DRgen:
MC generator for central exclusive production

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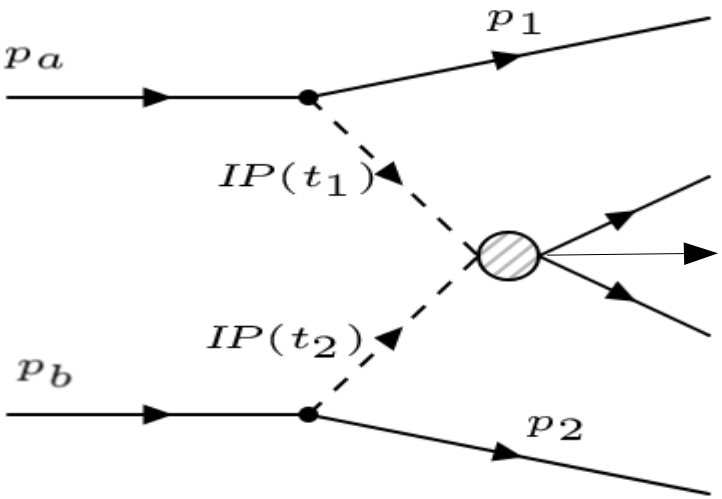
Introduction

- Central Exclusive Production (CEP) of hadron states in pp collisions has a big interest from physicists community;
- These processes were studied recently at SPS, Tevatron, LHC and other facilities;
- Different techniques are used for study such processes: detection of forward protons, Large Rapidity Gaps, …
- In such processes two protons interact via vacuum quantum numbers exchange in t-channel and produce hadron systems, including resonances.



ππ-, KK-continuum, … resonances

Introduction (2)

- Multiple number of resonances interfering with continuum mass production makes observed mass spectrum to be complicated;
- It's not enough only to calculate isotropical decay efficiency to estimate production cross sections of the states;
- One needs to estimate efficiency of the state according to its spin, parity and polarisation or perform full-scale partial wave analysis (PWA) of the angular distributions which allows to measure all above mentioned parameters;
- Generator DRgen was developed in order to provide predefined angular distributions of the decay products of centrally produced system: such generator can be used for PWA needs and detection efficiency estimation of particular resonance states by experimentalists.

Example

- Many states should be treated properly in terms of efficiency:

TABLE I: Light meson states allowed in DIPE . Branching fractions are in %. (PDG 2016)

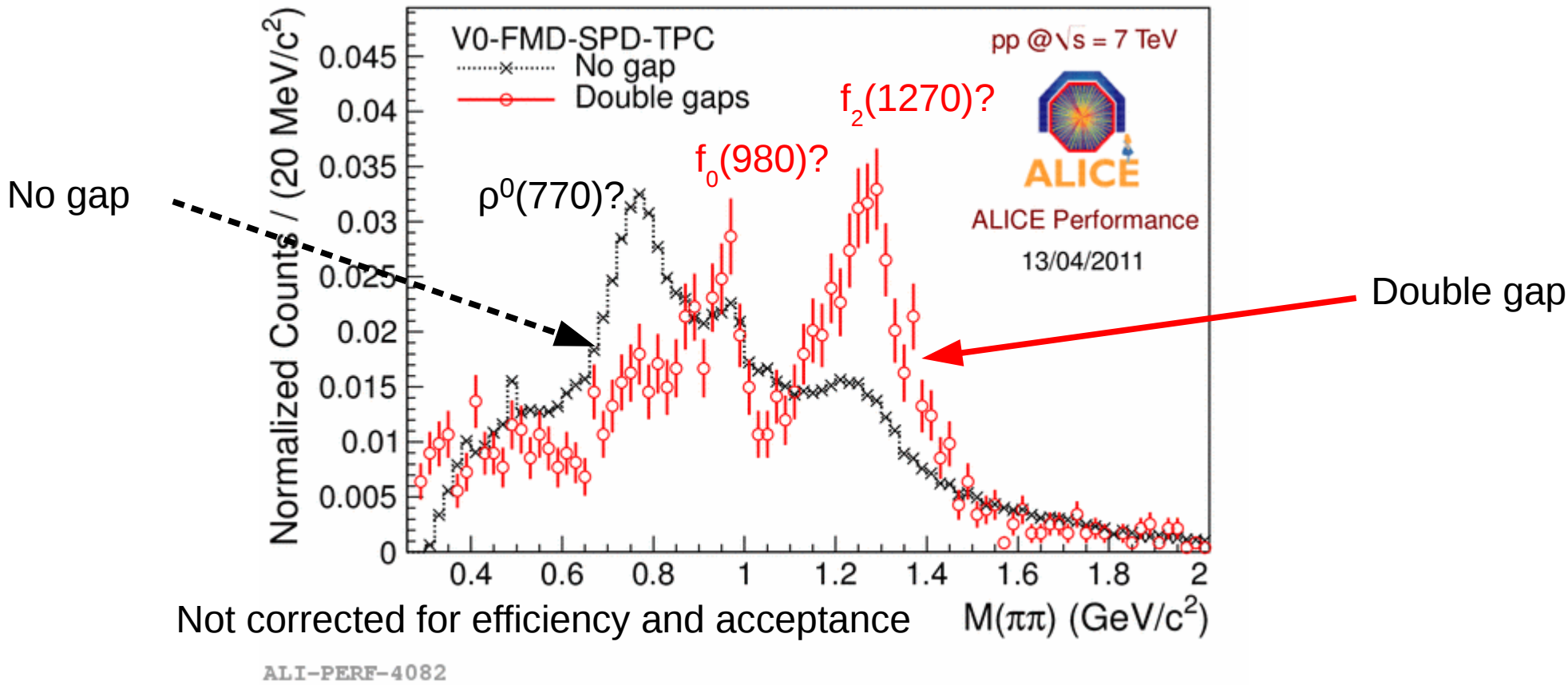
Name	M(MeV)	Γ(MeV)	$I^G J^{PC}$	$\pi\pi$	$K\bar{K}$	Other modes
$f_0(500)/\sigma$	400-550	400-700	0^+0^{++}	~100	-	-
$f_0(980)$	990±20	10-100	0^+0^{++}	dominant	seen	$\gamma\gamma$ seen
$f_2(1270)$	1275.5±0.8	$186.7^{+2.2}_{-2.5}3$	0^+2^{++}	$84.2^{+2.9}_{-0.9}$	$4.6^{+0.5}_{-0.4}$	$4\pi \sim 10\%$
$f_0(1370)$	1200-1500	200-500	0^+0^{++}	seen	seen	$\rho\rho$ dominant
$f_0(1500)$	1504±6	109±7	0^+0^{++}	34.9±2.3	8.6±1.0	4π 49.5±3.3
$f_2'(1525)$	1525±5	73^{+6}_{-5}	0^+2^{++}	0.8±0.2	88.7±2.2	$\eta\eta$ 10.4±2.2
$f_0(1710)$	1723^{+6}_{-5}	139±8	0^+0^{++}	seen	seen	$\eta\eta$ seen
$f_2(1950)$	1944±12	472±18	0^+2^{++}	seen	seen	$\eta\eta$ seen
$f_2(2010)$	2011^{+60}_{-80}	202±60	0^+2^{++}	-	seen	$\phi\phi$ seen
$f_4(2050)$	2018±11	237±18	0^+4^{++}	17%	~0.7%	$\eta\eta$ 0.2%
$f_2(2300)$	2297±28	149±40	0^+2^{++}	-	seen	$\phi\phi$ seen
$f_2(2340)$	2345^{+50}_{-40}	322^{+70}_{-60}	0^+2^{++}	-	-	$\phi\phi, \eta\eta$ seen

arXiv:1701.09092 [hep-ex] M. Albrow

Example (real experiment)

