National Research Center «Kurchatov Institute»

Institute for High Energy Physics named by A.A.Logunov of NRC «Kurchatov Institute»

Search for properties modification of nuetral mesons in nuclear matter at Hyperon-M experiment at U-70 accelerator

Hyperon-M collaboration:

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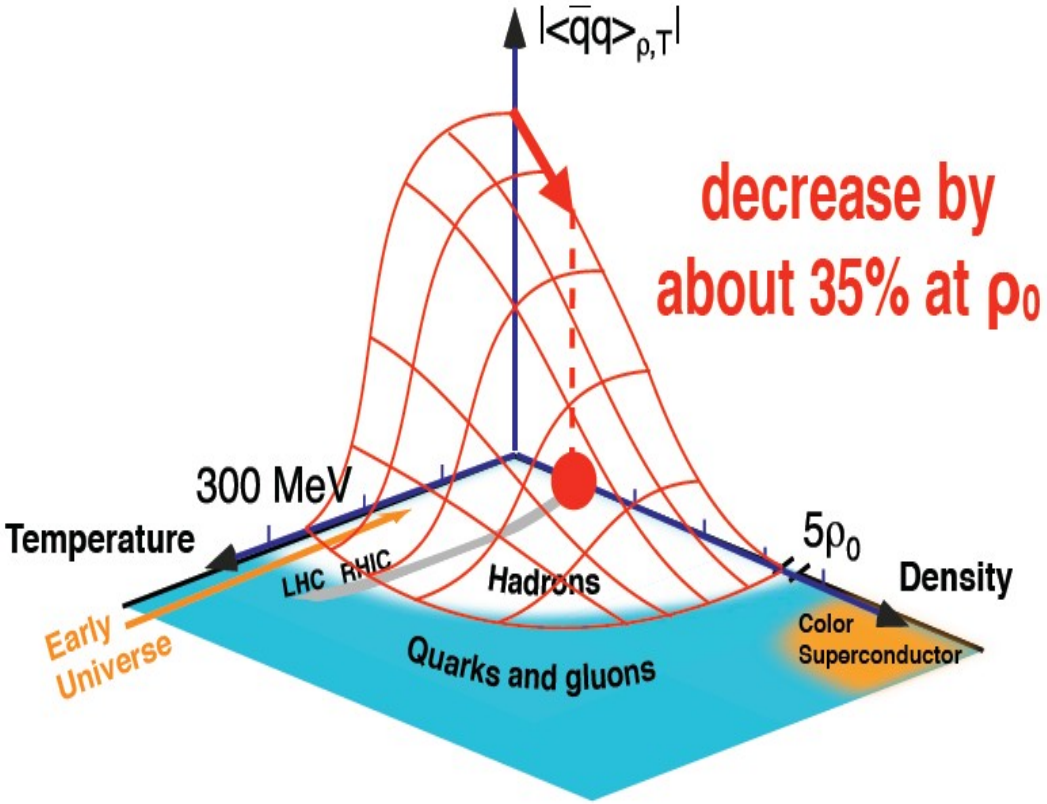
Motivation



$$\frac{\langle \bar{q}\, q \rangle_{T,\rho}}{\langle \bar{q}\, q \rangle_0} = 1 - \frac{T^2}{8 f_\pi^2} - \frac{\sigma_N^2}{m_\pi^2 f_\pi^2}\,\rho + \ldots$$

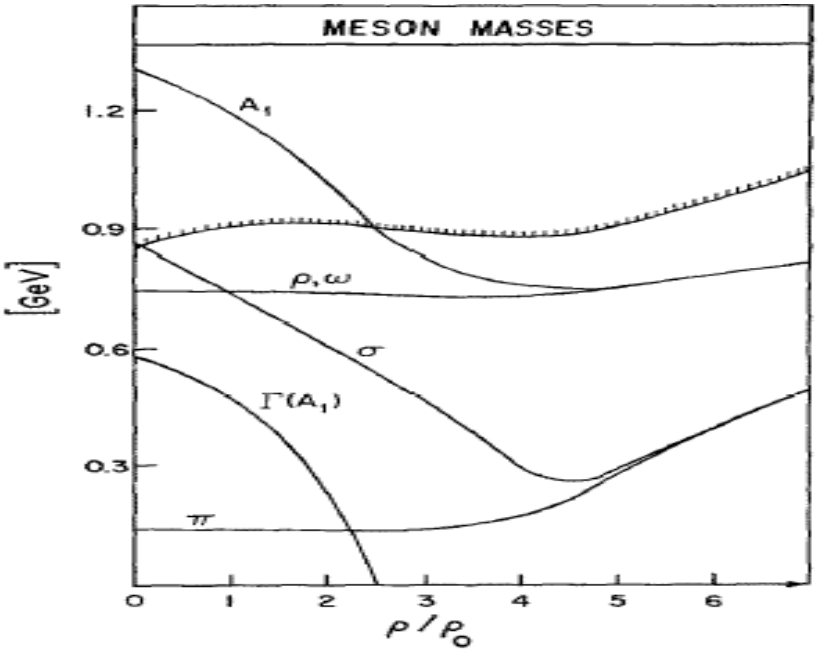
- Quark-antiquark condensate is decreased by ~35% in cold nuclear matter (T=0, ρ/ρ_0=1).

