Hadron Program @COMPASS

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on behalf of
the COMPASS collaboration

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Beijing, Sept.21 - Sept.25, 2009

Agenda

- Light quark spectrum and beyond
- Reactions in the COMPASS hadron program
- Detector description
- Data Reconstruction
- Production and decay amplitudes
- PWA formalisms and simulations
- Conclusion

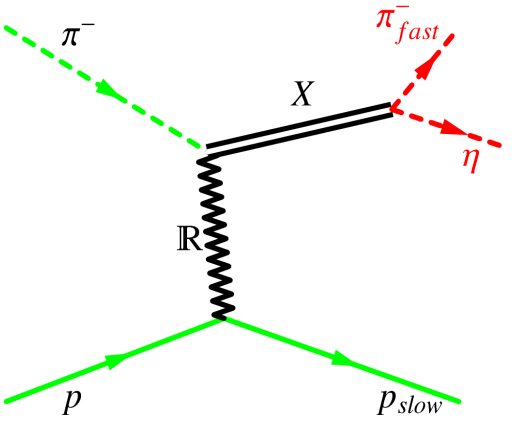
Light quark spectrum and beyond

- Conventional light quark mesons
- Glueballs
- Multiquark states
- Hybrids
- Diffractive scattering:
  E852@BNL, COMPASS@CERN
- Central production:
  WA102@CERN , COMPASS@CERN
- Photo-production
  CLAS@Jefferson
- Lepto-production:
  COMPASS@CERN

COMPASS hadron program 2008-2009

- Diffractively produced states in:

$$\pi^- p \to Xp, X \to \pi^-\pi^+\pi^-, K\overline{K}\pi^-, \eta\eta\pi^-, \eta\pi^- \ldots$$



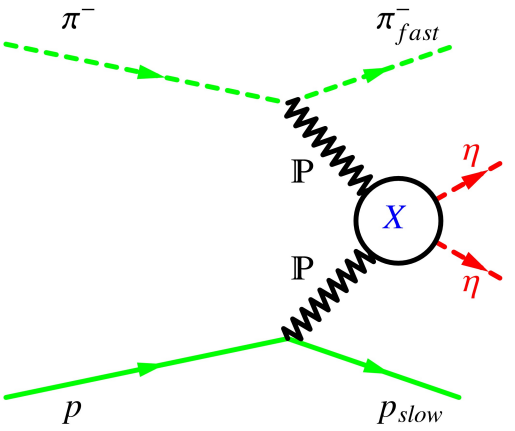
- Centrally produced states in:

$$\pi^- p \to \pi^- Yp, Y \to \pi\pi, K\overline{K}, \eta\eta, \eta\eta', 4\pi, \ldots$$

- Proton beam:

$$pp \to Xp, X \to p\pi^+\pi^-, pK\overline{K}, p\eta\eta, \ldots$$

$$pp \to p_{fast} Yp_{slow}, Y \to \pi\pi, K\overline{K}, \eta\eta, \ldots$$



- Kaon beam:

