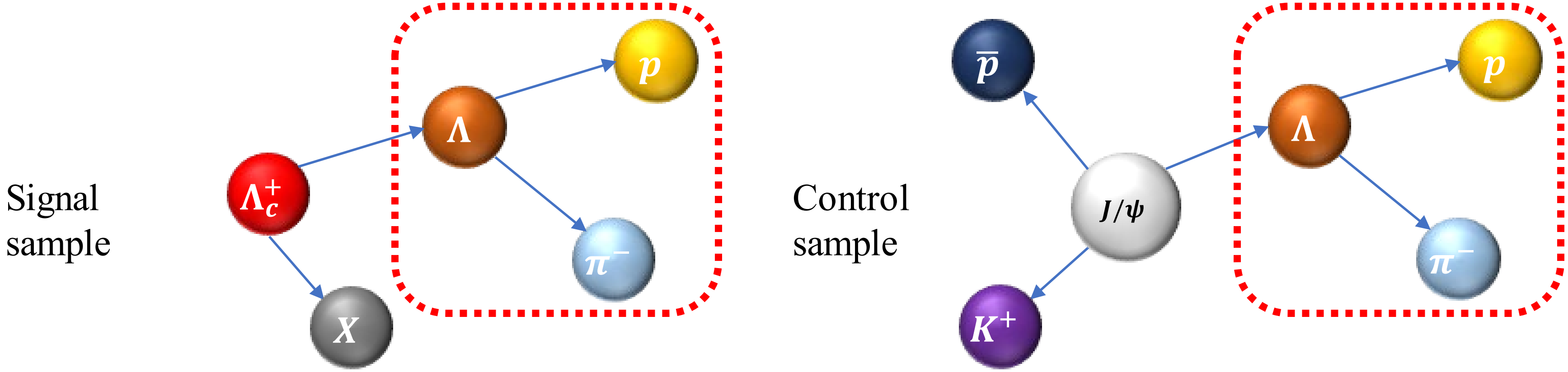
- The inclusive decay contains multiple exclusive decays, of which the phase space is complicated.
- There are still undiscovered exclusive decays.
- The efficiency in different phase space may vary greatly.

MC can not simulate the real data well.



➢Reasonability:

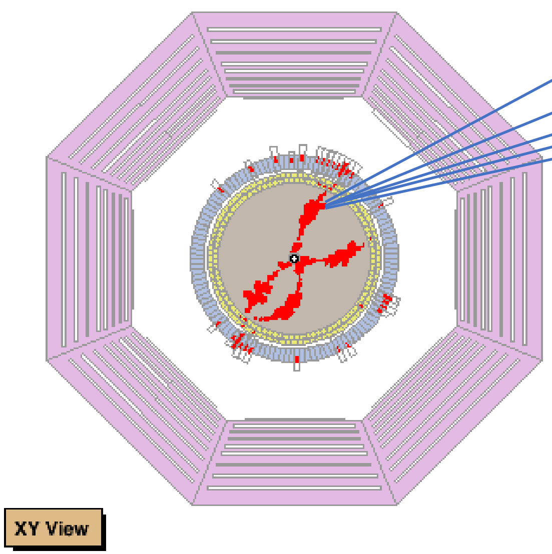
- The detector doesn't matter the history of particles.



Methods for inclusive decay

- **Unfolding**

Apply for single charged particles (e, μ, π, K, p)



$$\begin{pmatrix} N_e^{obs} \\ N_\mu^{obs} \\ N_\pi^{obs} \\ N_K^{obs} \\ N_p^{obs} \end{pmatrix} = \boxed{\begin{pmatrix} P_{e\to e} & \cdots & P_{p\to e} \\ \vdots & \ddots & \vdots \\ P_{e\to p} & \cdots & P_{p\to p} \end{pmatrix}} \cdot \begin{pmatrix} N_e^{true} \\ N_\mu^{true} \\ N_\pi^{true} \\ N_K^{true} \\ N_p^{true} \end{pmatrix}$$

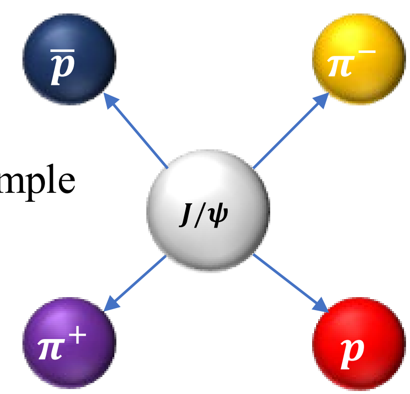
➢ Necessity:

- The stable charged particle can only be confirmed by PID.
- Loss and mistakes in PID.

➢ Difficulties:

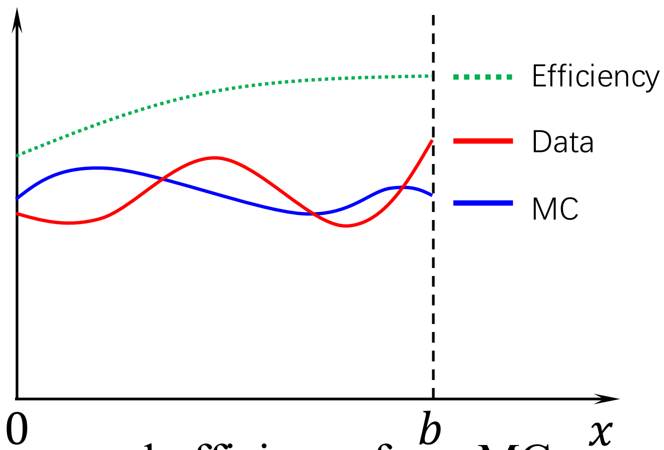
- Study control samples of 5 particles (e, μ, π, K, p) to obtain 5x5 elements of PID matrix;
- Unfolding in each phase space point.

Control sample



Methods for inclusive decay

- **Reweight**



Suppose that a variable $\boldsymbol{x}$ distribute differently in MC and data: $\boldsymbol{\rho_{MC}(x)}$ $\boldsymbol{\rho_{data}(x)}$

Problem:
How much of the difference of yields between using the efficiency from MC N'_{data} and real data N_{data} ?

- Averaged efficiency from MC:

- $$\overline{\varepsilon_{MC}} = \frac{n_{MC}}{N_{MC}} = \frac{\int_b N_{MC}(x)\varepsilon_{MC}(x)dx}{\int_b N_{MC}(x)dx} = \int_b \rho_{MC}(x)\varepsilon_{MC}(x)dx, \quad \rho_{MC}(x) = \frac{N_{MC}(x)}{\int_b N_{MC}(x)dx}$$

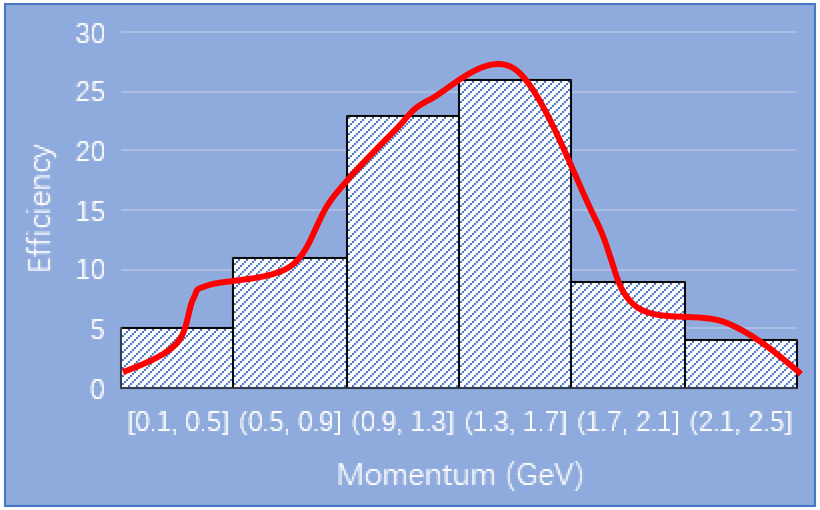
- Using averaged efficiency from MC to obtained the yields:

- $$N'_{data} = \frac{n_{data}}{\overline{\varepsilon_{MC}}} = \frac{\int_b N_{data}(x)\varepsilon_{data}(x)dx}{\int_b \rho_{MC}(x)\varepsilon_{MC}(x)dx} = N_{data}\cdot\boxed{\frac{\int_b \rho_{data}(x)\varepsilon_{data}(x)dx}{\int_b \rho_{MC}(x)\varepsilon_{MC}(x)dx}} \quad \rho_{data}(x) = \frac{N_{data}(x)}{\int_b N_{data}(x)dx}$$

Methods for inclusive decay

- **Dynamic binning**

The efficiency varies greatly in phase space.



$$\bar{\varepsilon} = \frac{\sum_{b_i} n_{b_i}}{\sum_{b_i} N_{b_i}}, \quad \varepsilon_{b_i} = \frac{n_{b_i}}{N_{b_i}}$$

The averaged efficiency is influenced by the phase space distribution. If the efficiency varies largely, the binning scheme will bring sizable bias.