- Gell-Mann – Ox – Renner relation (GOR)

$$f_\pi^2 m_\pi^2 \simeq -2(m_u + m_d)\langle \bar{q}\, q \rangle + O(m_q^2)$$

$\langle \bar{q}q \rangle_0$ ~ -250 MeV ± 10%

- Predicted that meson properties such as masses are changing with increase of medium density

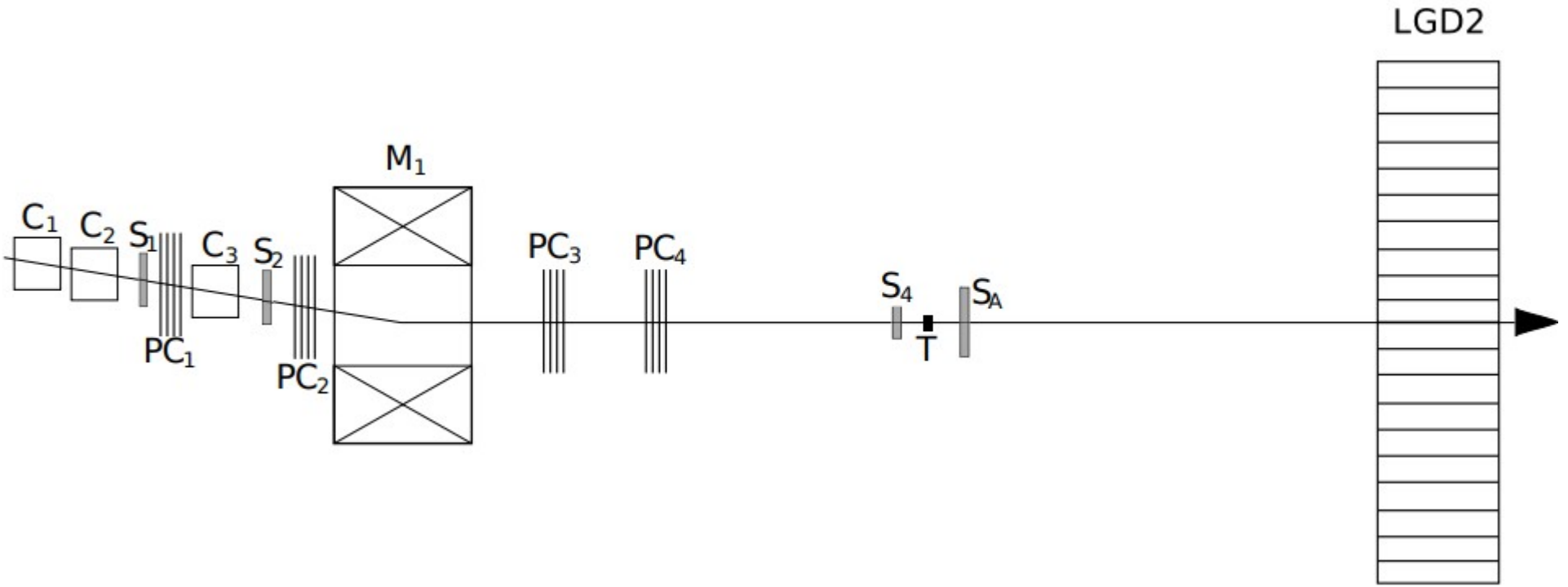


Motivation (2)

	M.Naruki et al., PRL 96 (2006) R. Muto et al., PRL 98 (2007)	T. Ishikawa et al., PLB608 (2005)	R.Nasseripour et al., PRL 99 (2007)	D. Trnka et al, PRL 94 (2005) M. Kotulla et al. PRL 100 (2008)	D. Adamova et al., PLB 666 (2008)	R. Arnaldi et al., PRL 96 (2006)
	KEK	**Spring8**	**Jlab**	**CBELSA TAPS**	**CERES**	**NA60**
reaction	**p A 12 GeV**	**γ A 1.5-2.4 GeV**	**γ A 0.6-3.8 GeV**	**γ A 0.7-2.5 GeV**	**Au+Au 158 AGeV**	**In+In 158 AGeV**
momentum acceptance	**p > 0.5 GeV/c**	**p > 1.0 GeV/c**	**p > 0.8 GeV/c**	**p > 0.0 GeV/c**	**p_t > 0.0 GeV/c**	**p_t > 0.0 GeV/c**
ρ	$\frac{\Delta m}{m} = -9\%$ $\Delta\Gamma \approx 0$		$\Delta m \approx 0$ $\Delta\Gamma \approx 70\,MeV$ $(\rho \approx \frac{\rho_0}{2})$		**broadening favoured over density dependent mass shift**	$\Delta m \approx 0$ **strong broadening**
ω				$\Delta m \approx 0$ $\Delta\Gamma \approx 130\,MeV$ $(\rho \approx \rho_0)$		
φ	$\frac{\Delta m}{m} = -3.4\%$ $\frac{\Gamma_\phi(\rho_0)}{\Gamma_\phi} = 3.6$	$\Delta\Gamma \approx 60\,MeV$ $(\rho \approx \rho_0)$				