Mass of 2track double gap events, all tracks assumed to be pions

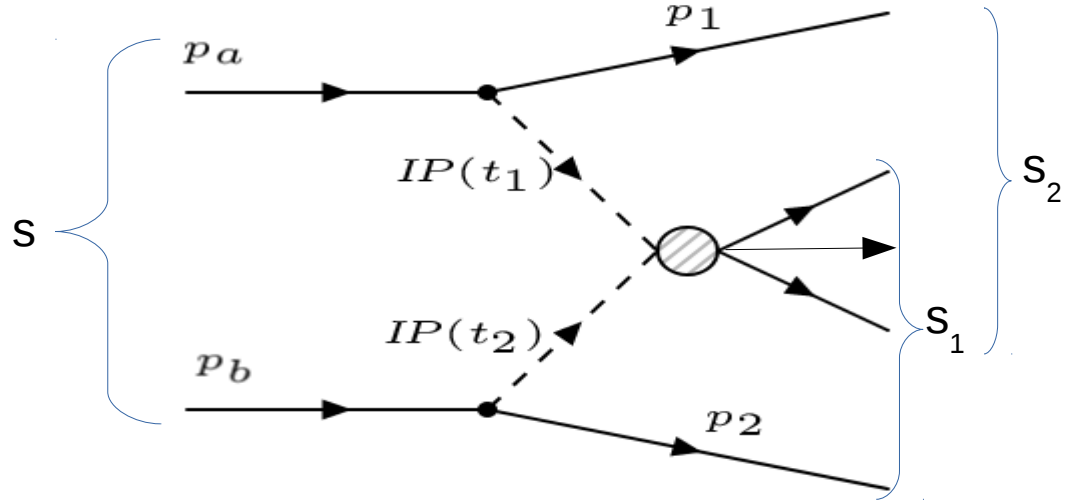
R. Schicker "Central diffraction in ALICE"
https://arxiv.org/pdf/1205.2588.pdf



- Partial Wave Analysis is needed to separate f_2 and f_0 states:
  - $f_0(980)$ spin 0 particle, isotropic decay;
  - $f_2(1270)$ spin 2 particle, can be polarised ← how to calculate efficiency?

Formalism

- In the Regge approach CEP is considered as Reggeon-Reggeon fusion



$z_{1,2} = \ln(s/s_{2,1})$

- Differential cross section is given by formula*

$$\frac{d\sigma}{dt_1 dt_2 dz_1 dz_2} = \frac{1}{4}\sigma_{RR}(M, t_1, t_2) g_{pR}^2(t_1) g_{pR}^2(t_2) e^{2z_1(\alpha_R(t_1)-1)} e^{2z_2(\alpha_R(t_1)-1)}$$

- Only reggeons with ε=α(0)-1>0 (Pomerons) survive at high energies:

$$\alpha_{IP}(t) = 1.08 + 0.25t$$

* M.R.Atayan et al., Z. Phys. C – Particles and Fields 50, 353-360 (1991)

Formalism (2)

- Parametrisations for p-IP vertex and IP-IP cross sections are given by* :

$$g^2_{pIP}(t) = g^2_{pIP}(0)e^{R_0^2 t}$$

$$\sigma_{IPIP}(M, t_1, t_2) = \sigma_{IPIP}(M, 0, 0)e^{R^2_{IP}(t_1+t_2)}$$

- Finally differential cross section is given by

$$\frac{d\sigma}{dt_1 dt_2 dz_1 dz_2} \propto \sigma_{IPIP}(M, 0, 0)\left(\frac{s}{s_1}\right)^{2(\epsilon_{IP}+\alpha'_{IP}t_2)}\left(\frac{s}{s_2}\right)^{2(\epsilon_{IP}+\alpha'_{IP}t_1)} e^{B(t_1+t_2)}$$