Loose binning => systematic uncertainty
Tight binning => statistical uncertainty.

➢ Necessity:

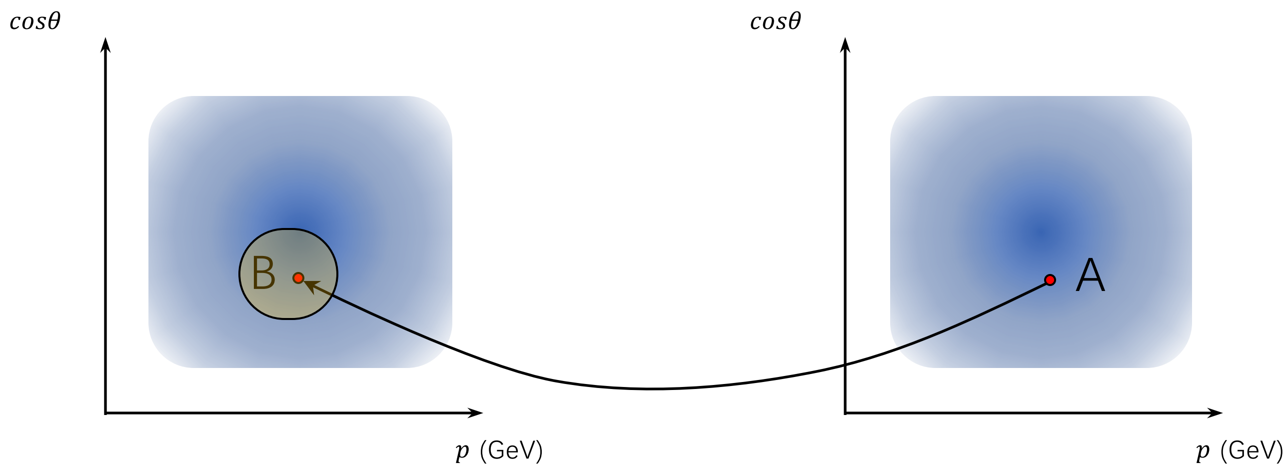
- Efficiency varies with the phase space distribution, MC differs with data;
- The binning scheme will influence the uncertainty.

➢ Difficulties:

- Reduce the sys. & sta. uncertainties simultaneously.

Methods for inclusive decay

- **Dynamic binning**

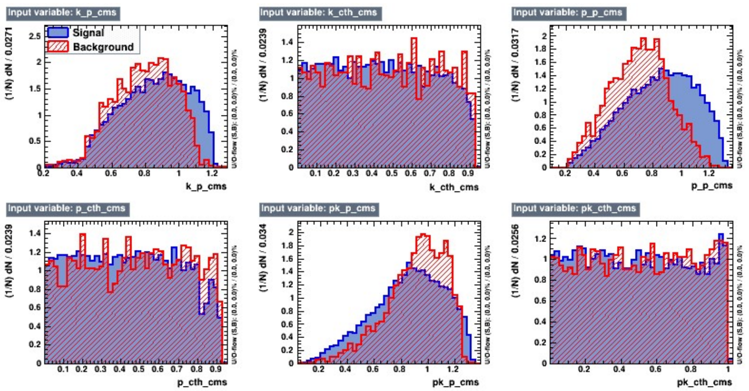


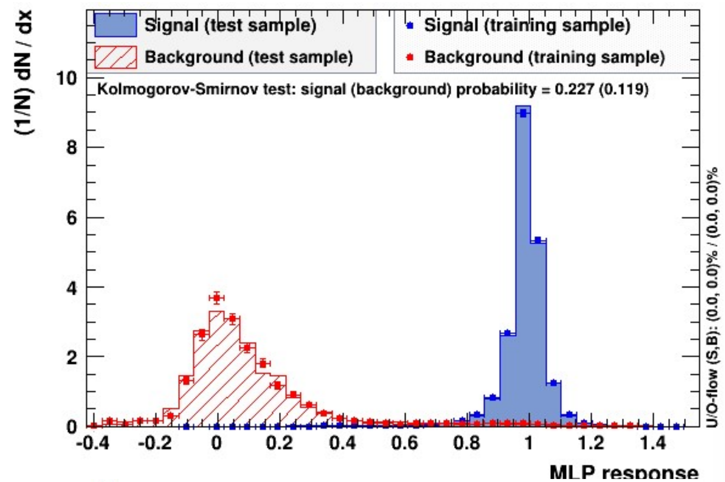
Control sample Real data

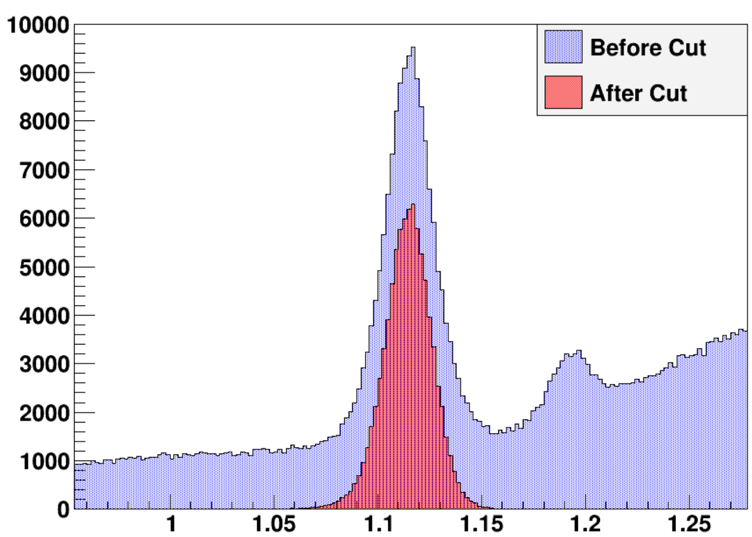
- For a certain point A in the phase space of real data, we can look for its corresponding point B in the control sample, then calculate the efficiency using the neighborhood region of B. The systematic and statistic uncertainty can be balanced by varying the size of neighborhood of B.

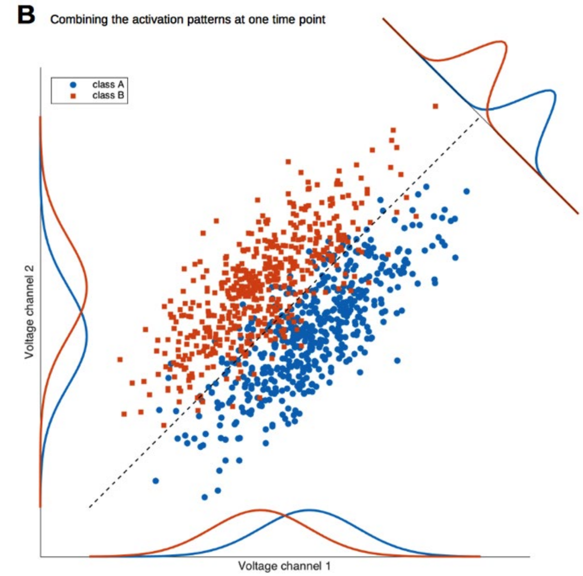
Methods for inclusive decay

- **Multivariate Analysis**









Methods for inclusive decay

- **Blind Analysis**

(In inclusive rare decay)