Existed measurements are in contradiction with each other so additional tests are needed

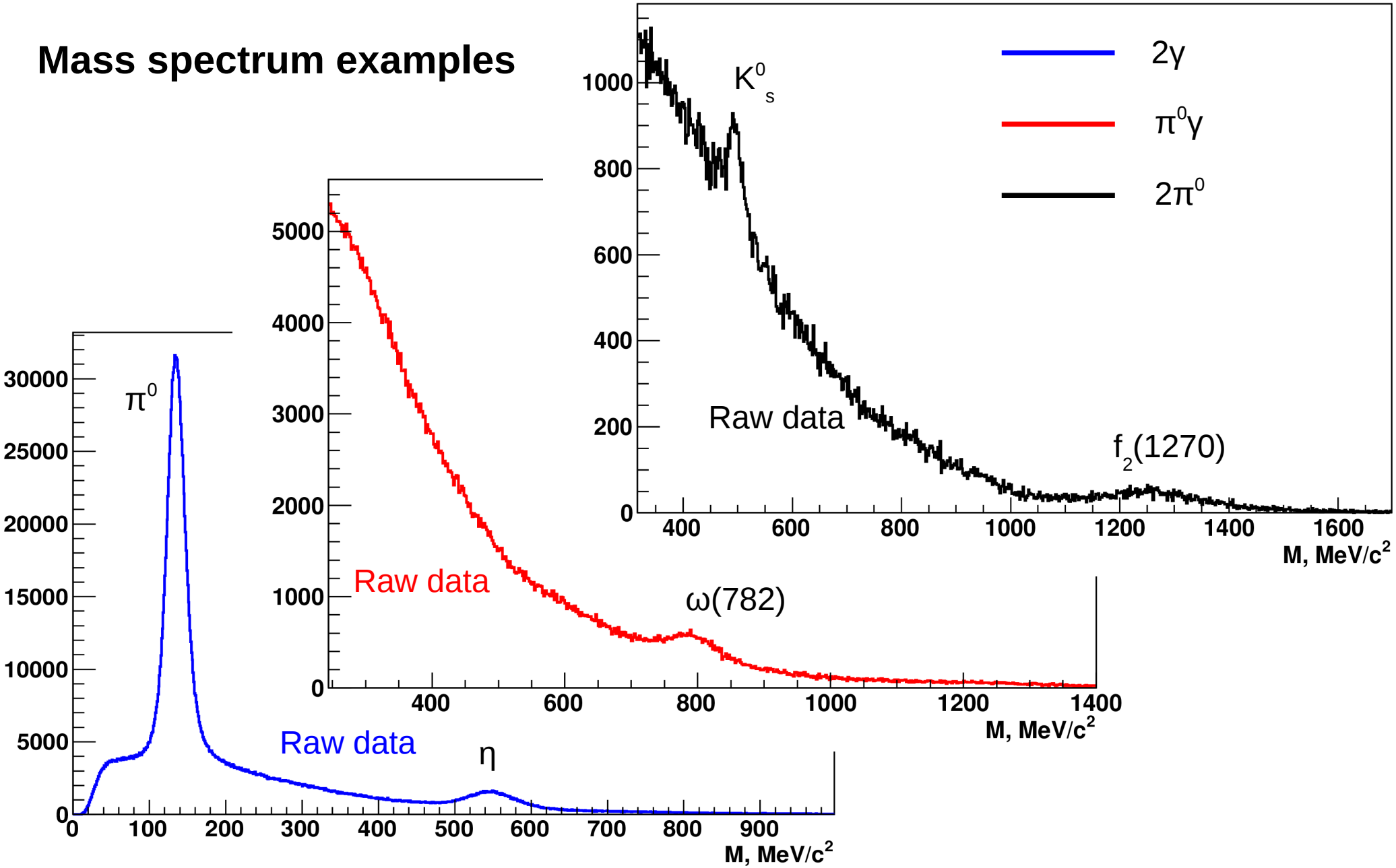
Hyperon-M experiment



- 7 GeV/c 60% π^+ + 35% p + 5%K^+ beam;
- Beam particles interact with target T (Be, C, Al, Cu, Sn, Pb) and produce secondaries;
- Scintillators trigger $S_1*S_2*S_4*!S_A$ selects events with neutral particles in electromagnetic calorimeter LGD2 (Lead Glass Detector);
- Neutral mesons decaying to ny final state;
- Gammas are detected by LGD2, mass spectrum of ny contains peaks of corresponding neutral mesons.