$$B = R_0^2 + R^2_{IP} + 2\alpha'_{IP} = 6 \pm 0.5 \text{ (GeV/c)}^{-2}$$

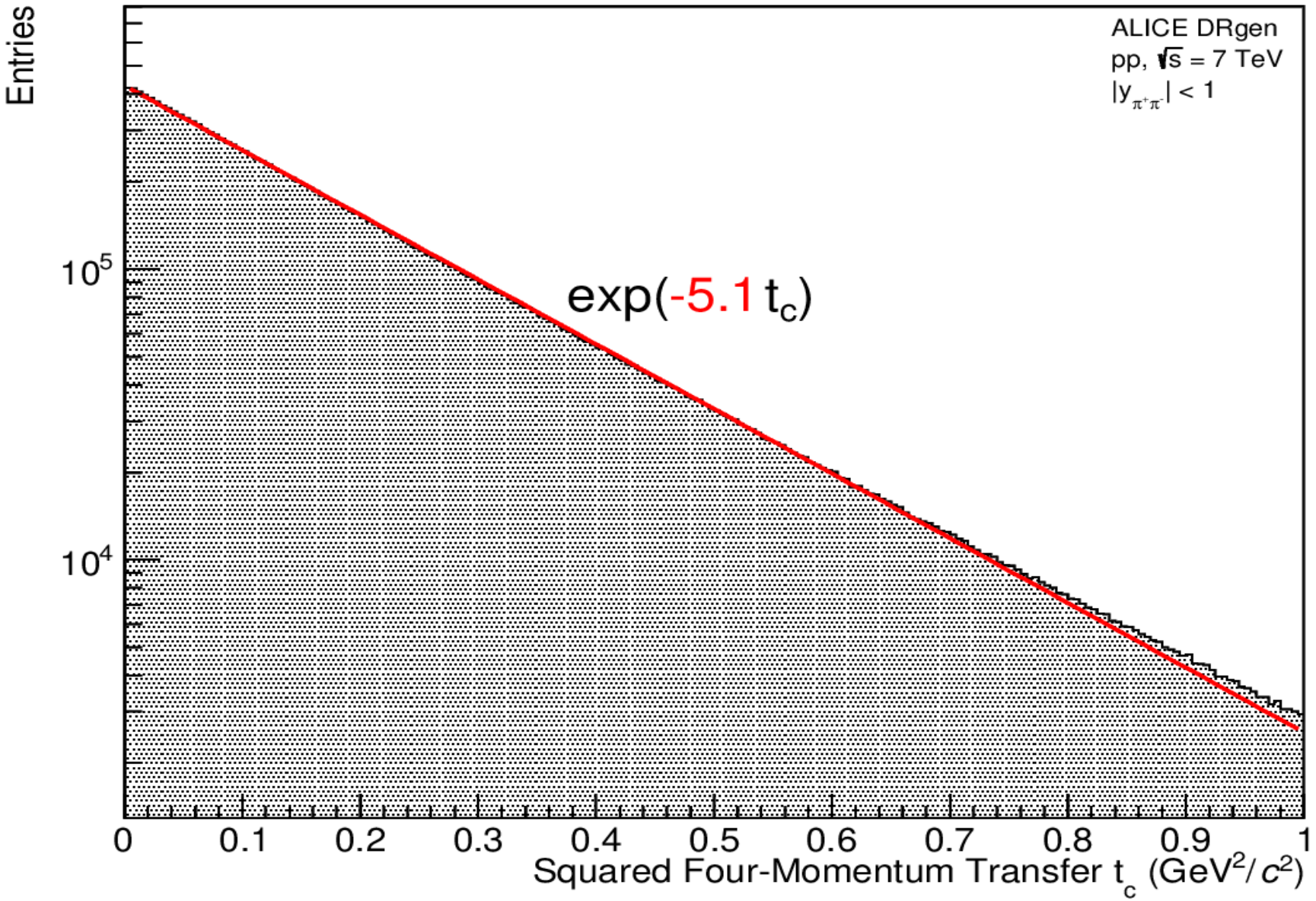
taken from *

* M.R.Atayan et al., Z. Phys. C – Particles and Fields 50, 353-360 (1991)

Realisation & Availability

- The generator's code is written using Fortran programming language by **D**mitri **R**yabchikov (**DR**gen);
- It was tuned and used for PWA of COMPASS experiment data;
- It was further tuned to be used at the LHC energies and integrated in AliRoot (computing framework for ALICE@LHC experiment) as C++ interface for Fortran library;
- AliRoot is publicly available:
  → https://github.com/alisw/AliRoot (source code)
  → https://alice-doc.github.io/alice-analysis-tutorial/ (instructions)
- No cuts on final state particles is applied: angular distribution is not affected ← essential condition for PWA