$$K^- p \to Xp, X \to K^-\pi^+\pi^- p, \ldots$$

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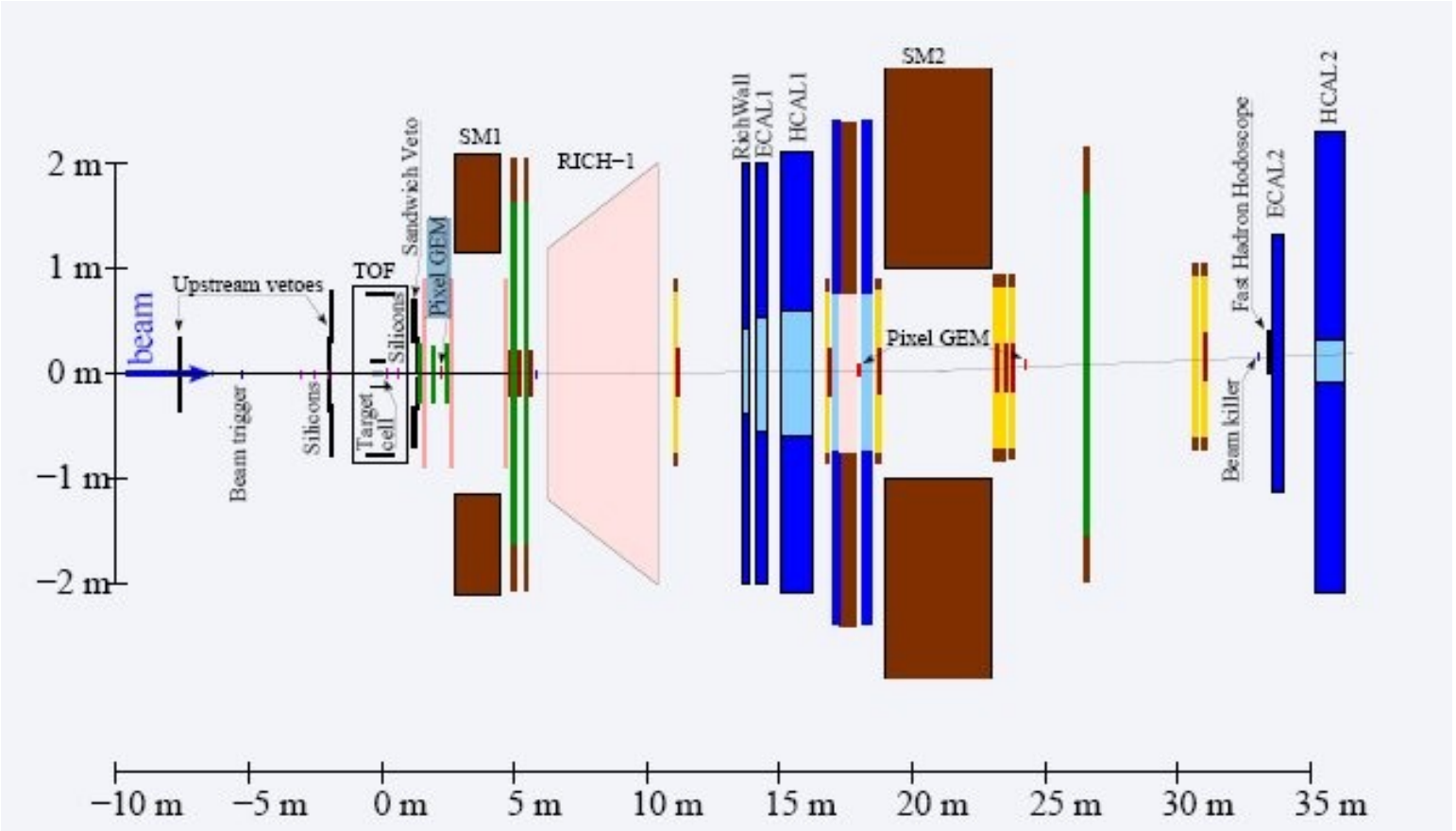
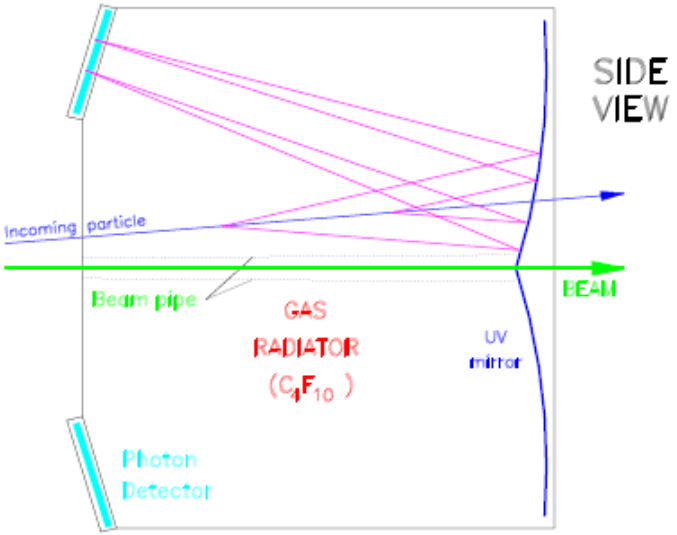