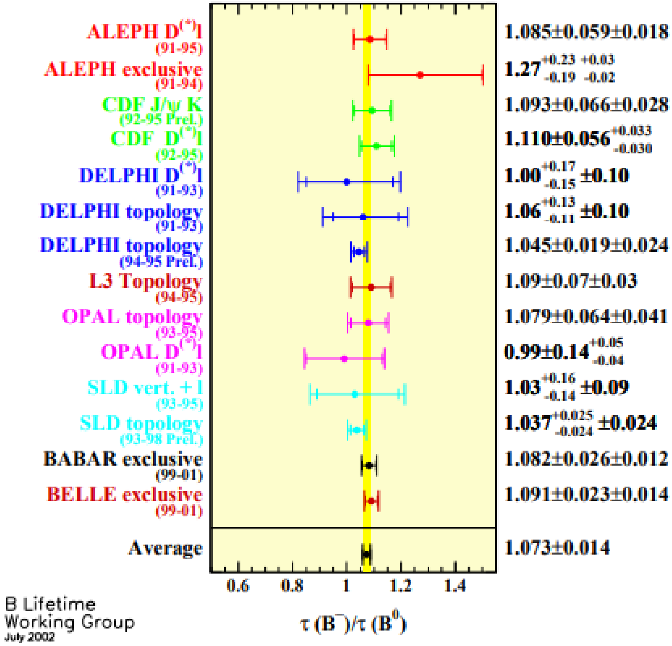
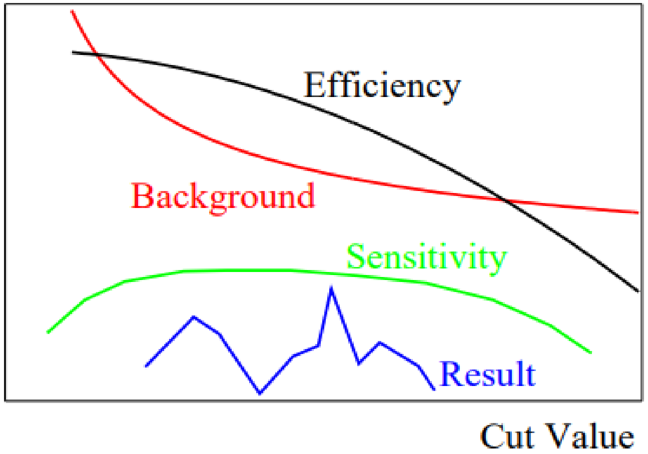


Figure 2: Summary of B meson lifetime ratio measurements. The average has a $\chi^2 = 4.5$ for 13 degrees of freedom.



Hide results to seek the truth

More fields should, like particle physics, adopt blind analysis to thwart bias, urge **Robert MacCoun** and **Saul Perlmutter**.

[“Blind Analysis in Particle Physics”]

[Nature volume 526, pages187–189 (2015)]

Status of inclusive decay

- $D^{\pm}$:

Inclusive modes			
Γ_1	e^+ semileptonic	CLEO,2010	$(16.07 \pm 0.30)\%$
Γ_2	μ^+ anything	BES2,2008	$(17.6 \pm 3.2)\%$
Γ_3	K^- anything	BES2,2007	$(25.7 \pm 1.4)\%$
Γ_4	$\overline{K}^0$ anything + K^0 anything	BES3,2023	$(61 \pm 5)\%$
Γ_5	K^+ anything	BES2,2007	$(5.9 \pm 0.8)\%$
Γ_6	$K^*(892)^-$ anything	BES2,2006	$(6 \pm 5)\%$
Γ_7	$\overline{K}^*(892)^0$ anything	BES,2005	$(23 \pm 5)\%$
Γ_8	$K^*(892)^0$ anything	BES,2005	$< 6.6\%$
Γ_9	η anything	CLEO,2006	$(6.3 \pm 0.7)\%$
Γ_{10}	η' anything	CLEO,2006	$(1.04 \pm 0.18)\%$
Γ_{11}	ϕ anything	BES3,2019	$(1.12 \pm 0.04)\%$

D^0:

Inclusive modes				
Γ_5	e^+ anything	CLEO,2010	[4]	$(6.49 \pm 0.11)\%$
Γ_6	μ^+ anything	BES2,2008		$(6.8 \pm 0.6)\%$
Γ_7	K^- anything	BES2,2007		$(54.7 \pm 2.8)\%$
Γ_8	$\overline{K}^0$ anything + K^0 anything	BES3,2023		$(47 \pm 4)\%$
Γ_9	K^+ anything	BES2,2007		$(3.4 \pm 0.4)\%$
Γ_{10}	$K^*(892)^-$ anything	BES2,2006		$(15 \pm 9)\%$
Γ_{11}	$\overline{K}^*(892)^0$ anything	BES,2005		$(9 \pm 4)\%$
Γ_{12}	$K^*(892)^+$ anything	BES2,2006		$< 3.6\%$
Γ_{13}	$K^*(892)^0$ anything	BES,2005		$(2.8 \pm 1.3)\%$
Γ_{14}	η anything	CLEO,2006		$(9.5 \pm 0.9)\%$
Γ_{15}	η' anything	CLEO,2006		$(2.48 \pm 0.27)\%$
Γ_{16}	ϕ anything	BES3,2019		$(1.08 \pm 0.04)\%$

- Λ_c^+:

Inclusive modes			
Γ_{76}	e^+ anything	$(3.95 \pm 0.35)\%$	→ BESIII, PRL
Γ_{77}	p anything	$(50 \pm 16)\%$	→ BESIII, on-going
Γ_{78}	n anything	$(50 \pm 16)\%$	→ BESIII, PRD
Γ_{79}	Λ anything	$(38.2^{+2.9}_{-2.4})\%$	→ BESIII, PRL
Γ_{80}	K^0_S anything	$(9.9 \pm 0.7)\%$	→ BESIII, EPJC
Γ_{81}	3prongs	$(24 \pm 8)\%$	

J/ψ: none

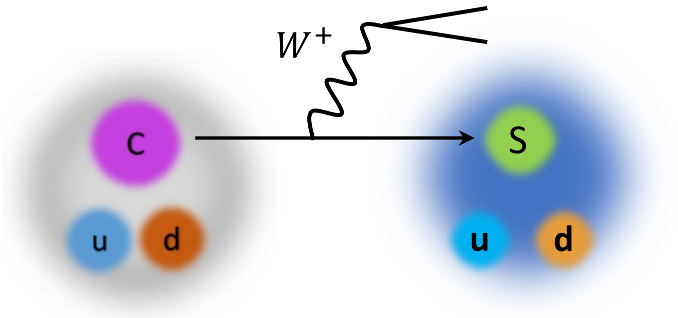
ψ': none

8 papers: 2 PRL, 1 EPJC, 5 PRD

$\Lambda_c^+ \to X e^+ \nu_e$

- **$\Lambda_c^+ \to X e^+ \nu_e$:** Phys. Rev. Lett. 121 251801

In HQET, the u、d plays as passive quarks, the decay of Λ_c^+ is dominated by $c \to s$ transition, including are semi-leptonic channels ($e^+\nu_e$ or $\mu^+\nu_e$) and non-leptonic channels(Λ、K_S^0、K^-)



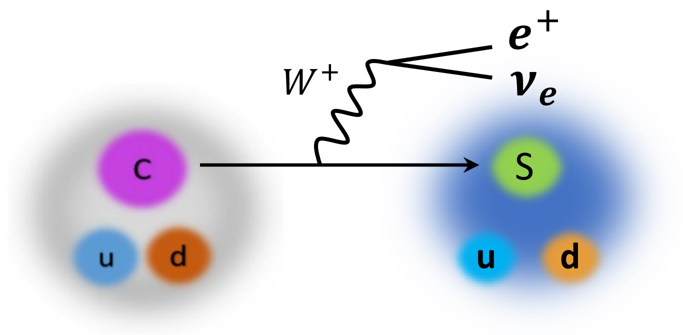
$c \to s(d)W^+$

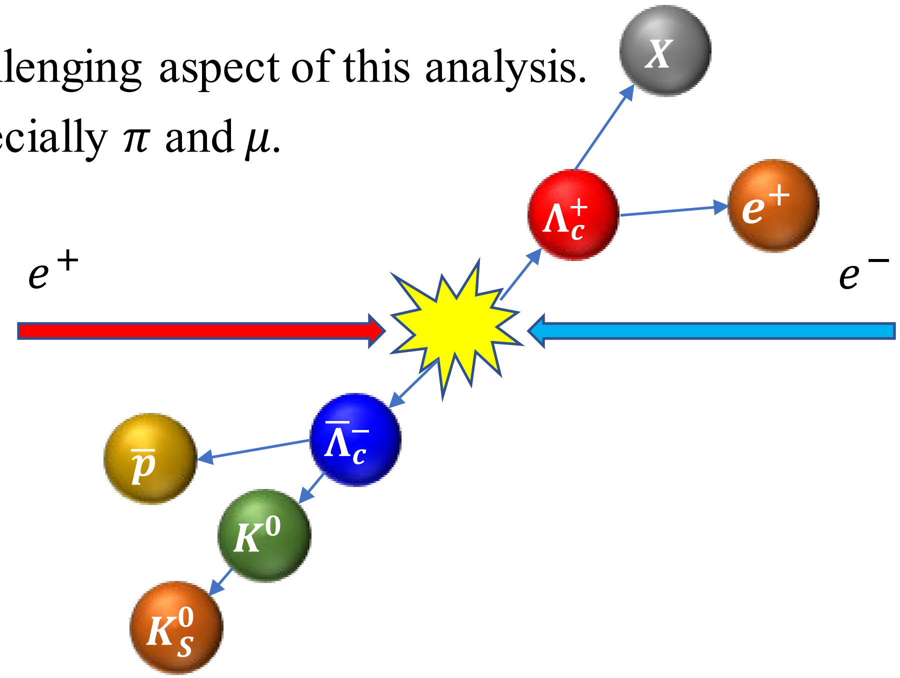
Example: $\Gamma(\Lambda_c^+ \to X e^+ \nu_e)/\Gamma(D^+ \to X e^+ \nu_e)$, theories provide different predictions, effective-quark predicts it to be 1.67, heavy-quark expansion predicts it to be 1.2. Precise measurement can distinguish different theories.