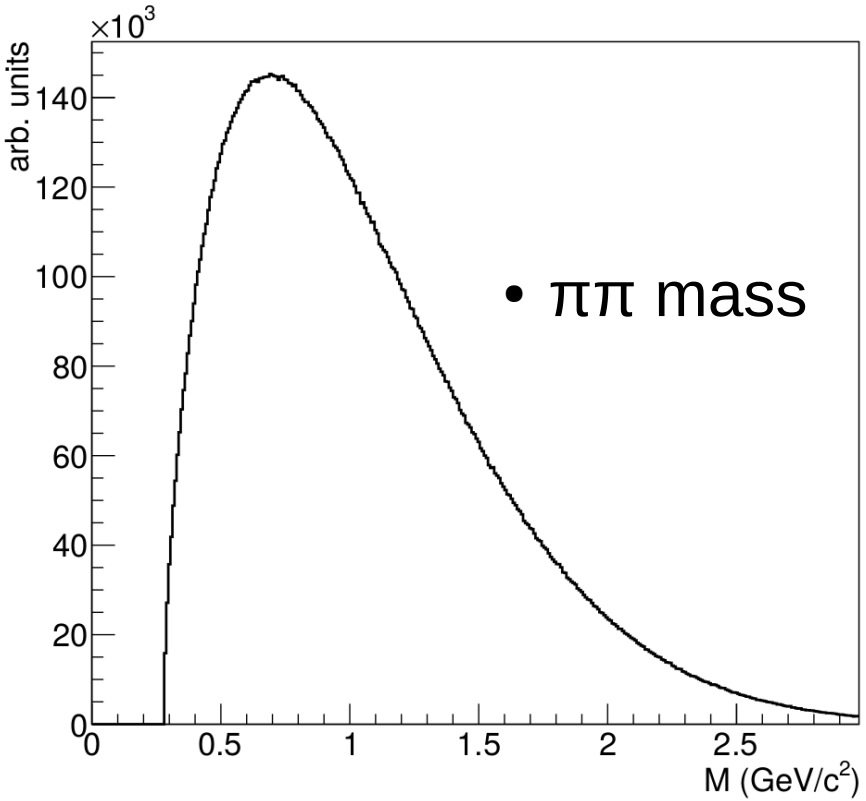
t-spectrum of Pomeron

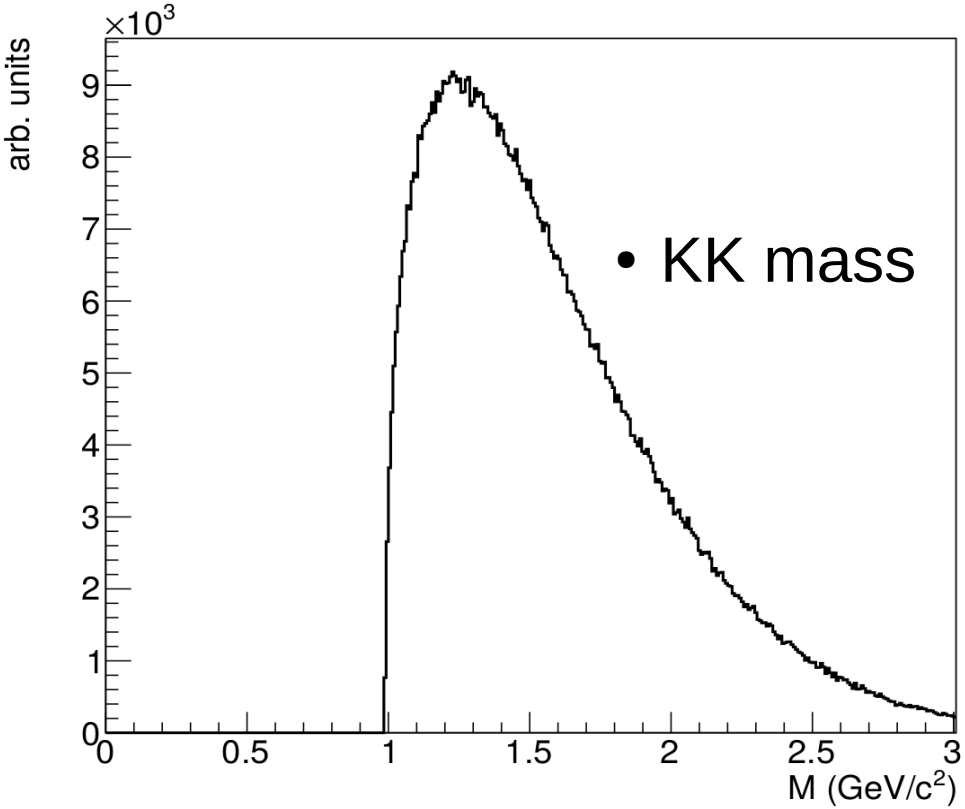


Continuum mass production

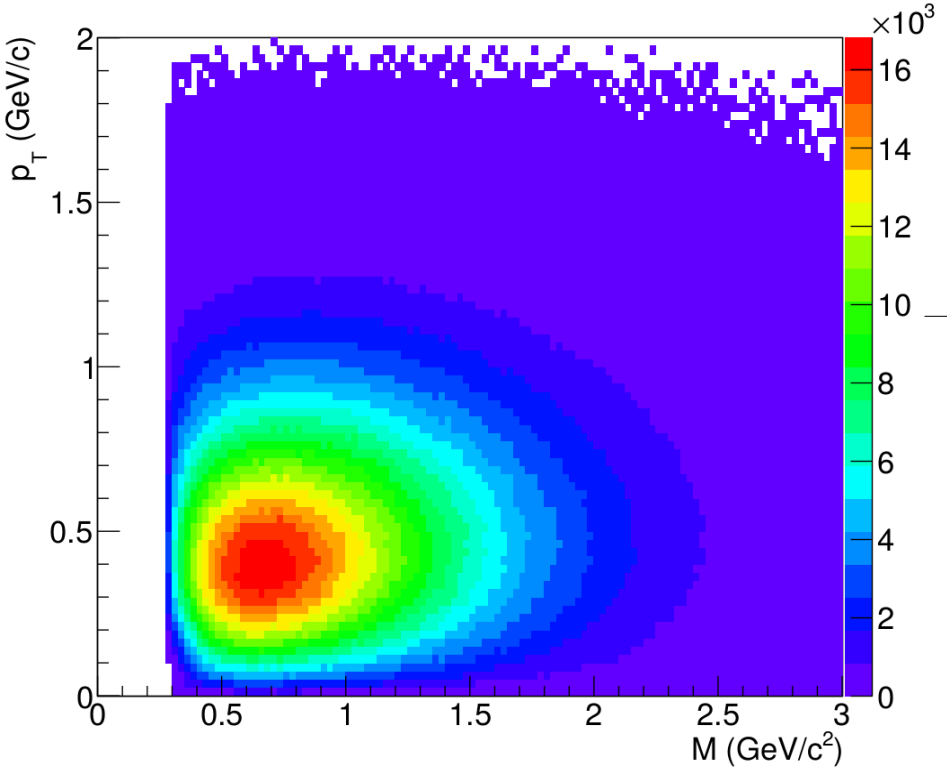
- Parametrisation for IP-IP cross section for ππ and KK channels are given by phase space volume:

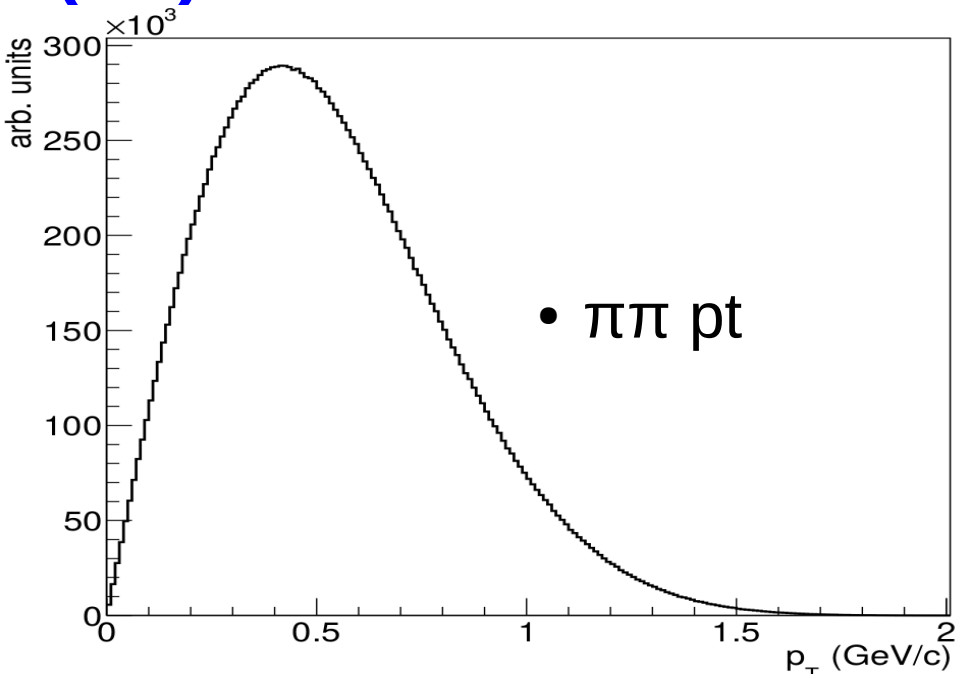
$$\sigma_{IPIP}(m_{\pi\pi},0,0) \sim \sqrt{1-\frac{4m_\pi^2}{m_{\pi\pi}^2}} \qquad \sigma_{IPIP}(m_{KK},0,0) \sim \sqrt{1-\frac{4m_K^2}{m_{KK}^2}}$$

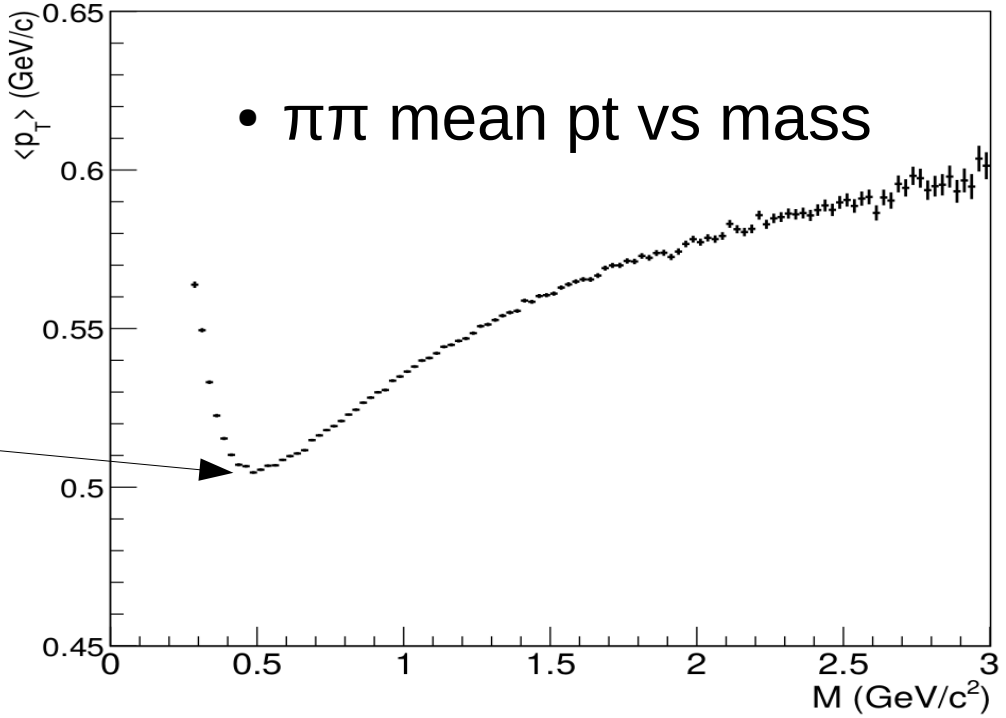




Pt vs mass (ππ)