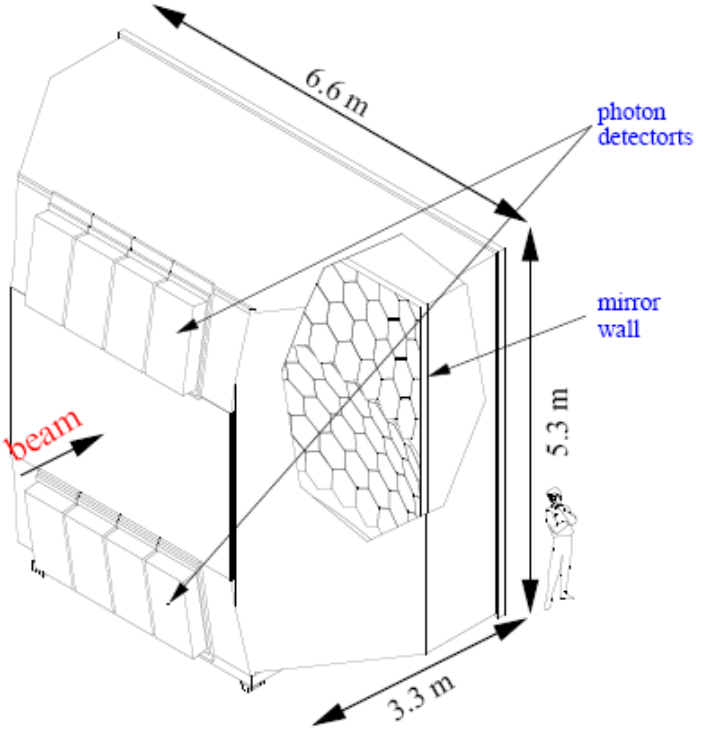
- Tracking: Straw, Drift chambers, MicroMegas, Sandwich Veto, PixelGEM, Recoil Proton Detector, ...
- ECAL1 (4x2.9 m) 1500 GAMS, MAINZ and OLGA cells
- ECAL2 (2.4x1.8 m) 3086 SHASHLYK and GAMS cells
- ECAL LED and LASER monitoring system
- RICH

CEDAR

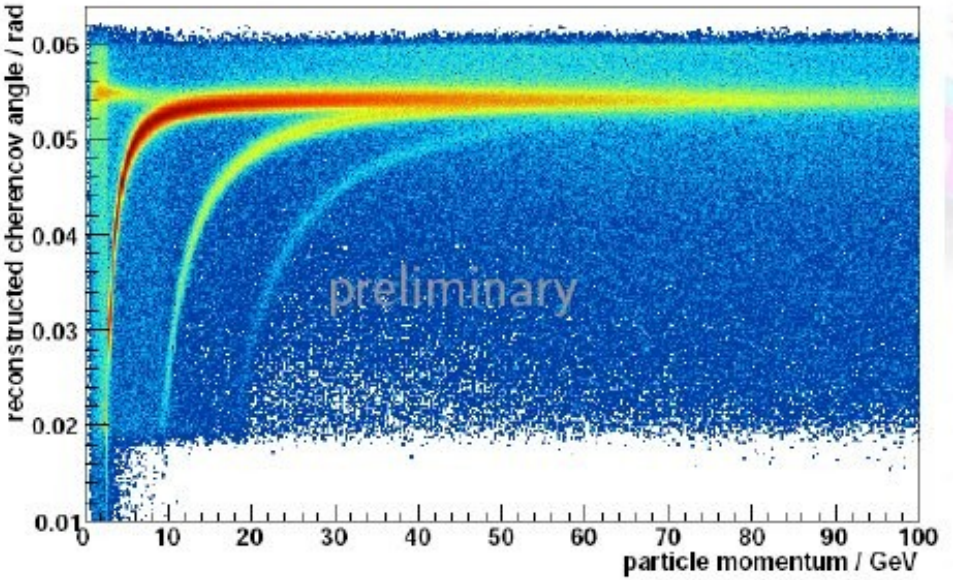
- Cerenkov differential counters with achromatic ring focus
- 2 vessels with 8 photo-multipliers each
- π, K and π identification