$\Lambda_c^+ \to X e^+ \nu_e$

- $\Lambda_c^+ \to X e^+ \nu_e$:

The difficulty of this analysis lies in the fact that the distinctive signal in the final state is only an e^+. It is challenging to effectively distinguish the e^+ from other particles and obtain the true number of $\Lambda_c^+ \to X e^+ \nu_e$.
Firstly, a double-tag method must be used;
Then, particle misidentification is the most challenging aspect of this analysis.
It is difficult to separate different particles, especially π and μ.





- **PID Unfolding**:

$$\begin{pmatrix} n_e^{obs} \\ n_\mu^{obs} \\ n_\pi^{obs} \\ n_K^{obs} \\ n_p^{obs} \end{pmatrix} = \begin{pmatrix} \varepsilon_{e\to e} & \varepsilon_{\mu\to e} & \varepsilon_{\pi\to e} & \varepsilon_{K\to e} & \varepsilon_{p\to e} \\ \varepsilon_{e\to \mu} & \varepsilon_{\mu\to \mu} & \varepsilon_{\pi\to \mu} & \varepsilon_{K\to \mu} & \varepsilon_{p\to \mu} \\ \varepsilon_{e\to \pi} & \varepsilon_{\mu\to \pi} & \varepsilon_{\pi\to \pi} & \varepsilon_{K\to \pi} & \varepsilon_{p\to \pi} \\ \varepsilon_{e\to K} & \varepsilon_{\mu\to K} & \varepsilon_{\pi\to K} & \varepsilon_{K\to K} & \varepsilon_{p\to K} \\ \varepsilon_{e\to p} & \varepsilon_{\mu\to p} & \varepsilon_{\pi\to p} & \varepsilon_{K\to p} & \varepsilon_{p\to p} \end{pmatrix} \cdot \begin{pmatrix} N_e^{truth} \\ N_\mu^{truth} \\ N_\pi^{truth} \\ N_K^{truth} \\ N_p^{truth} \end{pmatrix}$$

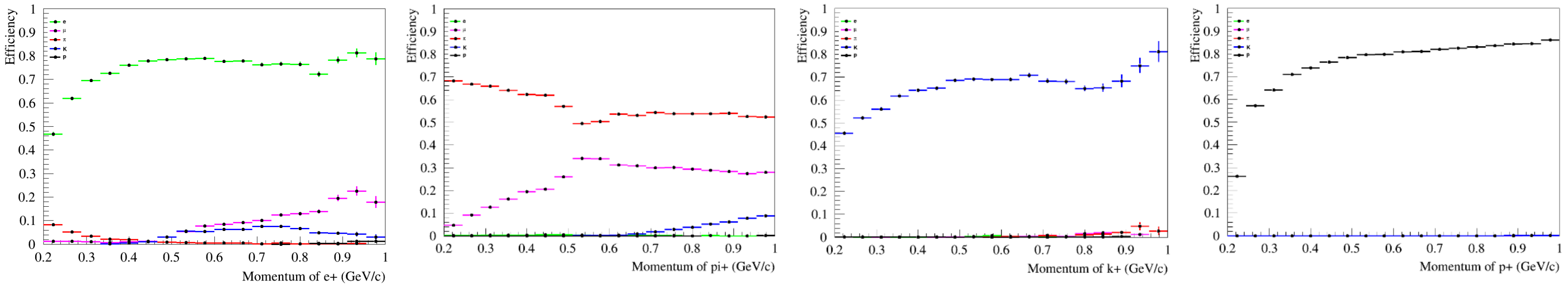
Basic idea： matrix inversion to estimate the number of each kind of particle.

- **Control sample:**

Pure control sample is essential for PID unfolding:

- $e^\pm$: $e^+e^- \to \gamma e^+e^-$;
- $\pi^\pm$: $J/\psi \to K^+K^-\pi^+\pi^-(\pi^0)$ and $J/\psi \to p\bar{p}\pi^+\pi^-(\pi^0)$;
- $K^\pm$: $J/\psi \to K^+K^-\pi^+\pi^-(\pi^0)$ and $J/\psi \to K^+K^-K^+K^-(\pi^0)$.
- $p(\bar{p})$: $J/\psi \to p\bar{p}\pi^+\pi^-(\pi^0)$.

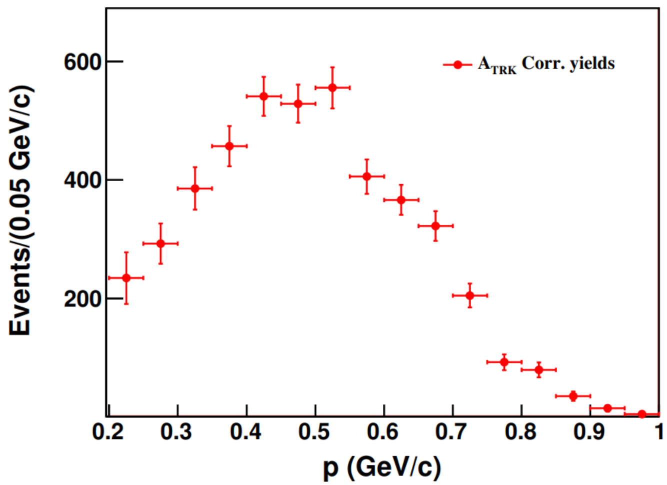
Then calculate the efficiency for each track identified as a certain particle.

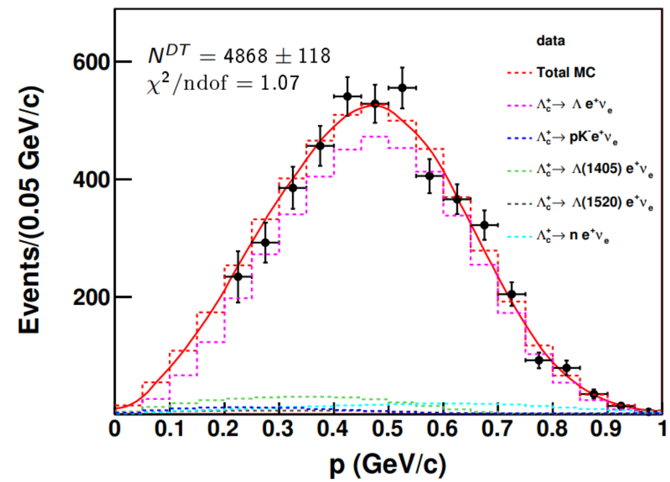


$\Lambda_c^+ \to Xe^+\nu_e$

- **Inverse & extension:**

By solving the matrix equation, the yield of $\Lambda_c^+ \to Xe^+\nu_e$ can be obtained.



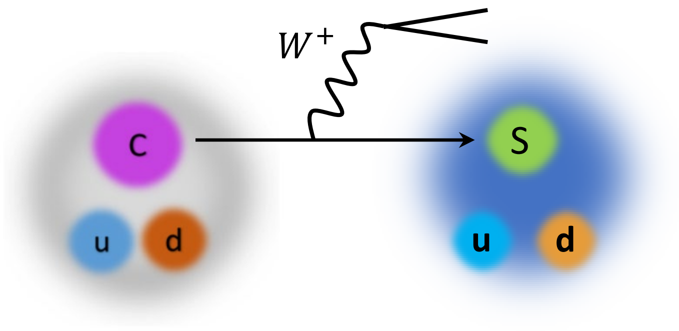


The electron with momentum below 0.2 GeV can not be detected by the spectrometer, the efficiency is extremely low. Extension to the whole region is essential to obtain the total yield.