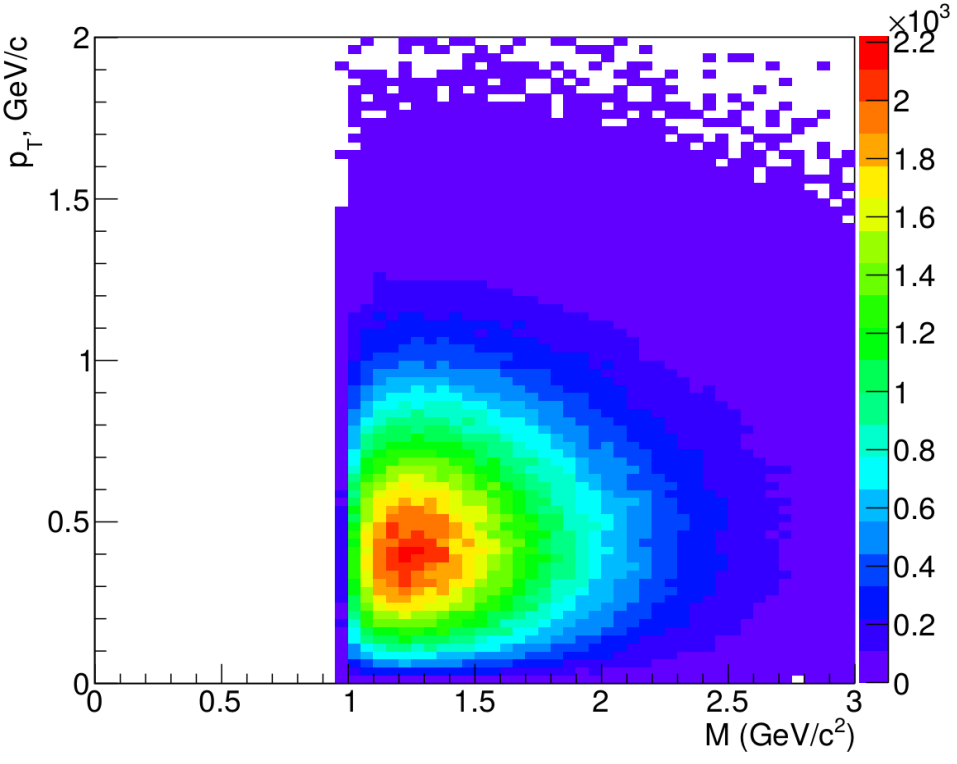


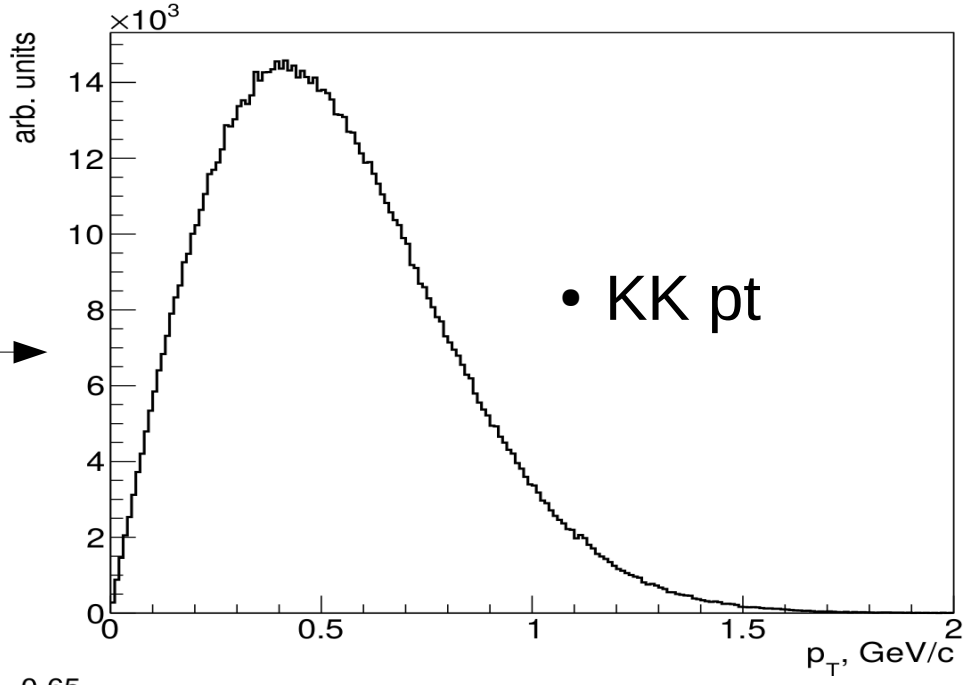




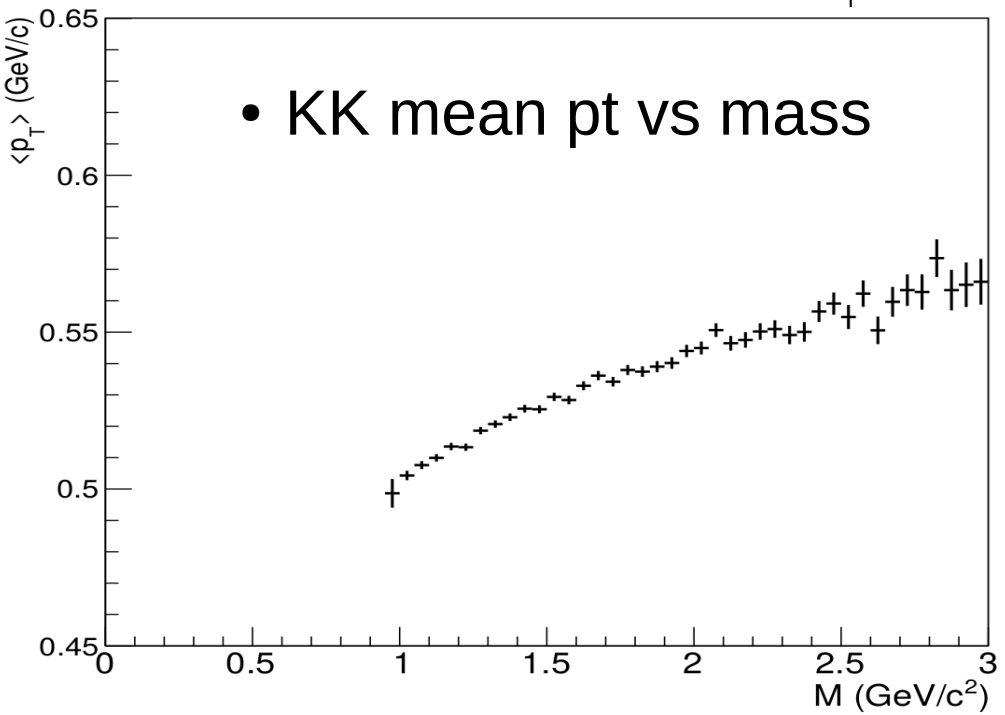
- Mean Pt predicted to be at level of 0.5-0.6 GeV/c;
- Note drop in mean Pt at low masses ~0.5 GeV/c^2.