Hyperon-M experiment (2)

Mass spectrum examples



Parametric unfolding

- Spectral shape is spoiled by non-ideal apparatus and reconstruction:

$$g_{meas}(x_{meas}) = \int g_{true}(x_{true}) \times A(x_{true}, x_{meas})\, dx_{true}$$

- In general case the unfolding of spectral shape is incorrect task;
- If we know parametrization of spectral shape a priori then we can simplify the task:

$$g_{meas}(x_{meas}) = \int g_{true}(x_{true}, \vec{a}) \times A(x_{true}, x_{meas})\, dx_{true} = F(x_{meas}, \vec{a})$$

- **Solution of this task is following:**
  - **Find F(x,$\bar{a}$)** (several possibilities):
    - Parametrization of A(x,x)(if possible) → analytic integration
    - Numerical tabulation of A(x,x) with MC → numerical integration
    - Parametrization of F(x,$\bar{a}$) ← parametric unfolding
  - **Find parameters $\bar{a}$:** minimization of discrepancy between g_{meas} and F(x,$\bar{a}$) using some metrics (for example χ^2 fit).

Parametric unfolding (2)

Unfolding of Breit-Wigner distribution in case of neutral mesons decays:

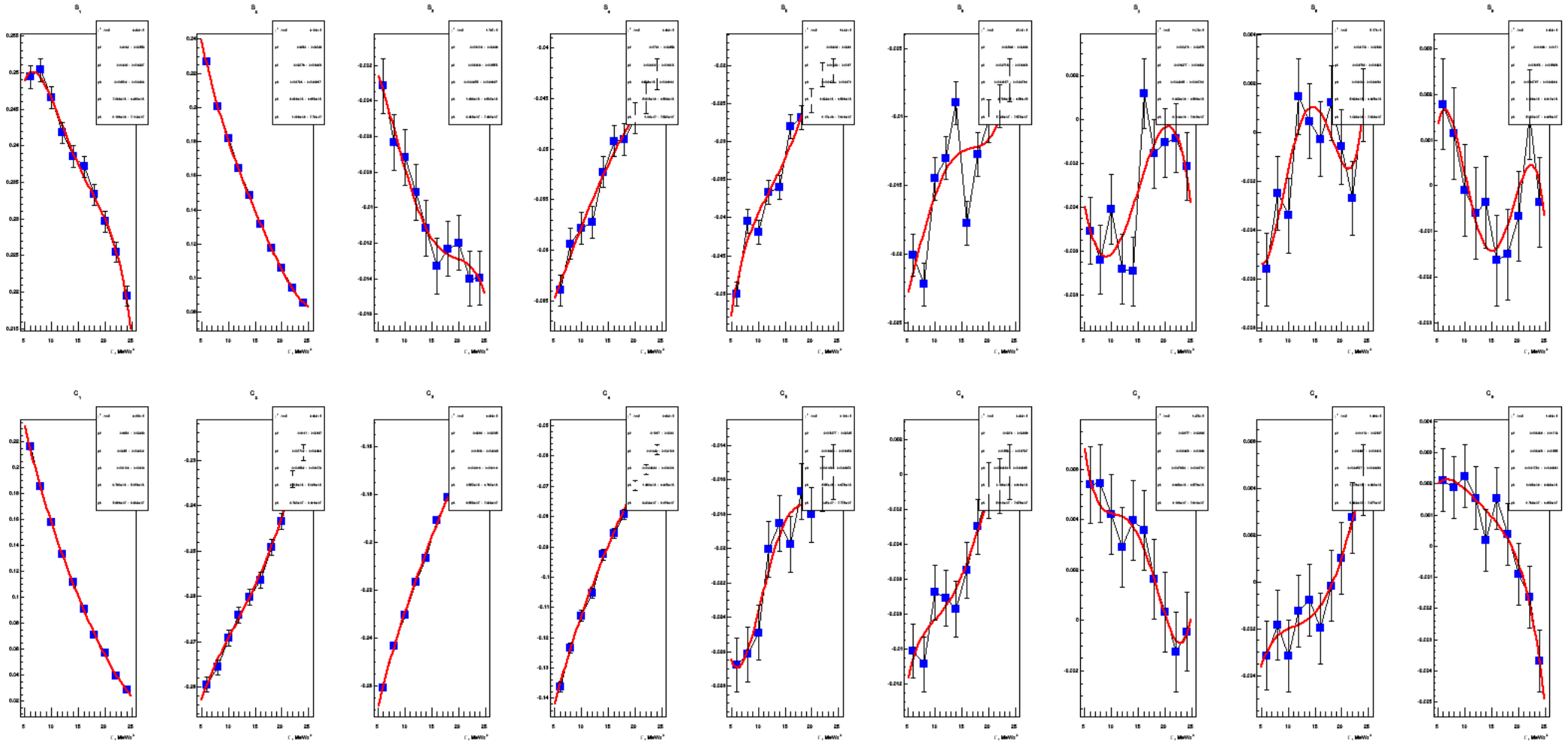
- Find F(x,$\vec{a}$):

