$\Lambda_c \to \Sigma\pi\pi$ decays at Belle

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On behalf of the Belle Collaboration

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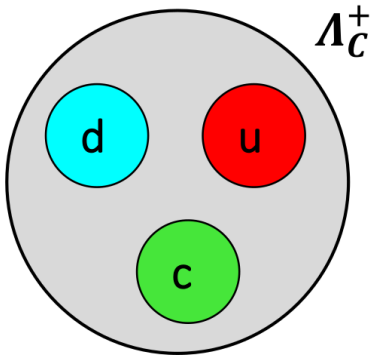
Physics of Λ_c



Λ_c^+ $I(J^P) = 0(1/2)^+$

$\Gamma(\Lambda_c \to p^+K^-\pi^+)/\Gamma_{total}$		
$5.84 \pm 0.27 \pm 0.23$	BES3	2016
$6.84 \pm 0.24^{+0.21}_{-0.27}$	Belle	2014
$\Gamma(\Lambda_c \to p^+K^+\pi^-)/\Gamma_{total}$ $[10^{-3}]$		
$2.35 \pm 0.27 \pm 21$	Belle	2016
$\Lambda_c \to K^+\pi^+p\pi^0$, s. f. $\Lambda_c \to \phi p\pi^0$		
arXiv:1707.00089	Belle	upcom.

- Lightest charmed baryon
- Outstanding importance for understanding of higher resonances
- A lot of hadronic modes haven't been measured yet

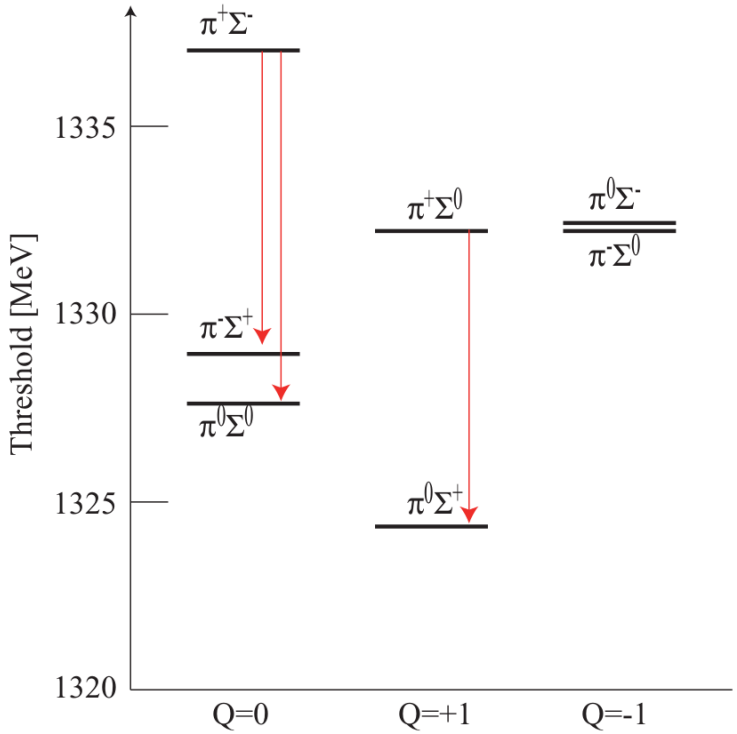
Motivation: $\Sigma\pi$ Scattering Lengths

- Long term goal: Measure the $\Sigma\pi$ scattering lengths based on "Cabibbo's method", T. Hyodo and M. Oka, Phys. Rev. C84, 035201 (2011)
- **This talk**: Measure the $\mathcal{B}(\Sigma\pi\pi)$ relative to $pK^-\pi^+$ + int. resonances.

Visible decay modes at Belle:

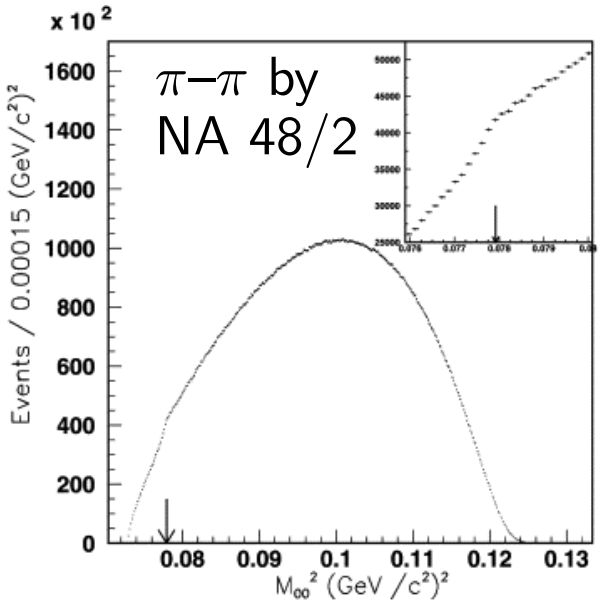
$$\Lambda_c \rightarrow \Sigma^+\pi^-\pi^+(4.57 \pm 0.29\%)^*$$
$$\Lambda_c \rightarrow \Sigma^0\pi^+\pi^0(2.3 \pm 0.9\%)^*$$
$$\Lambda_c \rightarrow \Sigma^+\pi^0\pi^0(\text{unknown})$$