RICH



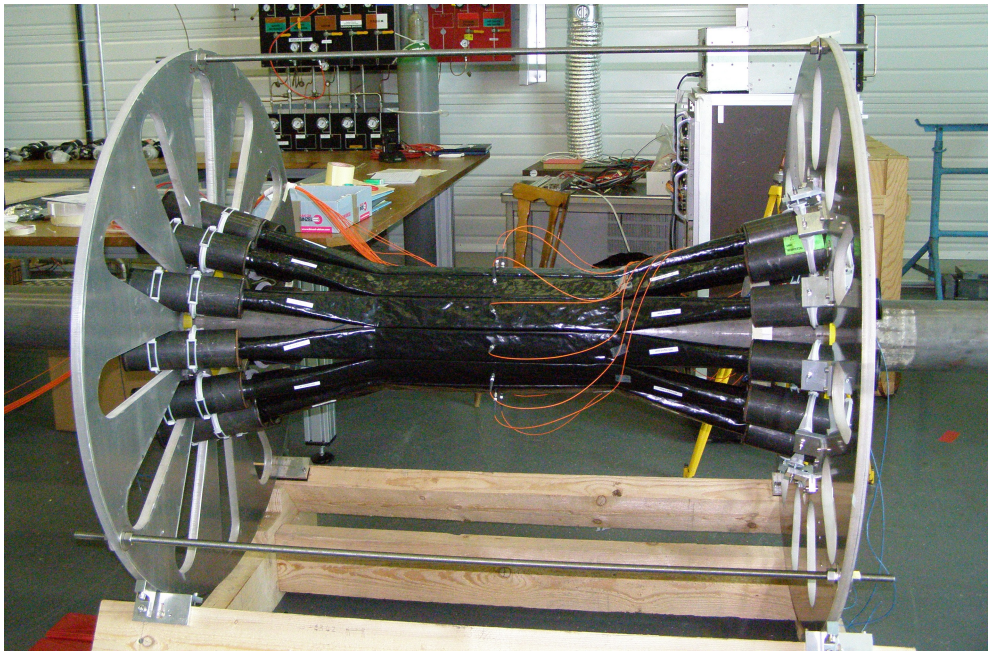


- 8 chambers 576x1152 mm^2
- large angle spectrometer 250x200 mrad
- π, K and p separation up to ~40 GeV/c