$$F(x,\vec{a}) \equiv F(M, M_{res}, \Gamma_{res}) = BW(M, M_{res}, \Gamma_{res}) \times \left(1 + \sum_{i=1}^{N} s_i(\Gamma_{res}) \sin i\pi y + c_i(\Gamma_{res}) \cos i\pi y\right),$$

$$y = \frac{M - M_{res}}{fit\ range}$$

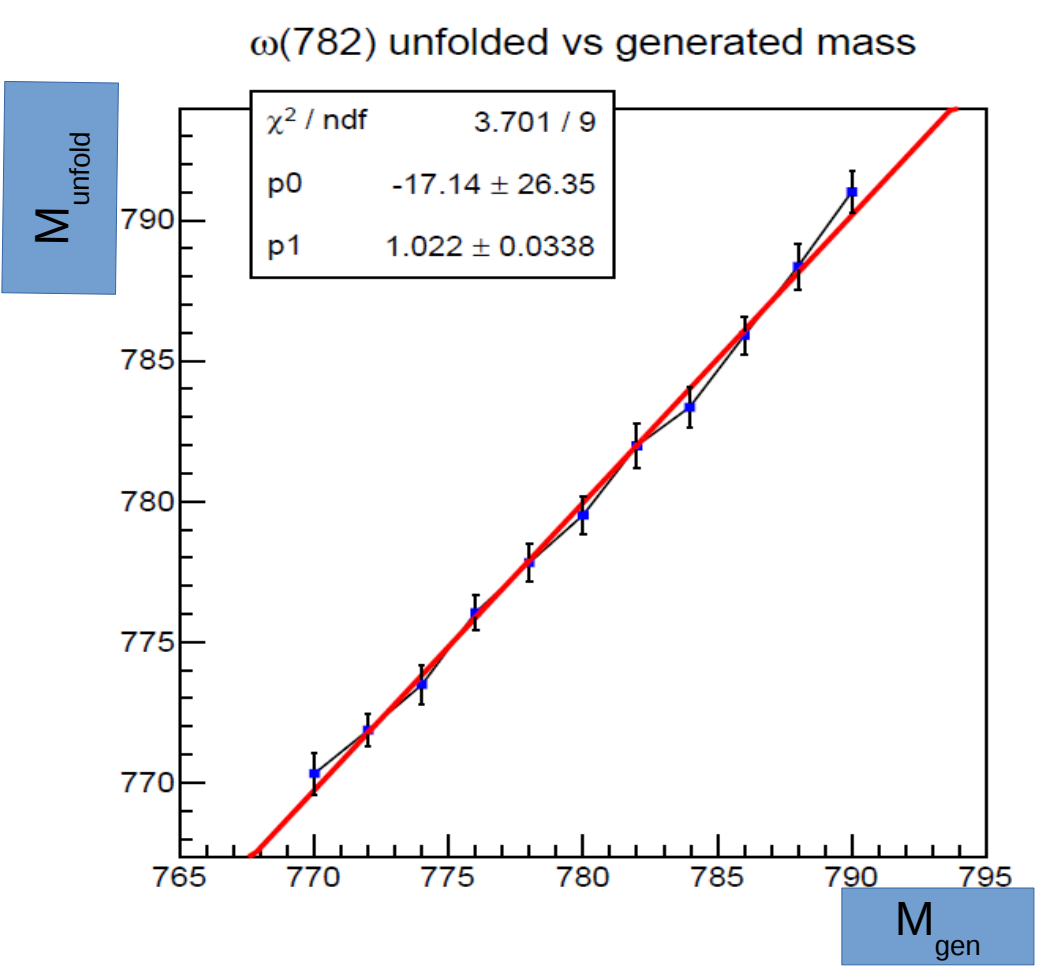
- $s_i(\Gamma_{res})$ and $c_i(\Gamma_{res})$ are defined from series of MC simulation with differentM_{res} and Γ_{res}).
- Data is fitted with F(M, M_{res}, Γ_{res}) using obtained $s_i(\Gamma_{res})$ и $c_i(\Gamma_{res})$ by varying M_{res}, Γ_{res}.