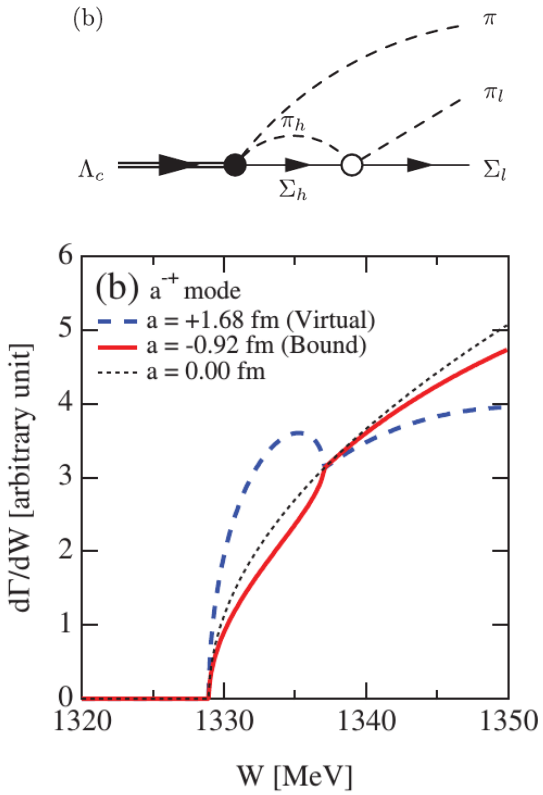
Energy difference of $\Sigma\pi$ under final state charge exchange.



* C. Patrignani *et al.* (Particle Data Group), Chin. Phys. C, **40**, 100001 (2016).

Motivation: $\Sigma\pi$ Scattering Lengths





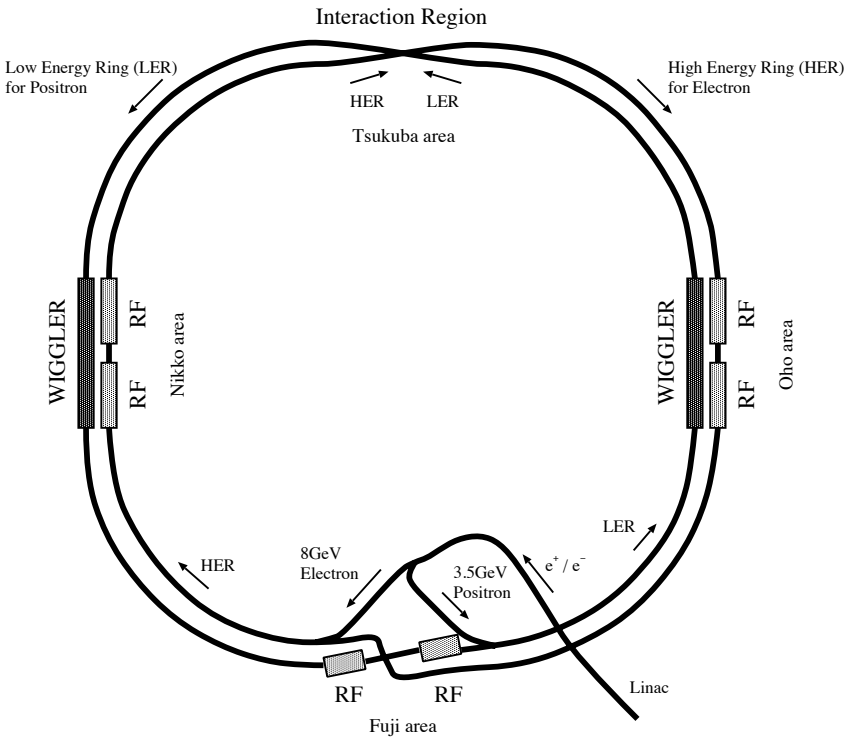
Another Motivation

I=1 suppressed production of $\Lambda(1405)$ at low mass, $\Lambda(1670)$

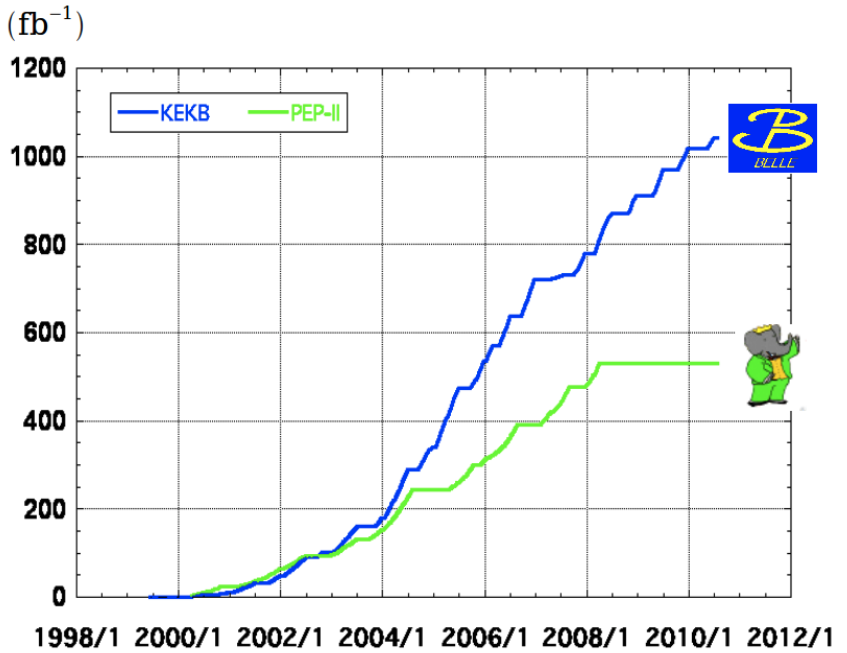
K. Miyahara, T. Hyodo, E. Oset, Phys. Rev. C. 92, 055204 (2015)