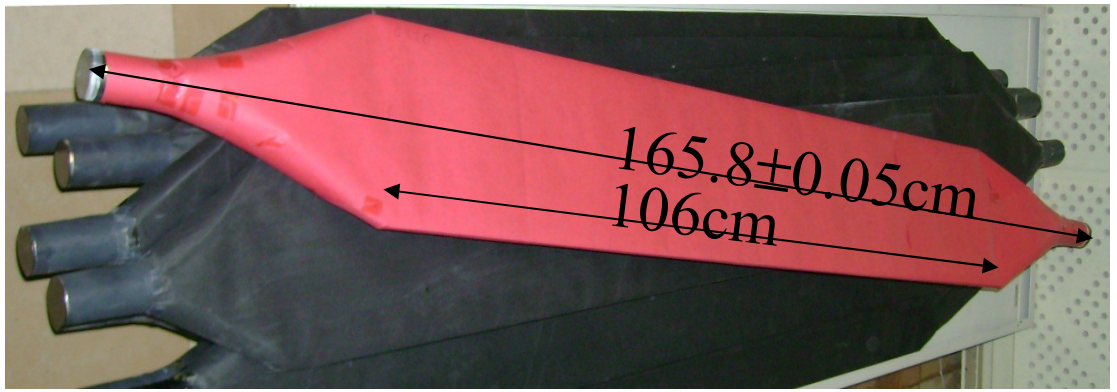


RPD

12 A scintillators: t=0.5cm L=50cm l=6.5cm



24 B scintillators: t=1cm L=106cm l=20cm



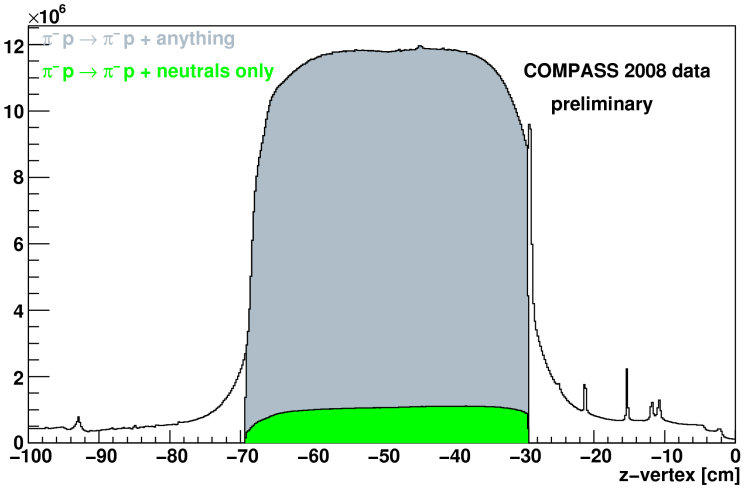
R_A=12.5cm

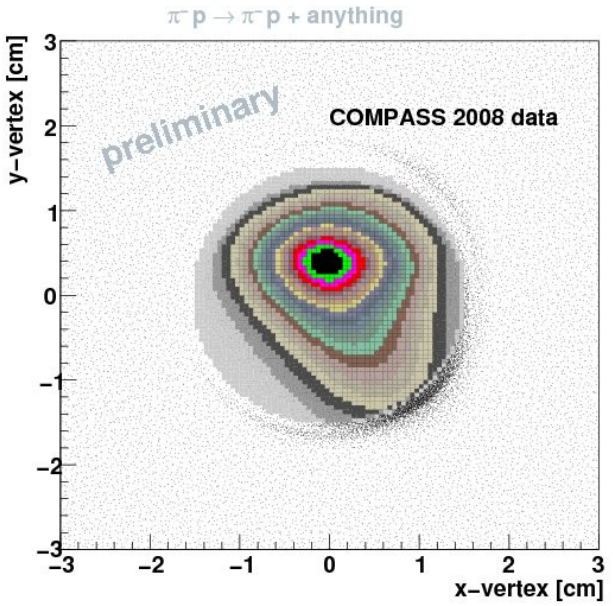
R_B=75.5cm

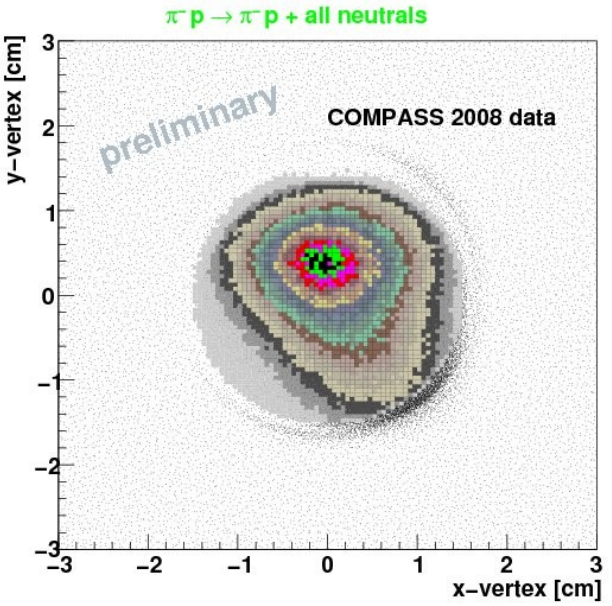
- detect recoiling proton from 0.27 to 2 GeV in 60'<θ<90' and $\phi=2\pi$
- z_A (ring A) and z_B (ring B)
- Time of flight and energy loss measurement: p, π identification