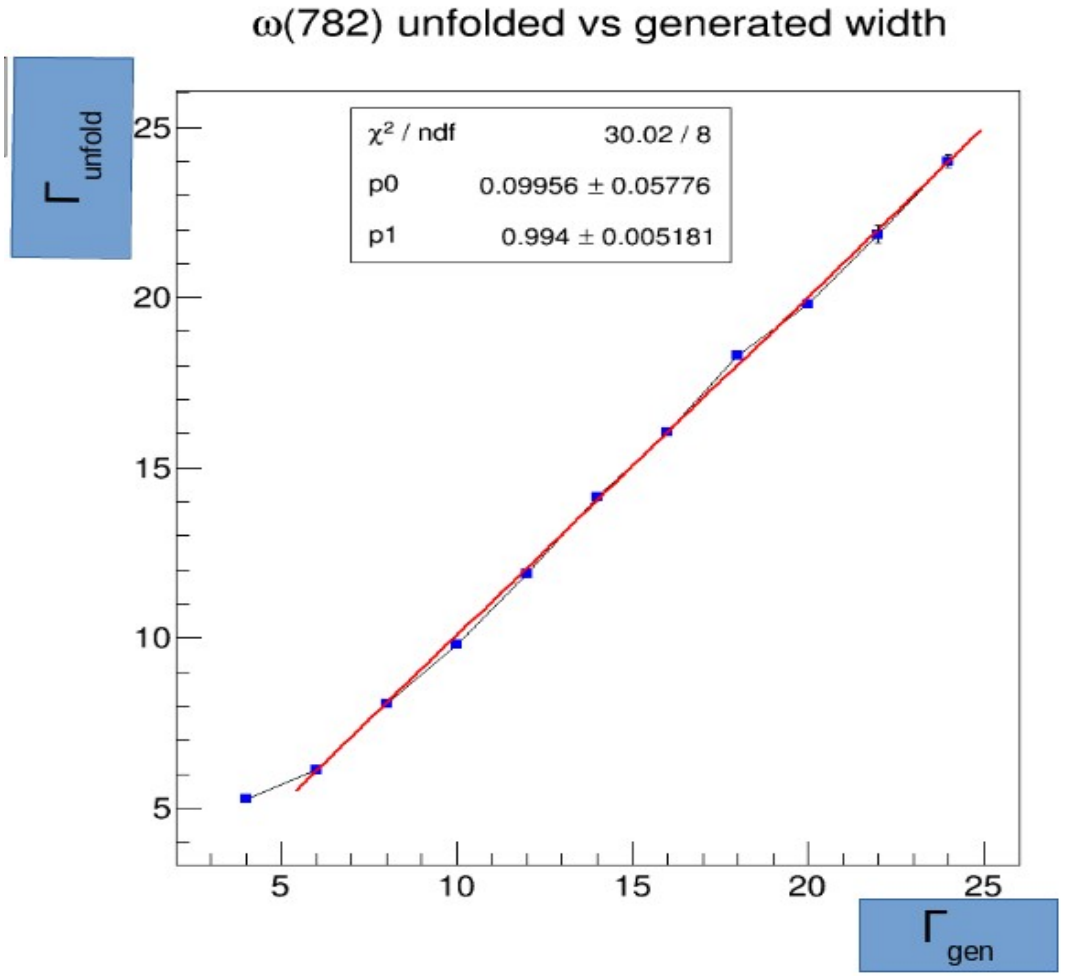
$s_i(\Gamma_{res})$ and $c_i(\Gamma_{res})$ for $\omega(782) \rightarrow \pi^0\gamma$