Pt vs mass (KK)

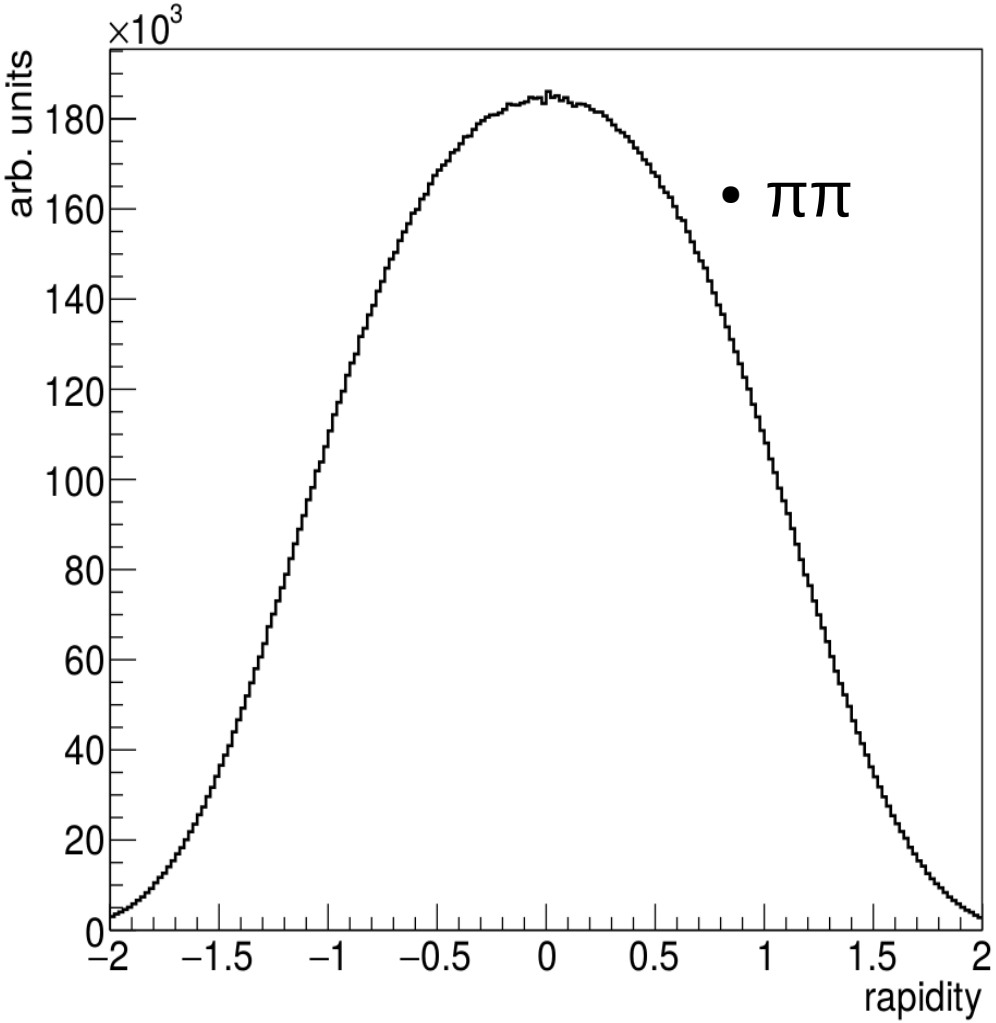


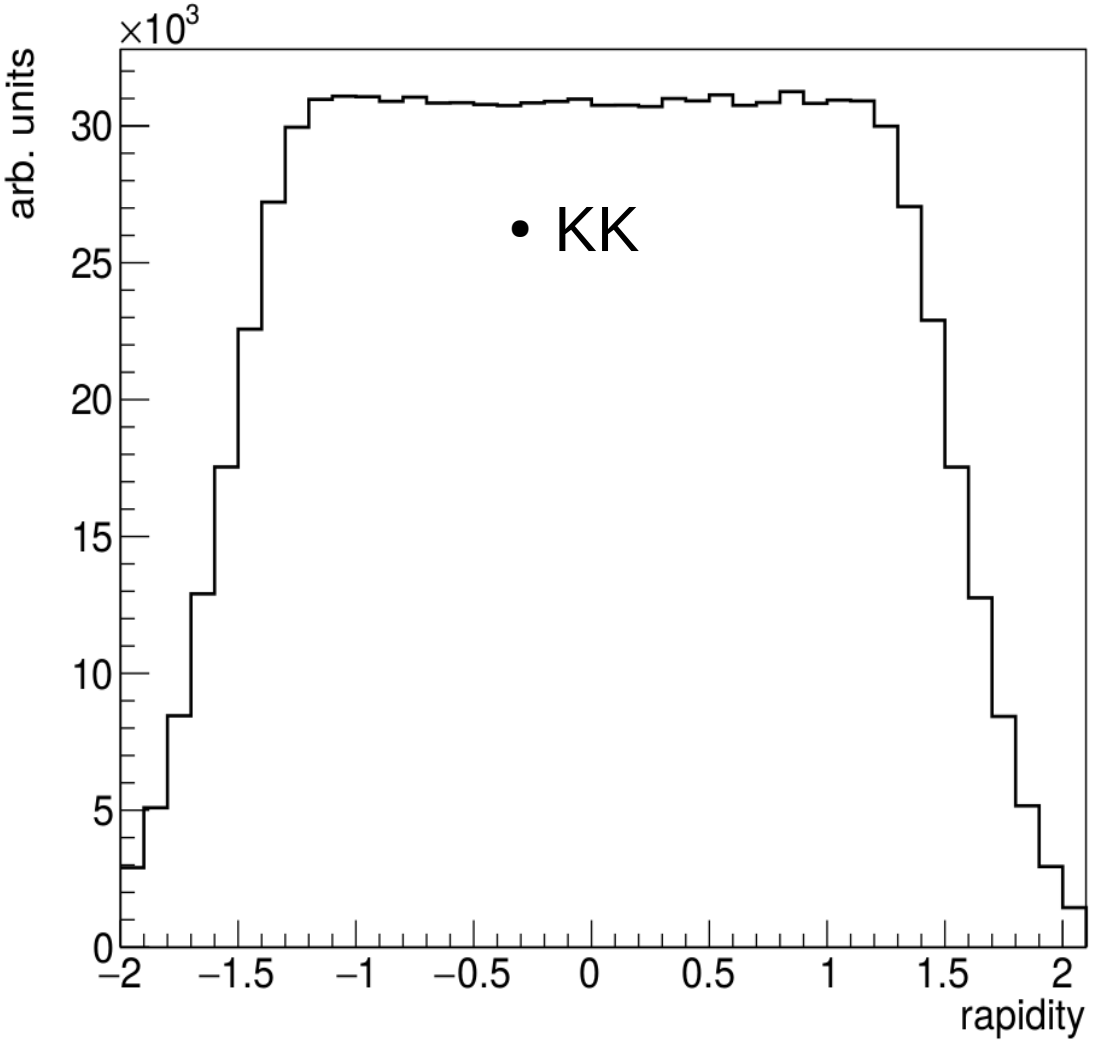


- Mean Pt predicted to be at level of 0.5-0.55 GeV/c;
- Mean Pt rises uniformly.