2008 data reconstruction: vertex fitter

Multiple vs. one outgoing track vertex fitter performance

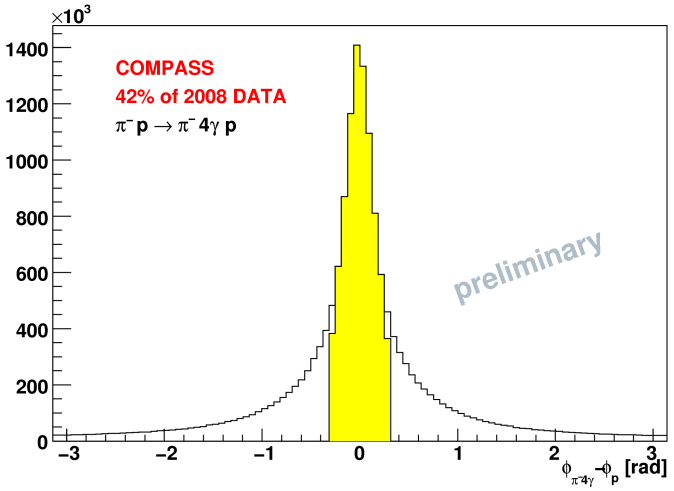


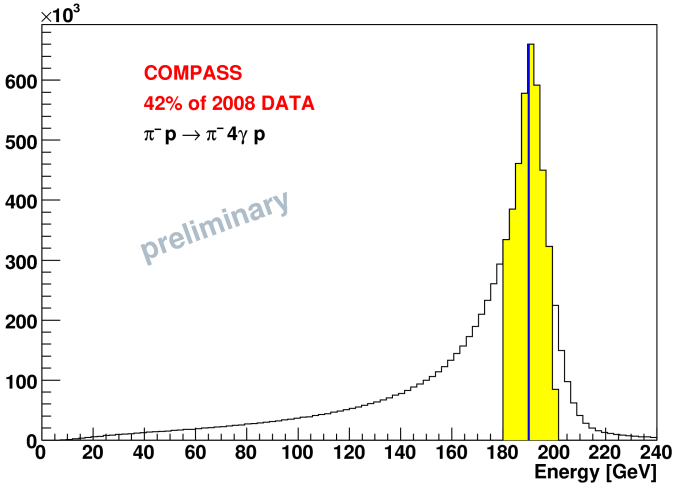


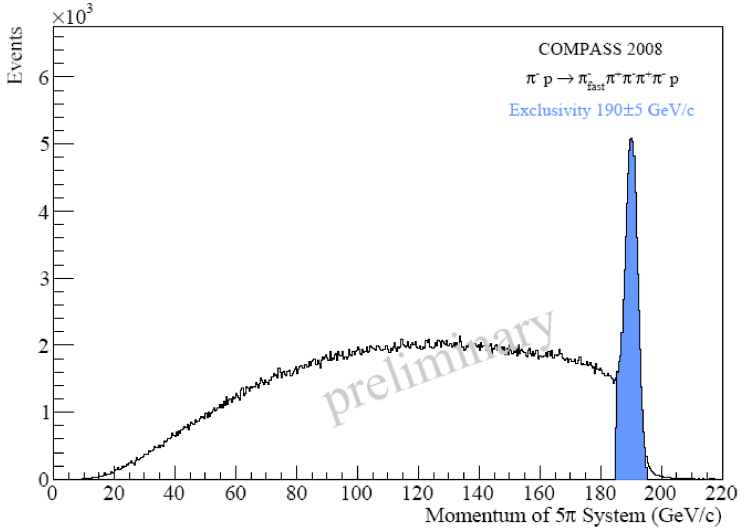


2008 data: exclusivity with RPD