Belle and B-Factories

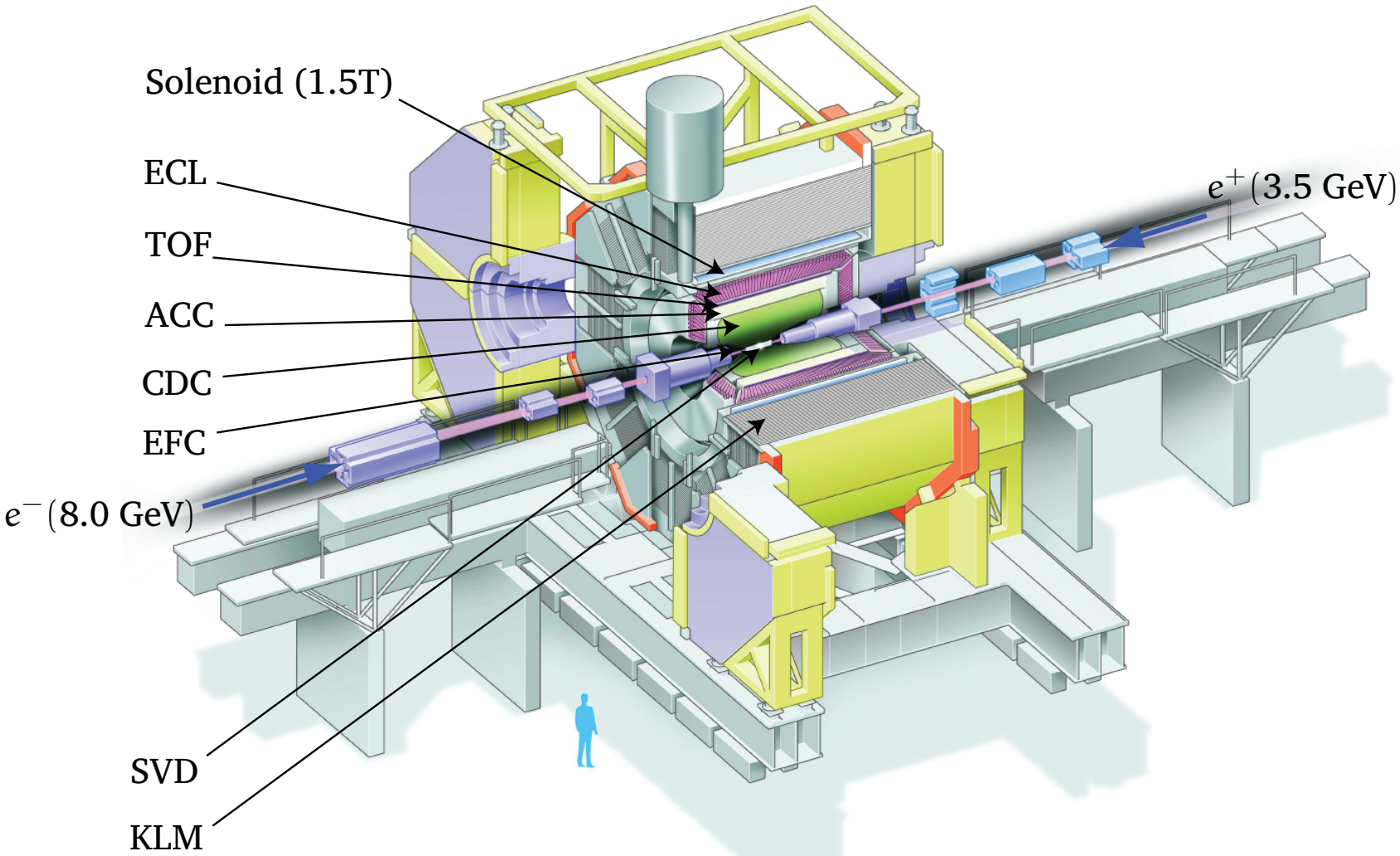
Belle is the detector at the KEKB asymmetric $e^+(3.5\text{ GeV})e^-(8\text{ GeV})$ collider.



Originally constructed for the study of CP violation. Its world record integrated luminosity of 1 ab^{-1} offers many opportunities for hadron physics.