$s_i(\Gamma_{res})$ and $c_i(\Gamma_{res})$ are fitted with 4-order polinoms

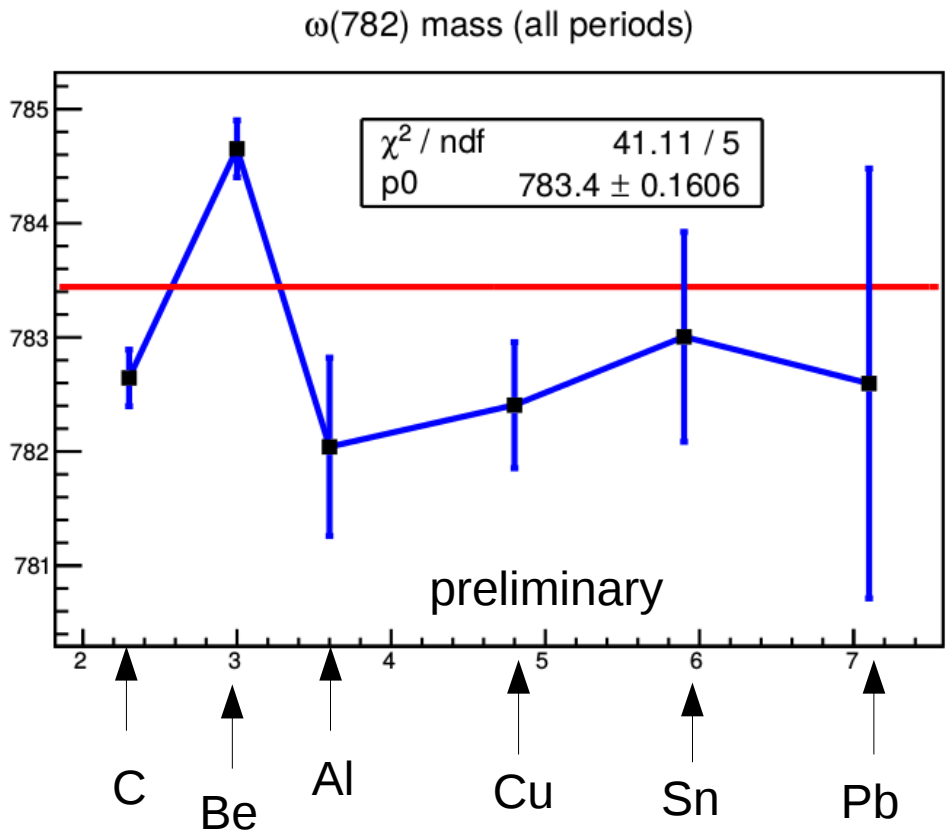
Cross-check of the method

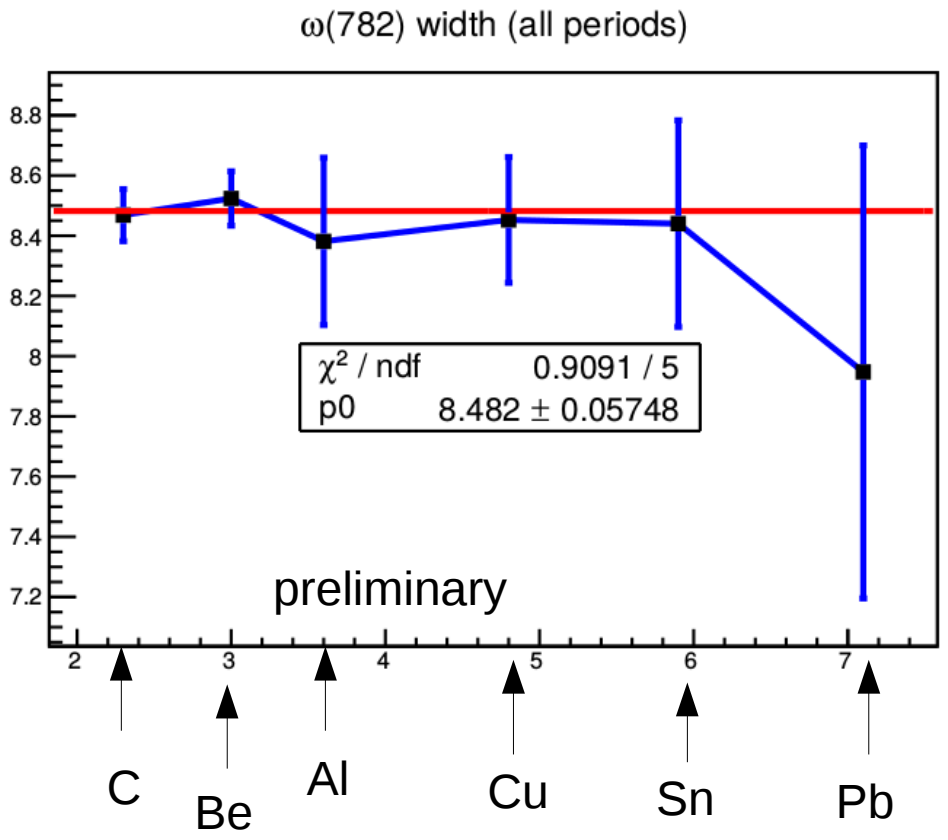




- Method is cross-checked by simulating signals with different values of mass and width of ω(782) together with exponential background;
- Unfolded vs generated parameters plots are in good agreement with line y=x;
- **Note that it's possible to access widths down to 6 MeV/c^2 while apparatus resolution is 40 MeV/c^2!**