one track +neutral vs all charged final state

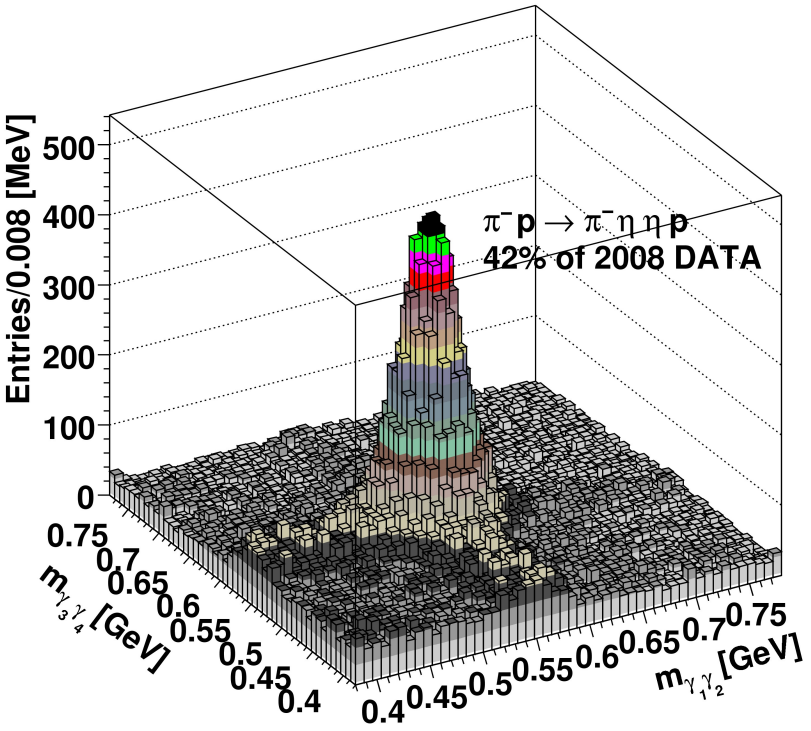


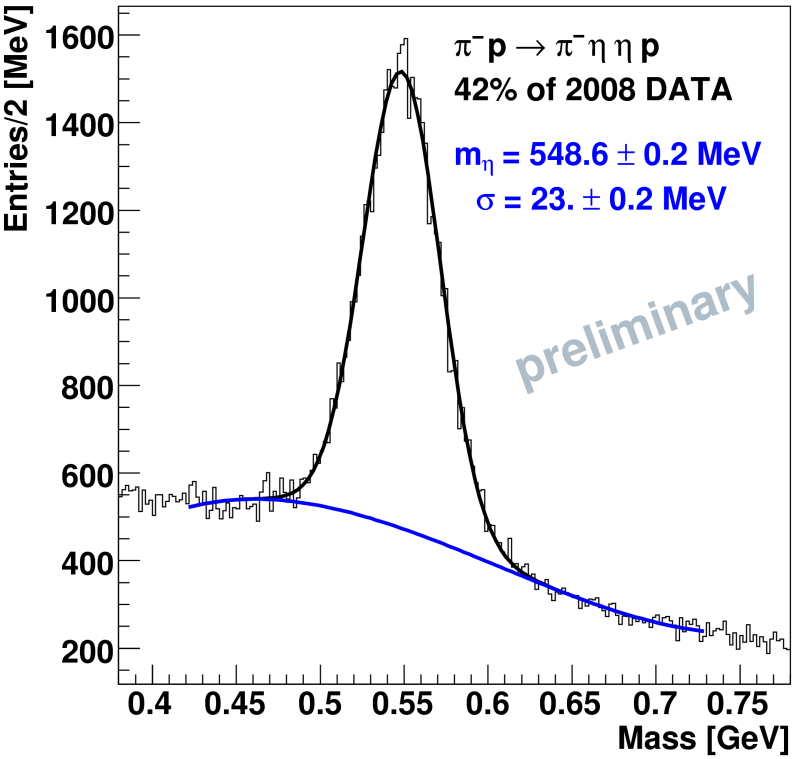




$\pi^- p \to \pi^- \eta\eta p$

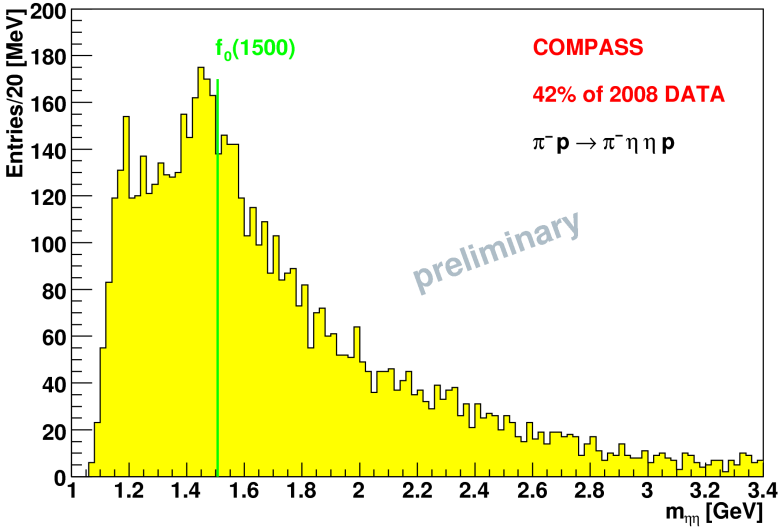
$\eta \to \gamma_1\gamma_2, \eta \to \gamma_3\gamma_4$