The Belle detector



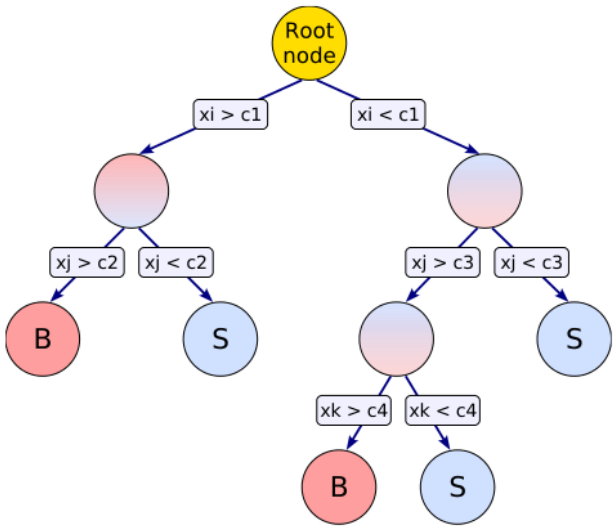
Selection and sample

Production processes

$$e^+e^- \rightarrow c\bar{c} \rightarrow \Lambda_c + X$$
$$e^+e^- \rightarrow c\bar{c} \rightarrow X' \rightarrow \Lambda_c + X$$

$$\Sigma^+ \rightarrow p\pi^0 \ (51.57 \pm 0.30)\%$$
$$\Sigma^0 \rightarrow \Lambda^0\gamma \ (100)\%$$
$$\Lambda^0 \rightarrow p\pi^- \ (63.9 \pm 0.5)\%$$

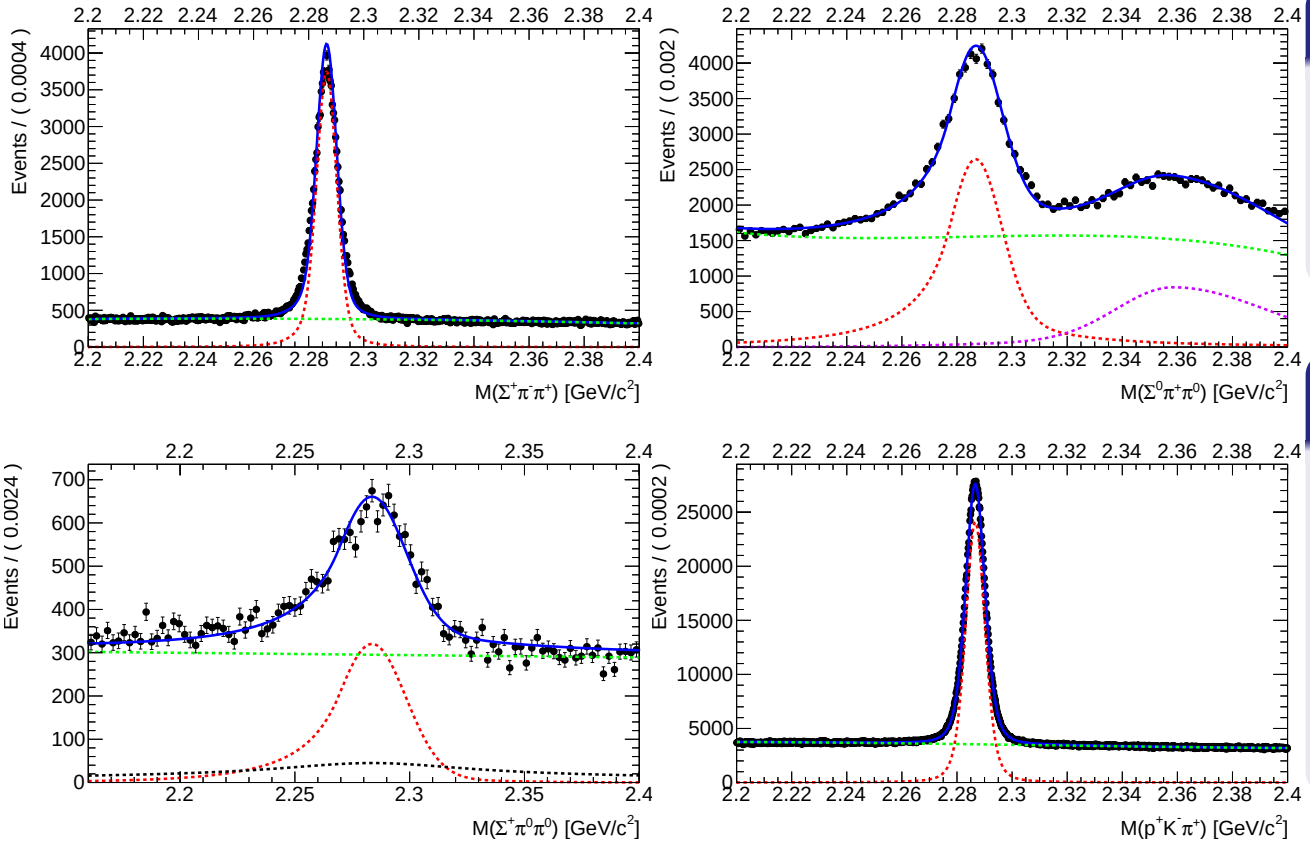
Selection with BDT



BDT input variables

Among others: p/p_{max}, the χ^2 of the vertex constrained fit, the cluster energy and direction of detected photons in the ECL