Latest result from BESIII is $\mathcal{B}(\Lambda_c^+ \to Xe^+\nu_e) = (4.06 \pm 0.10 \pm 0.09)\%$, the ratio with $D^+ \to Xe^+\nu_e$ is 1.28 ± 0.05. [Phys. Rev. D **107**, 052005]

$\Lambda_c^+ \to \Lambda X / K_S^0 X$

- $\Lambda_c^+ \to \Lambda X$: Phys. Rev. Lett. 121 062003



In the decay of Λ_c^+, the c quark mainly decays to an s quark, and there is a significant possibility of forming Λ baryons after hadronization of the final state.

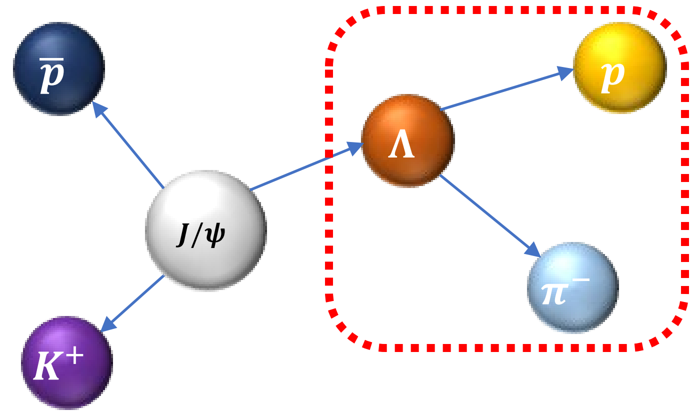
Until 2023, the sum of all decays of $\Lambda_c^+ \to \Lambda X / K_S^0$X exclusive channels are (30.1$\pm$1.2)% and (11.2 ± 0.5)%. Conducting measurements on this inclusive decay can help determine the upper limit of the exclusive decay and provide guidance for further research on Λ_c^+.

Unlike $\Lambda_c^+ \to Xe^+\nu_e$, the Λ signal reconstructed through $\Lambda(K_S^0) \to p\pi^-(\pi^+\pi^-)$ is very clean in this analysis. The challenge lies not in the correct reconstruction of $\Lambda(K_S^0)$, but in accurately estimating the efficiency of $\Lambda(K_S^0)$. Since the study of Λ_c^+ is still in its early stages, Monte Carlo simulations cannot accurately reflect the situation in real data. Therefore, a data-driven approach is necessary in this analysis.

- $\Lambda_c^+ \to K_S^0 X$: Eur. Phys. J. C. Lett. 80 935

$\Lambda_c^+ \to \Lambda X$

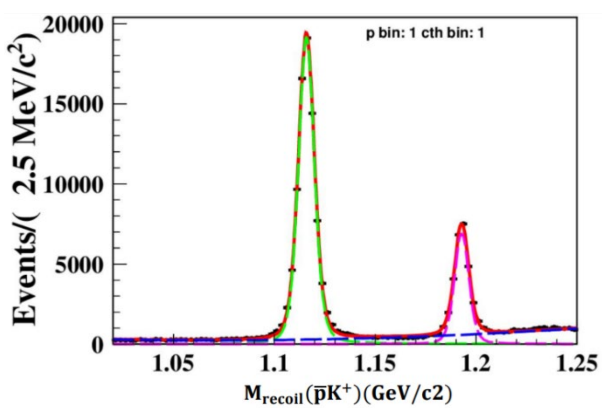
- **Control sample & binning:**

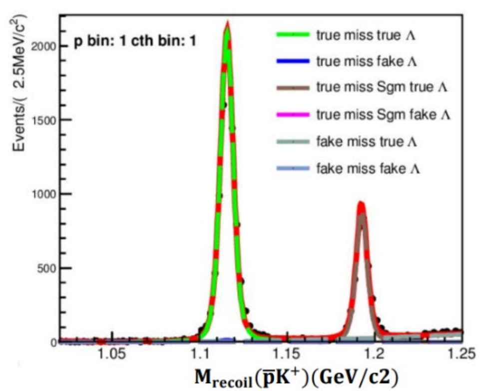


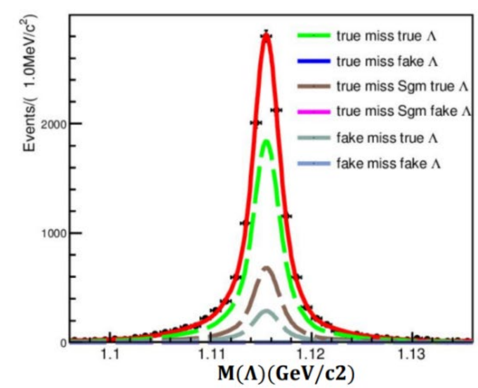
Taking advantage of high statistics of J/ψ (10^{10})

Control channel: $J/\psi \to \bar{p}K^+\Lambda$

Fit the spectrum of recoil mass of $\bar{p}$ and K^+ before find a Λ:





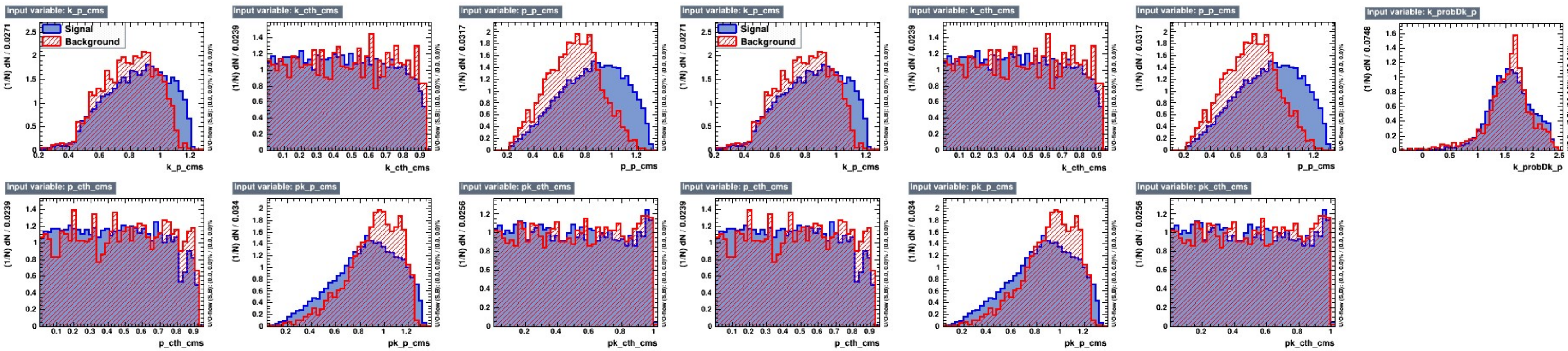


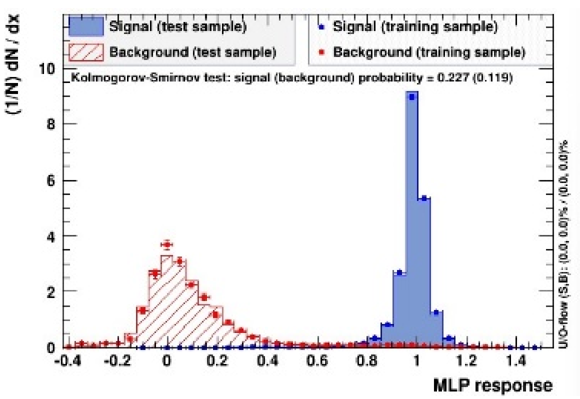
Then fit the $M_{recoil}(\bar{p}K^+)$ $v.s.$ $M_{p\pi^-}(\Lambda)$ after finding a Λ.