ω(782) mass and width measurements





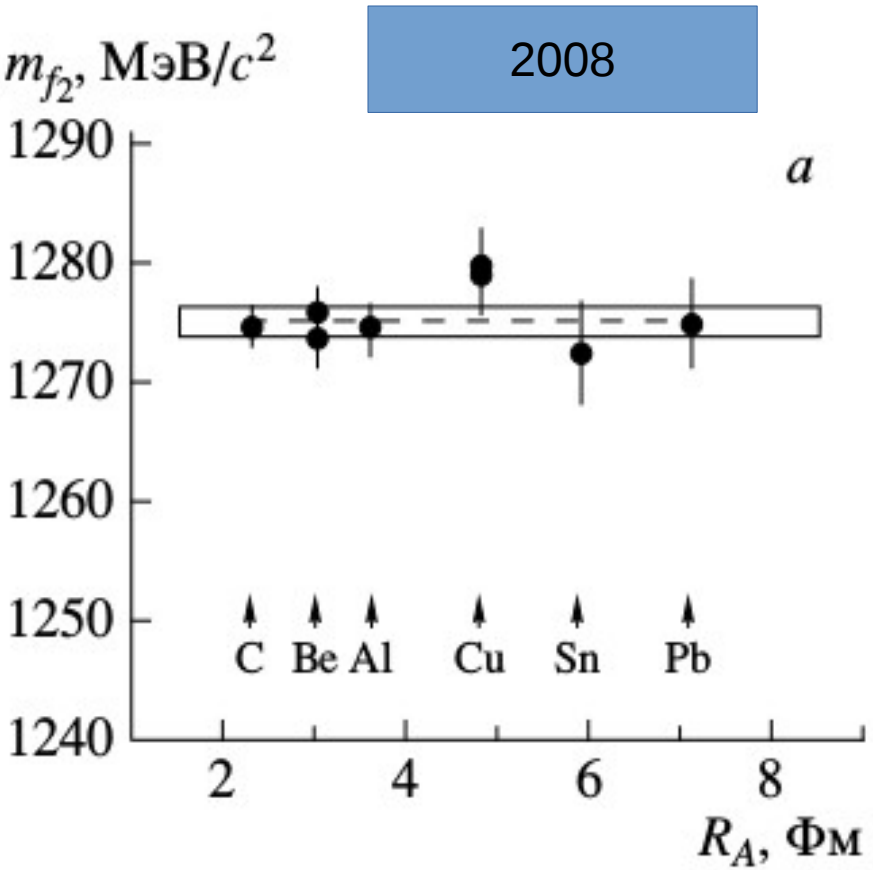
PDG2018 values: M= 782.65±0.12 MeV/c2; Γ = 8.49±0.08;

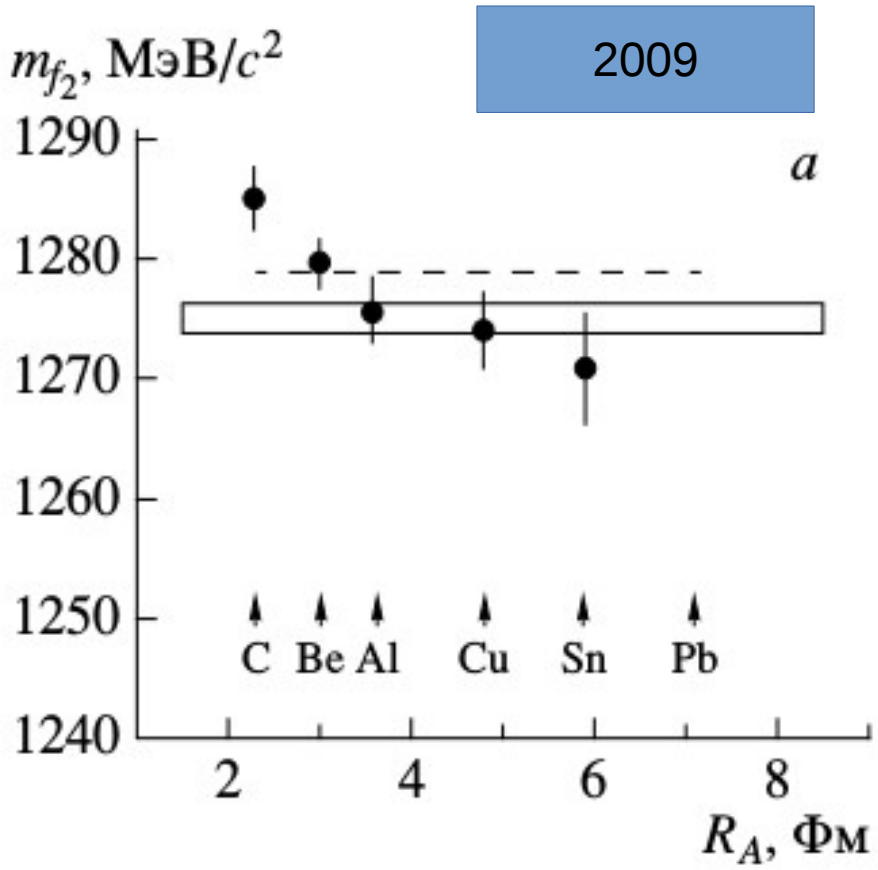
Improvement of global data is possible!

$f_2(1270)$ mass and width measurements

Previously Hyperon-M collaboration publicated paper with f2(1270) measurement:

- ЯДЕРНАЯ ФИЗИКА, 2013, том 76, No 11, с. 1389–1403 http://dx.doi.org/10.7868/S0044002713110044
- Data from 2 datataking periods is contradictory;
- Now we have collected much more data and are processing it using developed parametric unfolding;
- The results are coming soon!





Conclusion

- Parametric unfolding method is developed and cross-checked;
- It was used to obtain preliminary results on ω(782) mass and width measurement;
- No dependence on nuclear target type is obtained;
- Very promising precision is achieved which can help to improve global data;
- Method to be applied for $f_2(1270)$ mass and width measurements.

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