Invariant mass parameterization



MC studies

- Shape determination
- Consistency tests
- Model uncertainty

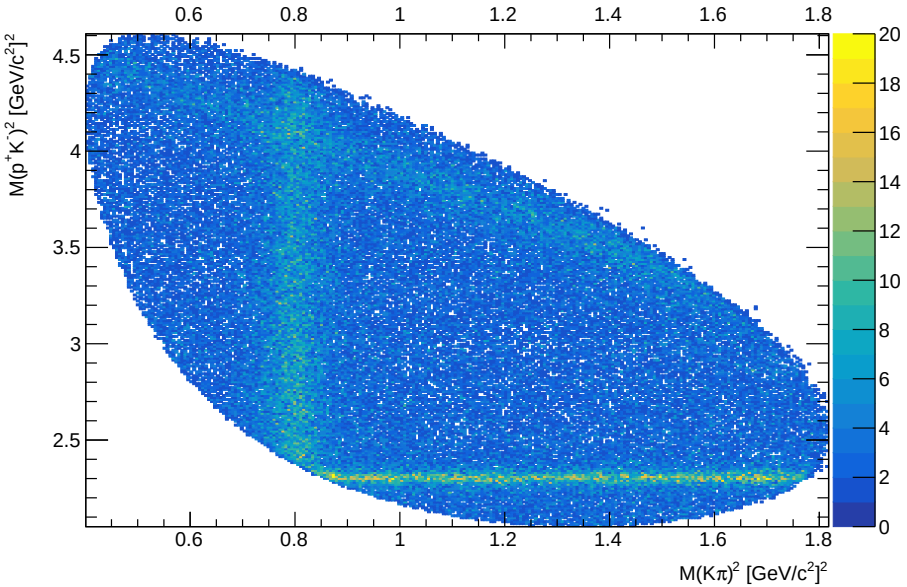
Λ_c in 711 fb^{-1} at $Y(4S)$

Final state	Yield
$\Sigma^+\pi^-\pi^+$	$100,208 \pm 369$
$\Sigma^+\pi^0\pi^0$	$5,951 \pm 261$
$\Sigma^0\pi^+\pi^0$	$46,995 \pm 413$
$p^+K^-\pi^+$	$1,182,781 \pm 1,351$

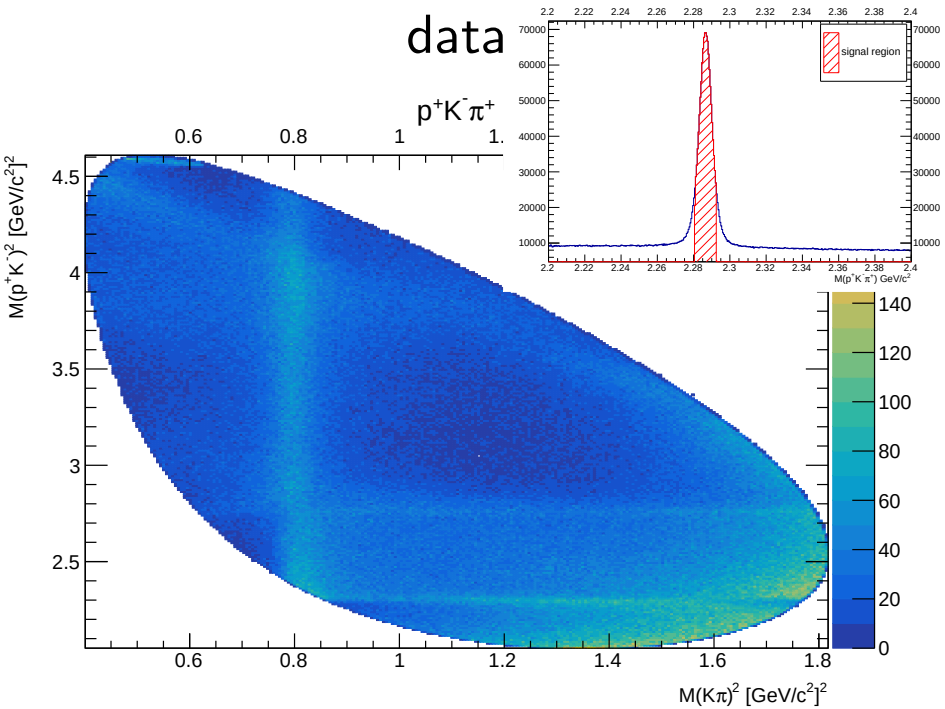
Signal: red, background: green, misreconstructed: black, $\Lambda^0\pi^+\pi^0 + \gamma$: violet