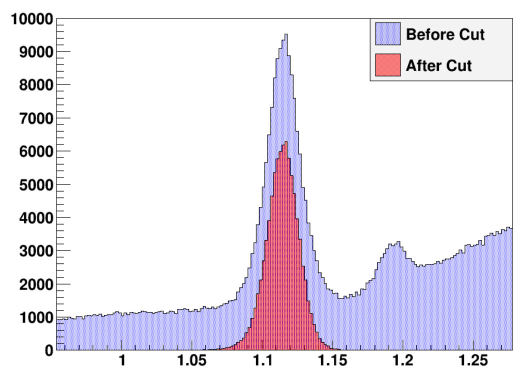
$\Lambda_c^+ \rightarrow \Lambda X$

- **MVA:**

In analysis for $\Lambda_c^+ \rightarrow \Lambda X$, the MVA can be used to obtain pure control sample using 13 variables in the training:





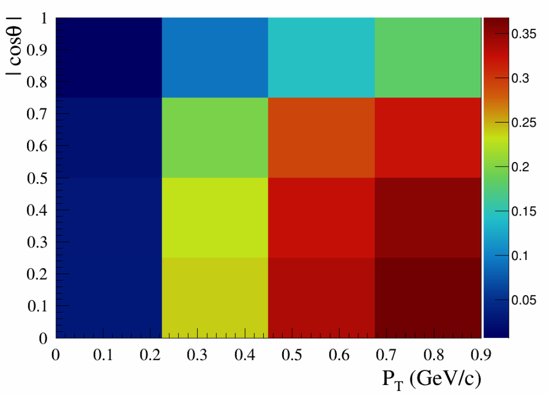


Control sample with high purity can be obtained after MVA selection.

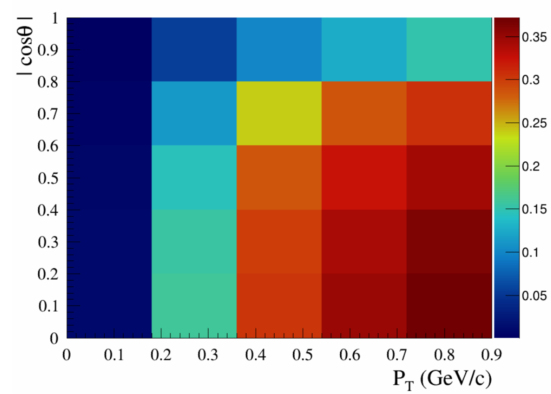
$\Lambda_c^+ \to \Lambda X$

- **Dynamic binning:**

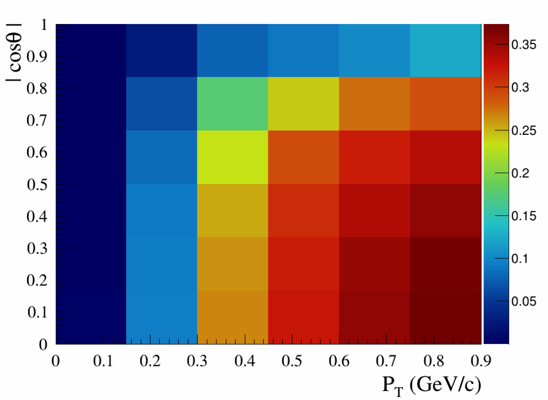
Due to high purity of the control sample, the efficiency of Λ can be obtained by just counting the numbers in each point after subtracting background.



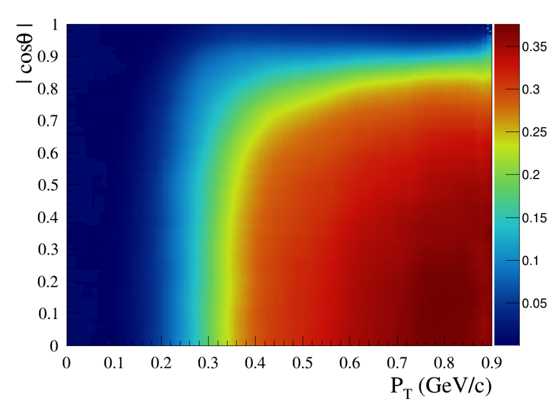
4×4



5×5



6×6



$unbin$

$\overline{\Lambda}_c^- \to \bar{n}X$

- $\overline{\Lambda}_c^- \to \bar{n}X$: Phys. Rev. D 108 L031101

Γ_{77}	p anything	$(50 \pm 16)\%$
Γ_{78}	n anything	$(50 \pm 16)\%$

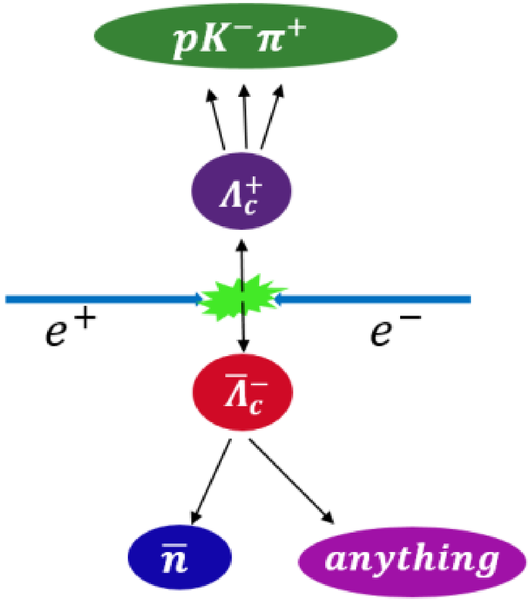
from PDG

The sum of exclusive decays of $\Lambda_c^+ \to pX$ and $\Lambda_c^+ \to nX$ are 44.5%、22.0%. Precise determination of inclusive decay may help search for undiscovered exclusive decays.

- **Tag mode:**

Only choose the $\Lambda_c^+ \to pK^-\pi^+$ as tag mode.
(Highest statistics, lowest background)

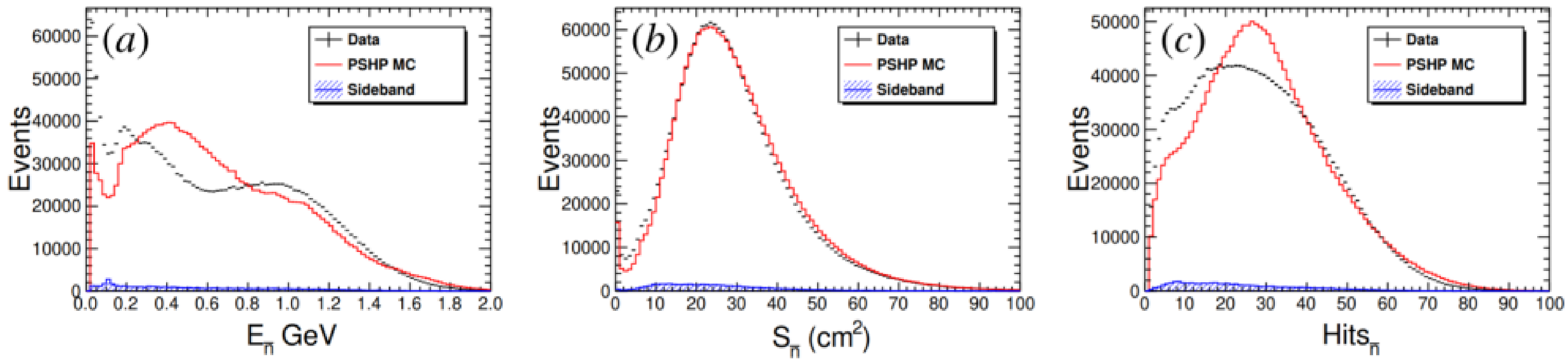
- **Control sample:** choose $J/\psi \to p\bar{n}\pi^-$.