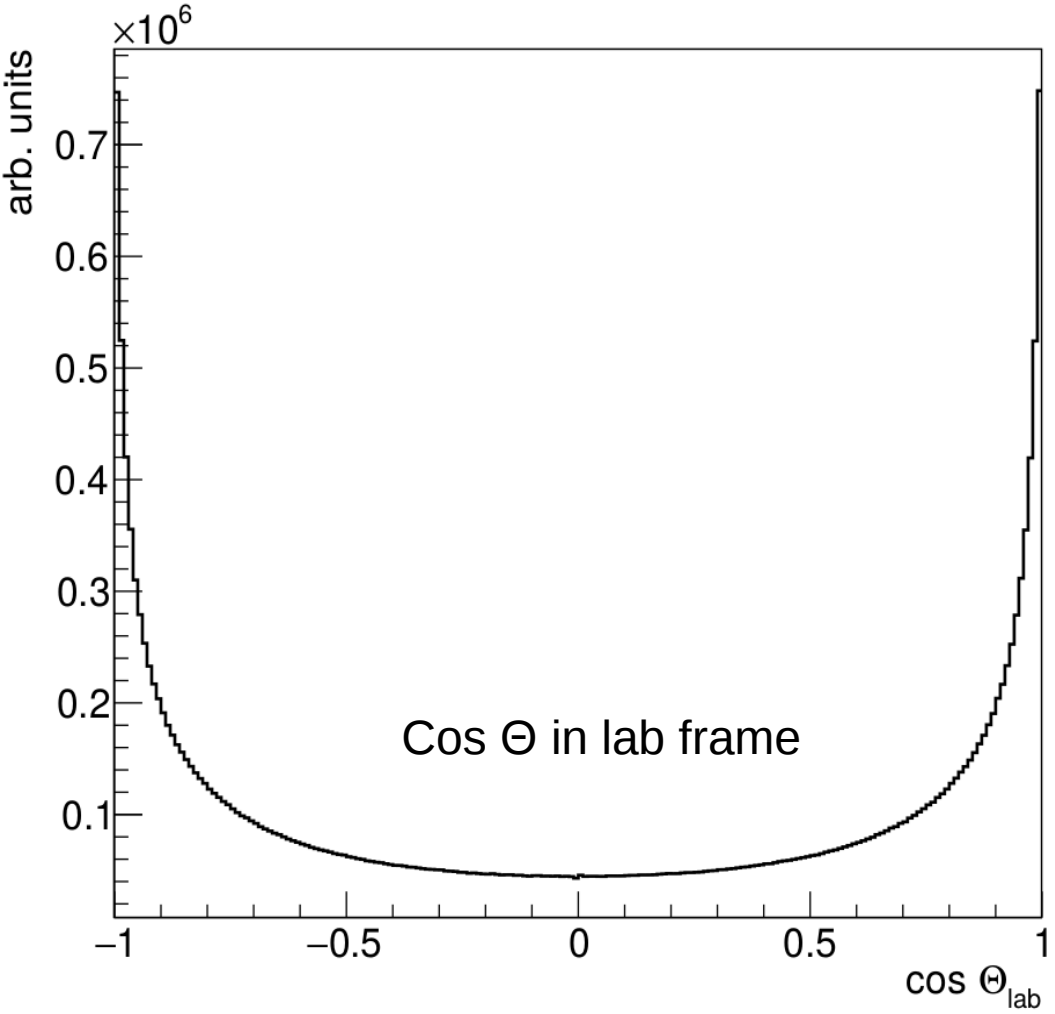


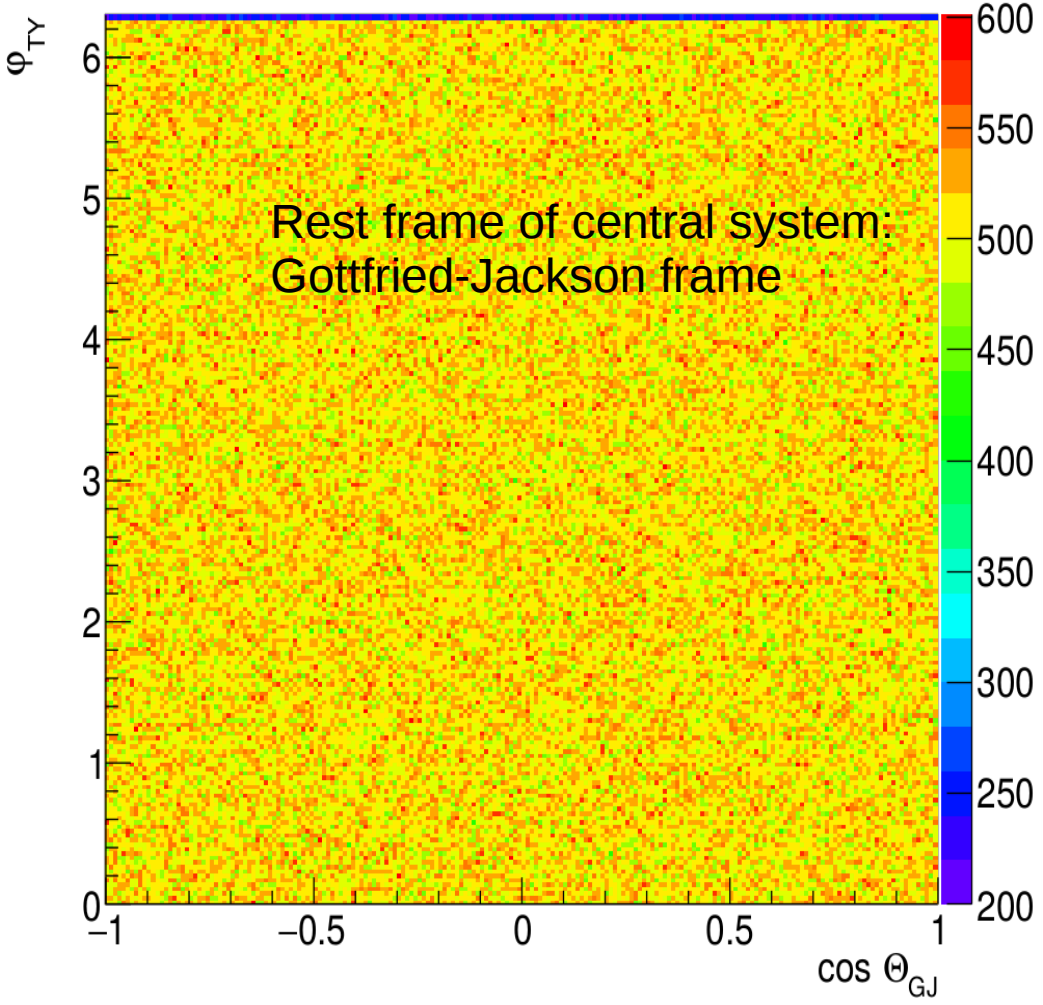
Rapidity distributions





Angular distributions





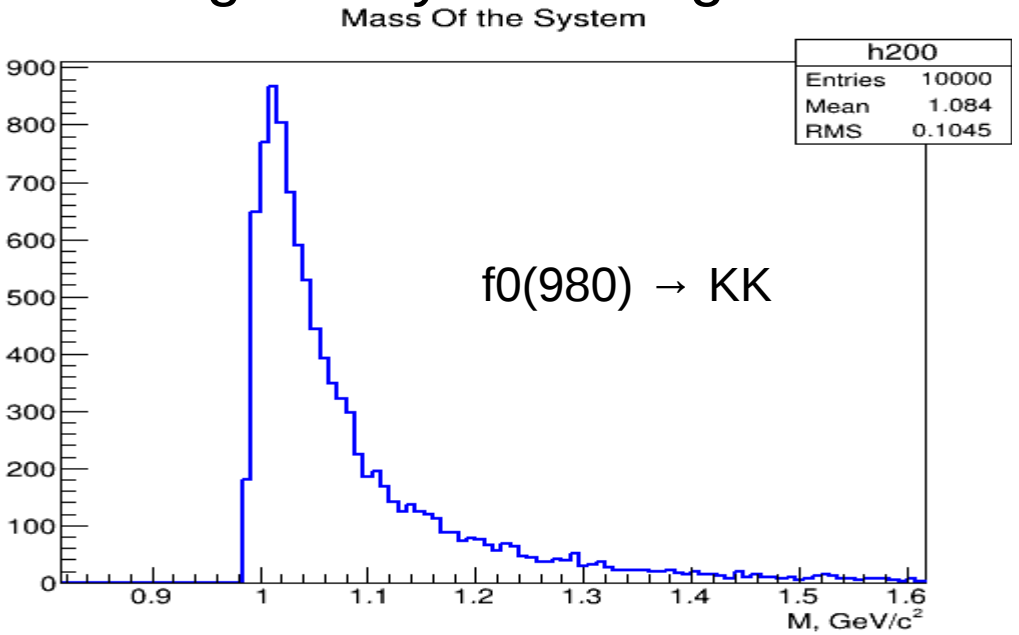
- The generator provides flat angular distribution in rest frame of central system;
- It can be used for PWA studies.

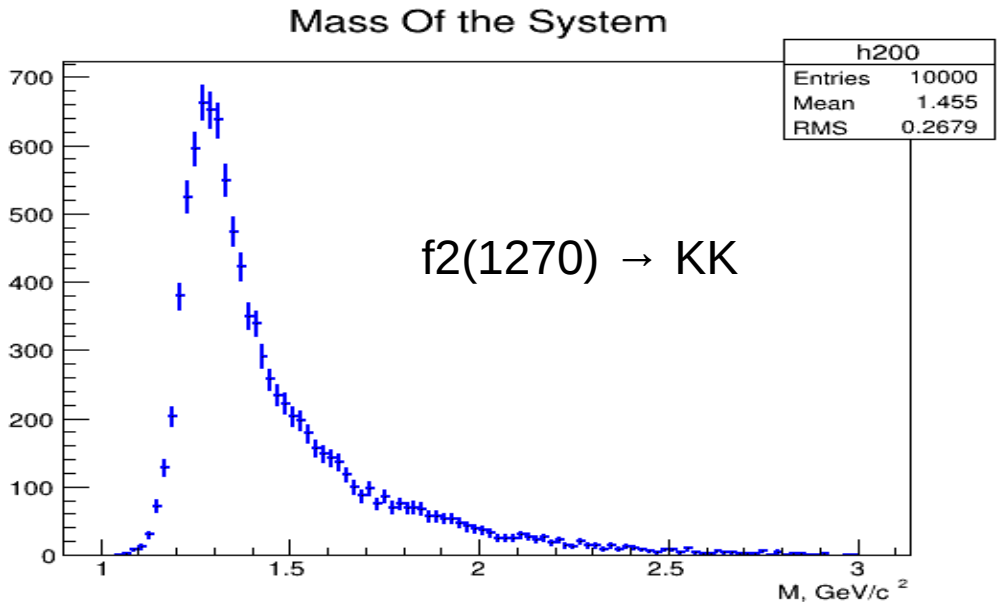
Resonance production

- Parametrisation for IP-IP cross section for ππ and KK channels are given by Breit-Wigner distribution;
- Angular distributions in the rest frame of resonance can be chosen by user (spin-0, spin-1, spin-2) according to polarisation;
- As polarisation is not known, it must be setted up by user;

Resonance production

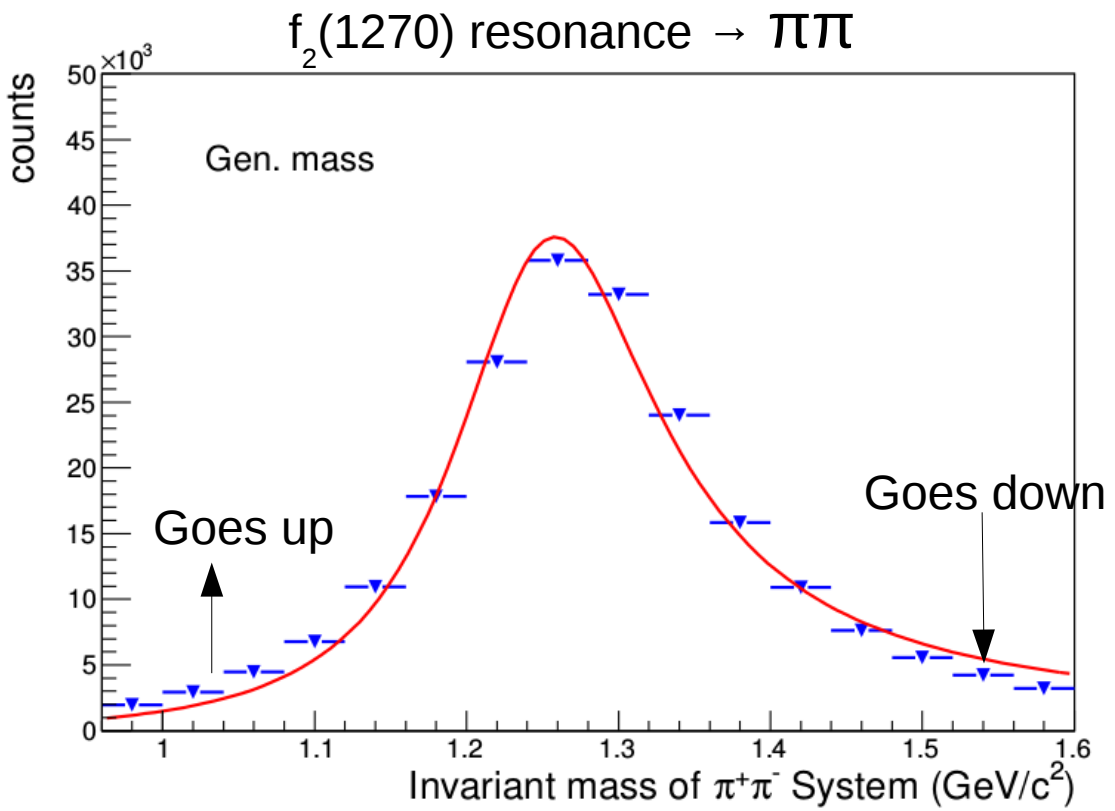
- Parametrisation for IP-IP cross section for ππ and KK channels are given by Breit-Wigner distribution





Change of resonance shape

- Breit-Wigner shape is distorted by IP-IP flux:
  $f_2(1270)$ obtains shifted mass position and becomes more narrow



	Mass, MeV	Width, MeV
Parameters used in MC → PDG	1275.5	185.9
Fit results	1255±1	167±1

Conclusion

- **DRgen**: IP-IP fusion generator for ππ and KK channels developed for Partial Wave Analysis needs;
- Based on Regge approach;
- Produces reasonable kinematic distributions;
- Can produce different angular distribution → suitable for efficiency estimation in experiments;
- The generator was successfully used for PWA in COMPASS experiment;
- The generator is integrated in AliRoot and now being exploited for PWA in ALICE experiment.