$p^+K^-\pi^+$ PDG 2016 MC vs data

PDG 2016 MC



data



Data MC discrepancies

Model independent extraction of signal yield

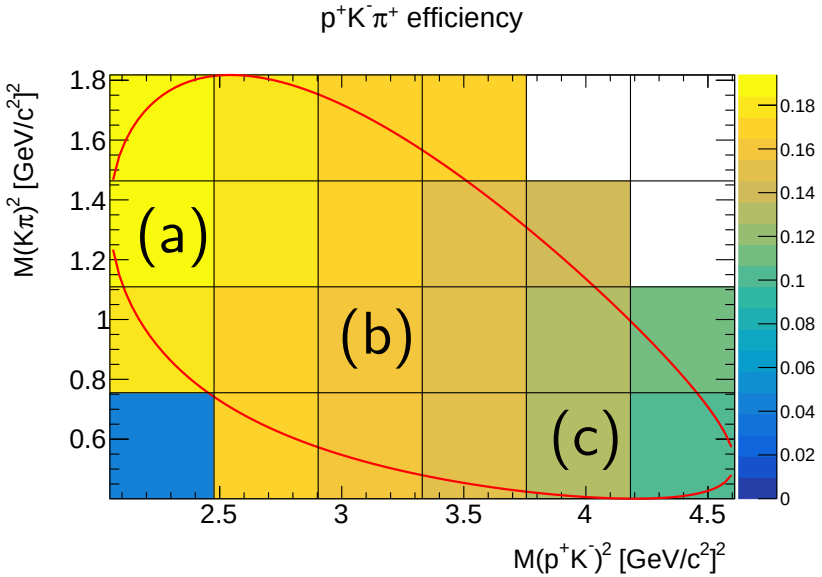
$p^+K^-\pi^+$

Efficiency Corrected yield

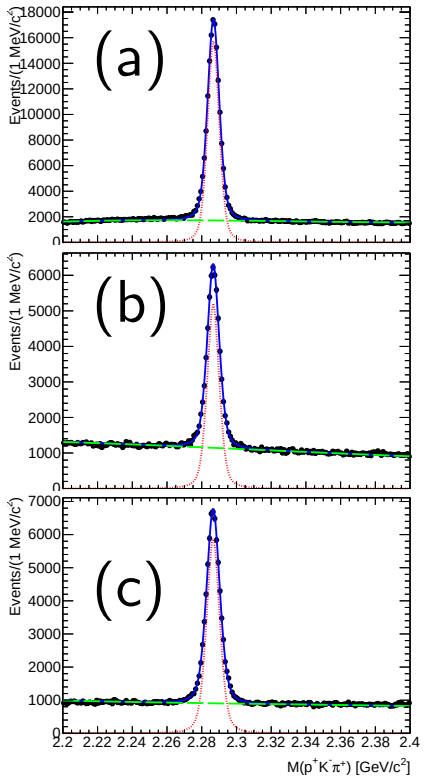
$$y_{data}^{corr} = \sum_i^n \frac{y_i}{\epsilon_i}, \quad \frac{y_{PDG}^{corr}}{y_{data}^{corr}} = 1.05$$

21 bins, ϵ_i^{min}=0.1, ϵ_i^{max}=0.19

Comp. with 75 bins $\rightarrow$ Syst.



$p^+K^-\pi^+$ mass distribution



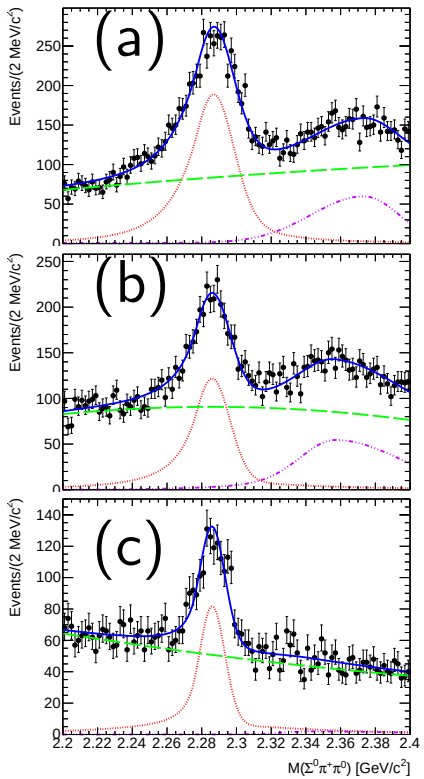
Model independent extraction of signal yield

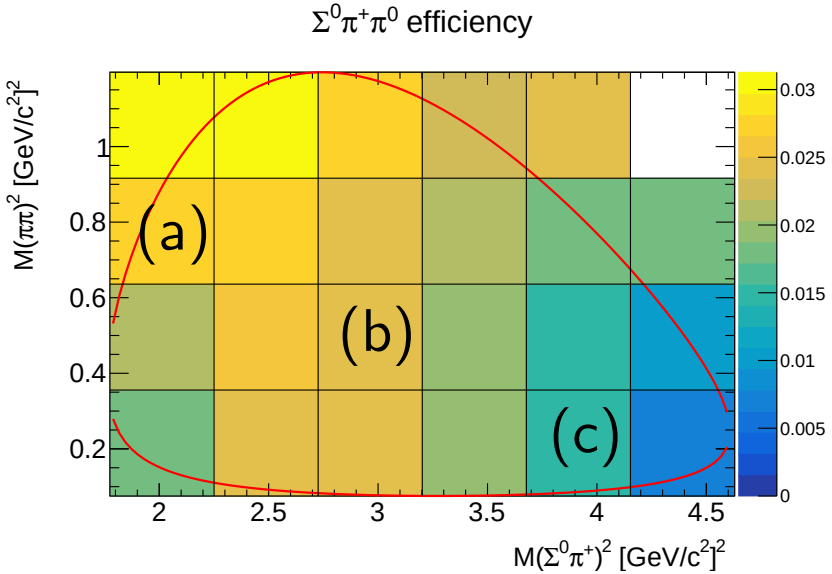
$\Sigma^0\pi^+\pi^0$

Varying $\Lambda^0\pi^+\pi^0 + \gamma$ background

23 bins, ϵ_i^{min}=0.007, ϵ_i^{max}=0.03
Comp. with 83 bins $\rightarrow$ Syst.