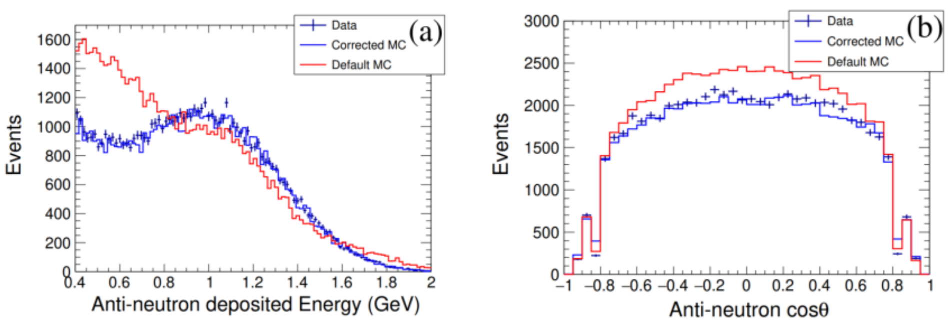
  - $E_{\bar{n}} > 0.48\ GeV$
  - Number of hits $Hits_{\bar{n}} > 20$
  - second moment $S_{\bar{n}} > 18\ cm^2$
  - $N_{\bar{p}} = 0$

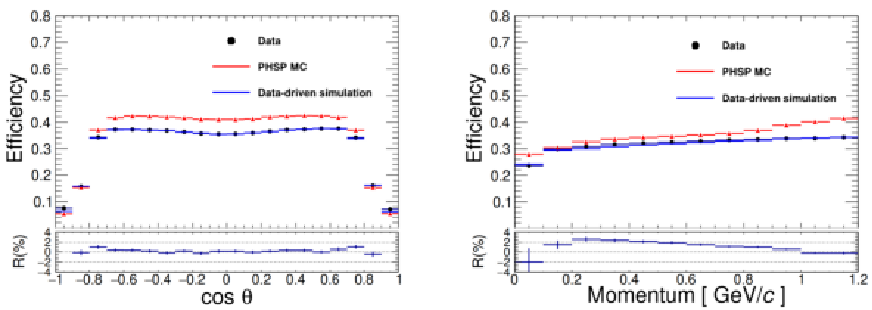
$\bar{\Lambda}_c^- \to \bar{n}X$

- **Data-driven simulation:**



Discrepancy between MC and data => Reweight the MC using data-driven.

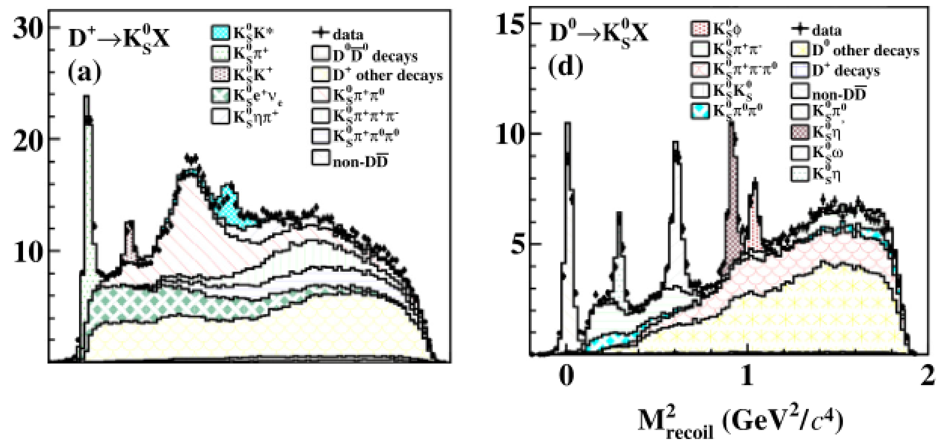




$D^{0/+} \to K_S^0 X$

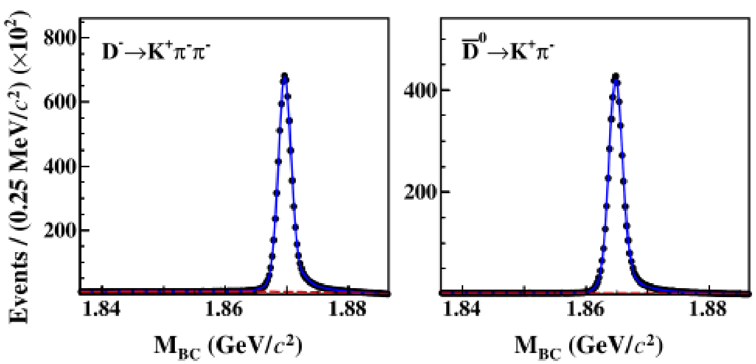
- $D^{0/+} \to K_S^0 X$: Phys. Rev. D 107 112005

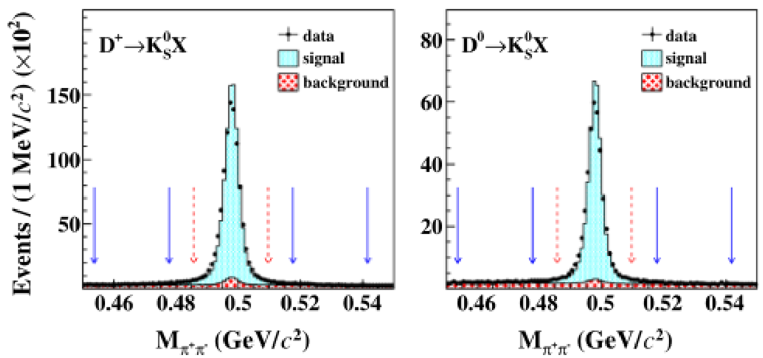
Recoil mass spectrum:



The D meson has been well studied by hep experiments, the Monte Carlo can be trusted in efficiency study of inclusive decay of D meson.

- **2D Fit:**





Results:

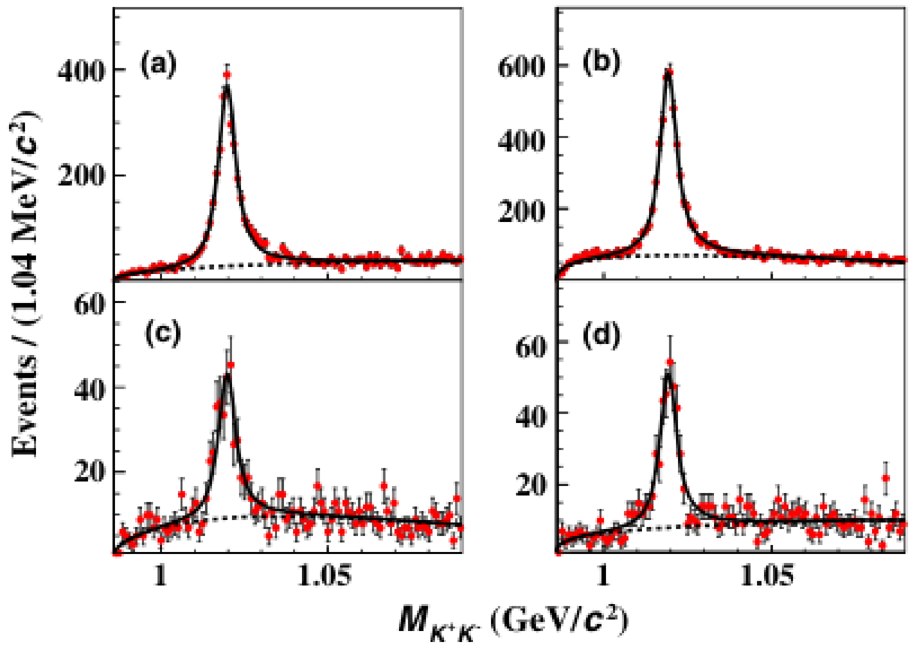
Decay mode	Mark-III (%) [1]	BES (%) [2]	PDG (%) [3]	This study (%)	$\mathcal{B}^{\rm sum}_{\rm exclusive}$ (%)
$D^+ \to K_S^0 X$	$30.60 \pm 3.25 \pm 2.15$	$30.25 \pm 2.75 \pm 1.65$	30.5 ± 2.5	$33.11 \pm 0.13 \pm 0.36$	31.68 ± 0.32
$D^0 \to K_S^0 X$	$22.75 \pm 2.50 \pm 1.60$	$23.80 \pm 2.40 \pm 1.50$	23.5 ± 2.0	$20.75 \pm 0.12 \pm 0.20$	18.16 ± 0.72

$D^{0/+} \to \phi X$

- $D^{0/+} \to \phi X$: Phys. Rev. D 100 072006

The efficiency is also obtained from MC. The remaining difference between data and MC is studied with data-driven hadronic events.