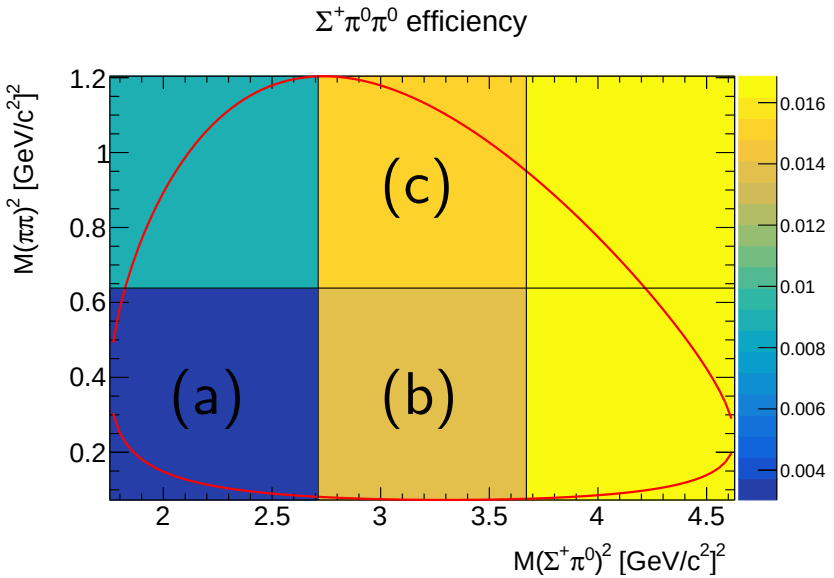
$\Sigma^0\pi^+\pi^0$ mass distribution



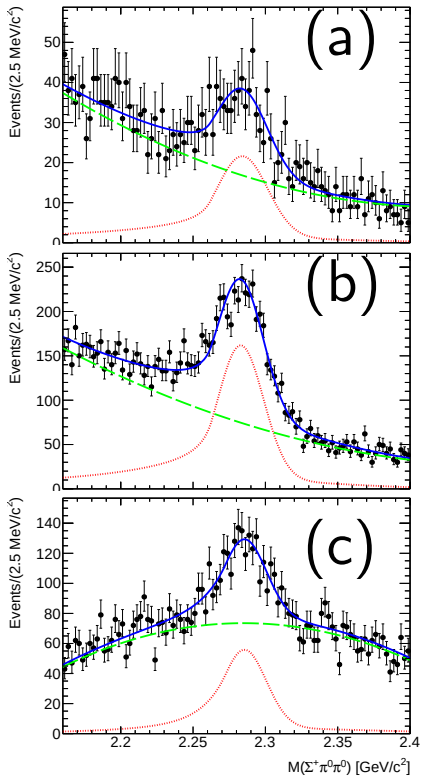


Model independent extraction of signal yield
$\Sigma^+\pi^0\pi^0$

Reduced binning due to lacking statistics.
6 bins, ϵ_i^{min}=0.003, ϵ_i^{max}=0.017
Comp. with one bin $\rightarrow$ Syst.



$\Sigma^+\pi^0\pi^0$ mass distribution



Systematic Errors

Systematic studies

π^0: $\tau^- \to \pi^- \pi^0 \nu_\tau$ Λ^0: $B \to \Lambda \bar{\Lambda} K^+$

K π: $D^{*+} \to D^0 \pi^+$, $D^0 \to K^- \pi^+$ PDF: toy MC

Source	$\Delta y(\Sigma^+\pi^+\pi^-)$	$\Delta y(\Sigma^+\pi^0\pi^0)$	$\Delta y(\Sigma^0\pi^+\pi^0)$	$\Delta y(pK\pi)$
Pdf Model	1.3	3.1	1.84	1.04
Dalitz structure	0.3	2.4	0.7	0
Proton identification	0.42	0.39	0.39	0.47
K π identification	2.2		3.1	1.64
Tracking	0	0	0	0.7
Λ identification			2.68	
π^0 identification	2.44	6.8	2.27	
MC statistics	0.1	0.6	0.3	0
$\mathcal{B}_{\mathrm{PDG}}$	0.3	0.3	0.5	
Total	4.38	8.02	5.15	2.64

Preliminary $\mathcal{B}$ results

Errors are in order stat., sys. and $(\mathcal{B}(pK\pi))$.

Final state	$\mathcal{B}(\Sigma\pi\pi)/\mathcal{B}(pK\pi)$	$\mathcal{B}(\Sigma\pi\pi)$ [%] [1]	$\mathcal{B}_{PDG}(\Sigma\pi\pi)$ [%]
$\Sigma^+\pi^+\pi^-$	$0.706 \pm 0.003 \pm 0.036$	$4.48 \pm 0.02 \pm 0.23 \pm 0.23$	4.57 ± 0.29
$\Sigma^0\pi^+\pi^0$	$0.491 \pm 0.005 \pm 0.028$	$3.12 \pm 0.03 \pm 0.18 \pm 0.16$	2.3 ± 0.9
$\Sigma^+\pi^0\pi^0$	$0.198 \pm 0.006 \pm 0.017$	$1.26 \pm 0.04 \pm 0.11 \pm 0.07$	-

$\mathcal{B}(\Sigma^+\pi^+\pi^-)$ is compatible with the current world average,
$\mathcal{B}(\Sigma^0\pi^+\pi^0)$ is the most precise measurement to date and
$\mathcal{B}(\Sigma^+\pi^0\pi^0)$ is measured for the first time
(min $-ln\mathcal{L} = -509,532$ vs. $-54,768.3$ for only background).