- **Fit & sideband subtraction**



Decay mode	$\mathcal{B}$
$D^+ \to \phi\pi^+\pi^0$	$(2.3 \pm 1.0)\%$
$D^+ \to \phi\rho^+$	$< 1.5\%$
$D^+ \to \phi\pi^+$	$(5.70 \pm 0.14) \times 10^{-3}$
$D^+ \to \phi K^+$	$(8.86 \pm 1.14) \times 10^{-6}$
Sum	$(2.87 \pm 1.00)\%$
$D^0 \to \phi\gamma$	$(2.81 \pm 0.19) \times 10^{-5}$
$D^0 \to \phi K^0_S$	$(4.13 \pm 0.31) \times 10^{-3}$
$D^0 \to \phi K^0_L$	$(4.13 \pm 0.31) \times 10^{-3}$
$D^0 \to \phi\omega$	$< 2.1 \times 10^{-3}$
$D^0 \to \phi(\pi^+\pi^-)_{\text{S-wave}}$	$(20 \pm 10) \times 10^{-5}$
$D^0 \to (\phi\rho^0)_{\text{S-wave}}$	$(14.0 \pm 1.2) \times 10^{-4}$
$D^0 \to (\phi\rho^0)_{\text{D-wave}}$	$(8.5 \pm 2.8) \times 10^{-5}$
$D^0 \to (\phi\rho^0)_{\text{P-wave}}$	$(8.1 \pm 3.8) \times 10^{-5}$
$D^0 \to \phi\pi^0$	$(1.17 \pm 0.04) \times 10^{-3}$
$D^0 \to \phi\eta$	$(1.81 \pm 0.46) \times 10^{-4}$
Sum	$(1.14 \pm 0.09)\%$

Results:

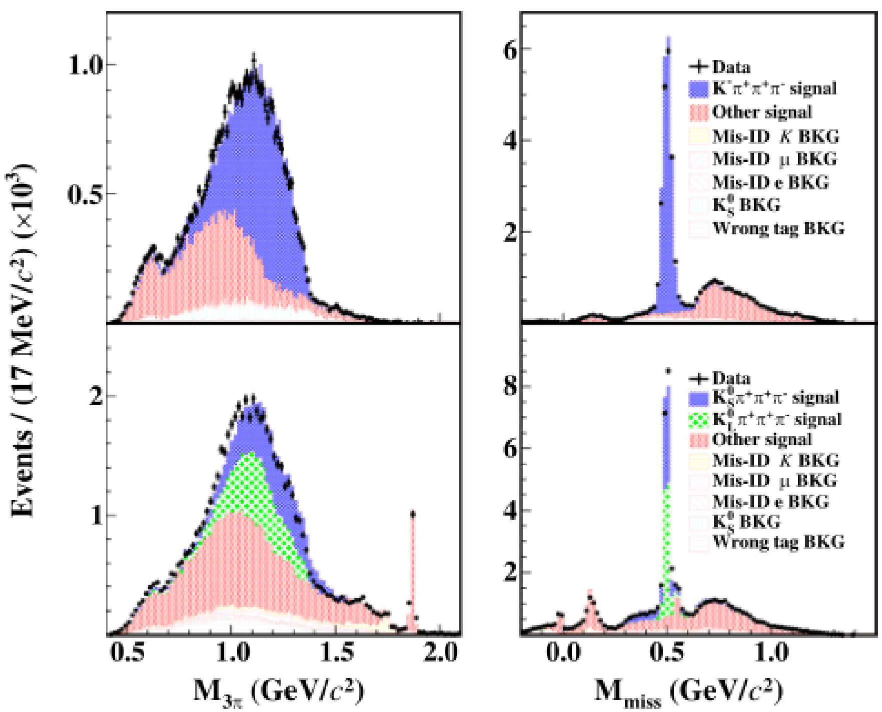
	$\mathcal{B}(D^0 \to \phi X)$	$\mathcal{B}(D^+ \to \phi X)$
This Work	$(1.278 \pm 0.032 \pm 0.041)$ %	$(1.235 \pm 0.036 \pm 0.037)$ %
CLEO-c	$(1.05 \pm 0.08 \pm 0.07)$ %	$(1.03 \pm 0.10 \pm 0.07)$ %
BES	$(1.71^{+0.76}_{-0.71} \pm 0.17)$ %	< 1.8 %

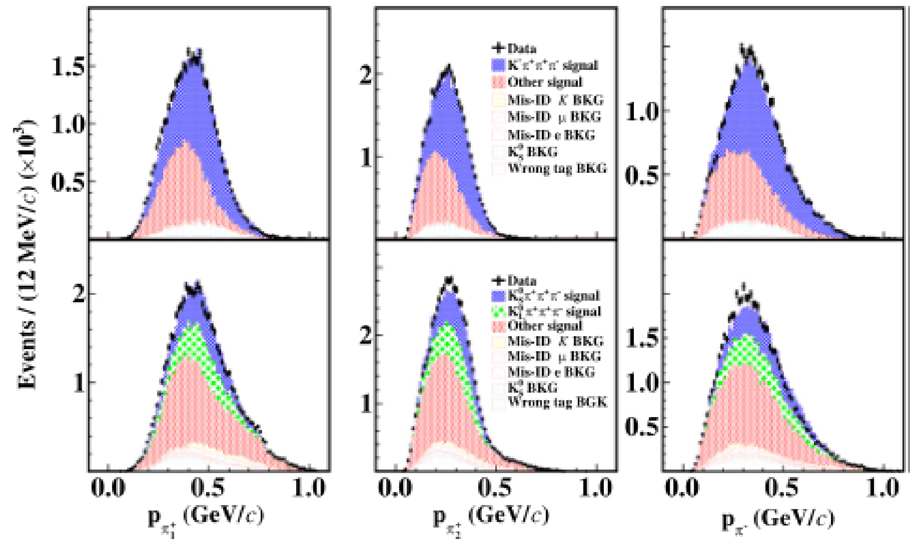
$D^{0/+} \to \pi^+\pi^+\pi^- X$

- $D^{0/+} \to \pi^+\pi^+\pi^- X$: Phys. Rev. D 107 032002

Estimate the leading background in $B^0 \to D^{*-}\tau^+\nu_\tau, \tau^+ \to \pi^+\pi^+\pi^-\nu_\tau$ (test LFU).

- **Data & MC consistency:**





Results:

$$\mathcal{B}(D^0 \to \pi^+\pi^+\pi^- X) = (17.60 \pm 0.11 \pm 0.22)\%,$$

$$\mathcal{B}(D^+ \to \pi^+\pi^+\pi^- X) = (15.25 \pm 0.09 \pm 0.18)\%,$$

Summary & Prospect

- **BESIII has obtained a series of achievement on inclusive decays, mature analytical techniques are developed.**

- **Inclusive decays of Λ_c^+ are widely studied, on-going analyses:**
  - $\Lambda_c^+ \to \Lambda X$、$\Lambda_c^+ \to K_S^0 X$、$\Lambda_c^+ \to pX$、$\Lambda_c^+ \to \Sigma^+ X$、$\Lambda_c^+ \to \Sigma^0 X$、$\Lambda_c^+ \to X\mu^+\nu_\mu$

- **Inclusive decays of charmed meson are performed mainly on BES2, waiting for update:**
  - $D^{0/+} \to Xe^+\nu_e$、$D^{0/+} \to X\mu^+\nu_\mu$、$D^{0/+} \to K^\pm X\ldots$

- **Inclusive decays of charmonium remain blank, possible analyses:**
  - $J/\psi \to pX$、$J/\psi \to nX$、$J/\psi \to \Lambda X$、$J/\psi \to K_S^0 X\ldots$

- **Some BNV channels can be searched via inclusive decay:**
  - $J/\psi \to \Lambda_c^+ X$、$J/\psi \to ppX$、$D^{0/+} \to pX\ldots$

Summary & Prospect

- **Dataset at BESIII: (from BESIII physics page)**

For J/Ψ

Sample type	Ecms (GeV)	Run ID	Event number (Int. luminosity)
On-J/ψ (2009)	3.097	9947-10878	224.0±1.3M (80 pb-1)
On-J/ψ (2012)	3.097	27255-28236	1088.5±4.4M (315 pb-1)
On-J/ψ (2017-2019)	3.097	52940-54976 55861-56546 56788-59015	8774.0±39.4M (2571 pb-1)

For $\Psi(3686)$

Sample type	Ecms (GeV)	Run ID	Event number (Int. luminosity)
On-ψ(3686) (2009)	3.686	8093-9025	107.0±0.8M (161.63±0.13 pb-1)
On-ψ(3686) (2012)	3.686	25338-27090	341.1±2.1M (506.92±0.23 pb-1)

For $\Psi(3770)$

Sample type	Ecms (GeV)	Run ID	Int. luminosity
On-ψ(3770) (2010)	3.773	11414-13988 14395-14604	2931.8±0.2±13.8 pb-1
On-ψ(3770) (2011)	3.773	20448-23454	

For above 4.6 GeV:

Energy points	4.600 GeV	4.612 GeV	4.628 GeV	4.641 GeV	4.661 GeV	4.682 GeV	4.698 GeV
Lumi(pb^{-1})	566.90	103.45	519.93	548.15	527.55	1664.34	534.40

- **BESIII is an ideal platform to study inclusive decay!**

Thanks for your attention!