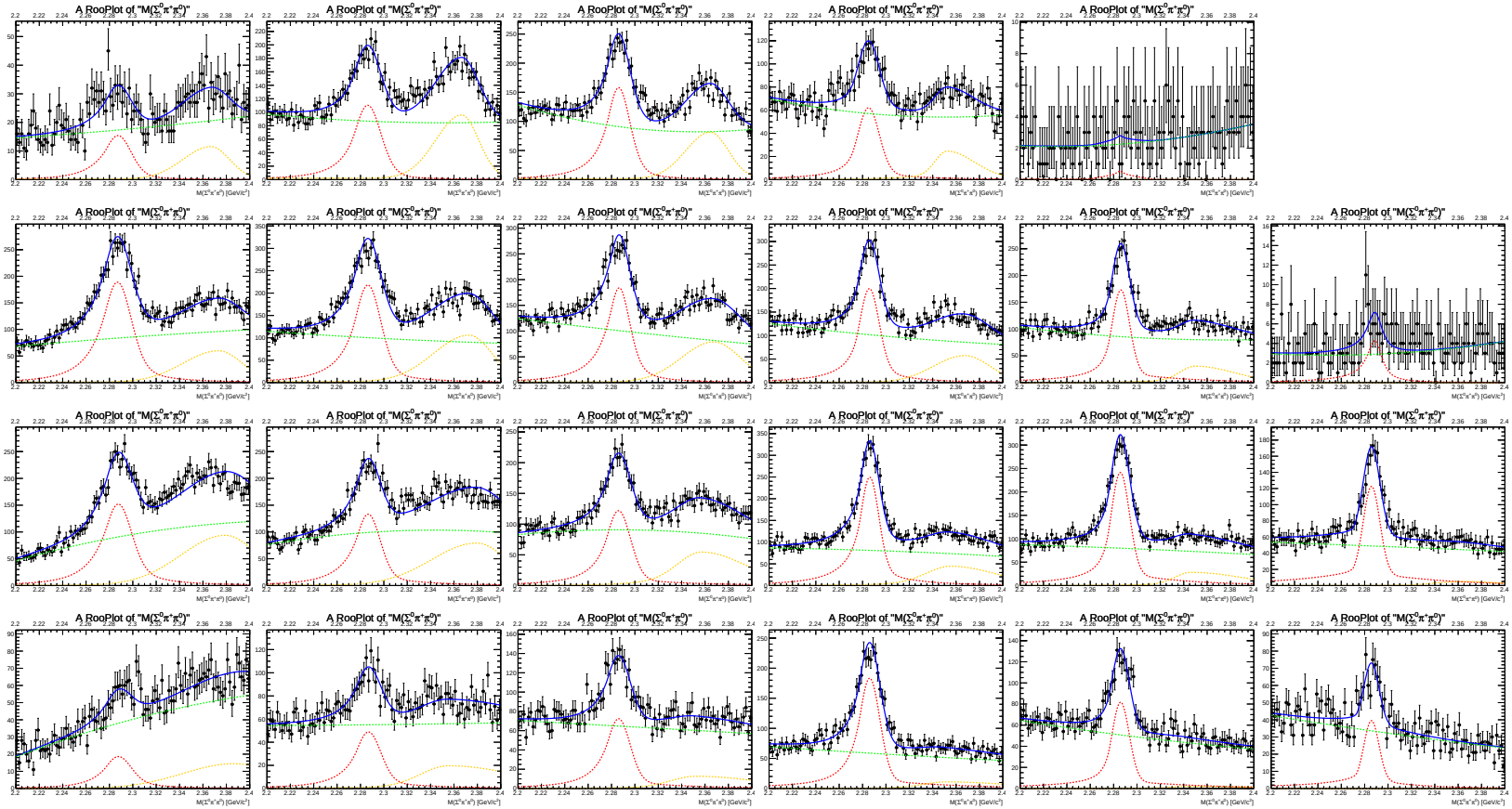
[1] Using $\mathcal{B}(pK\pi) == 6.35 \pm 0.33$

Summary and outlook

- We analyze weak $\Lambda_c \to \Sigma\pi\pi$ decays.
- A proper binning is introduced to the Dalitz plane in order to arrive at the reconstruction efficiency in a model independent way.
- Branching fractions for $\Sigma^+\pi^+\pi^-$,$\Sigma^+\pi^0\pi^0$ and $\Sigma^0\pi^+\pi^0$ have been measured.
- Next step:
  - PWA $pK\pi - \Sigma\pi\pi$ coupled channel analysis.
  - $\Sigma\pi$ scattering lengths analysis.
  - $\Lambda(1405)$ pole position analysis, $\Lambda(1670)$...

Backup

Binned fits
$M(\Sigma^0\pi^+\pi^0)$



Efficiency estimation

$\Sigma^+\pi^-\pi^+$