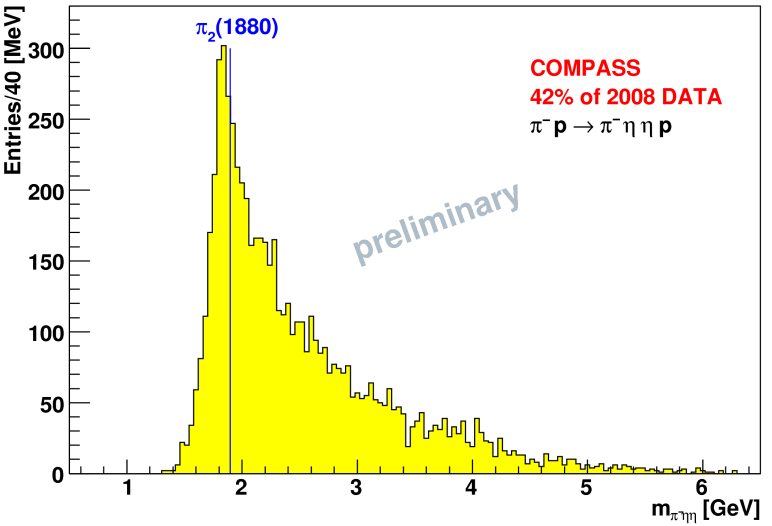




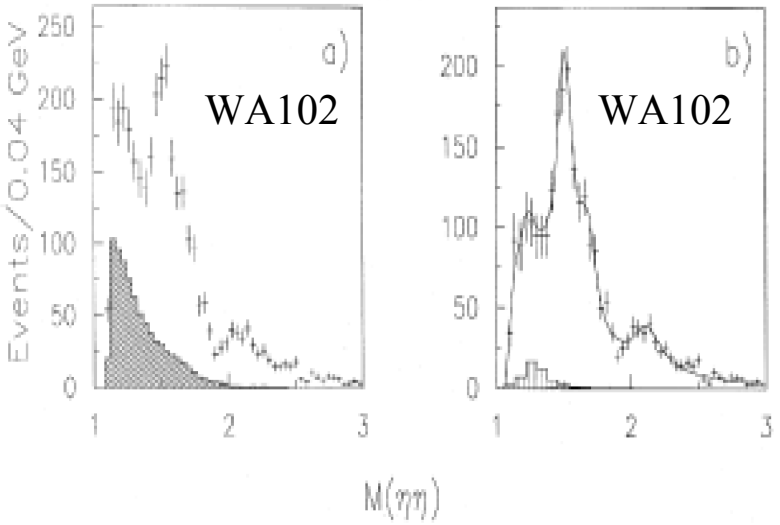
$\pi^- p \to \pi^- \eta\eta p$ at 190 GeV

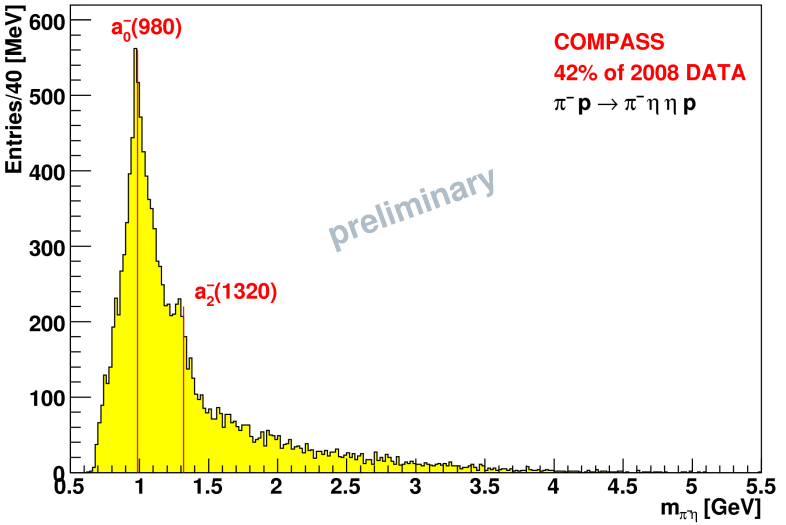
I=0, J=0^{++},2^{++},4^{++},…



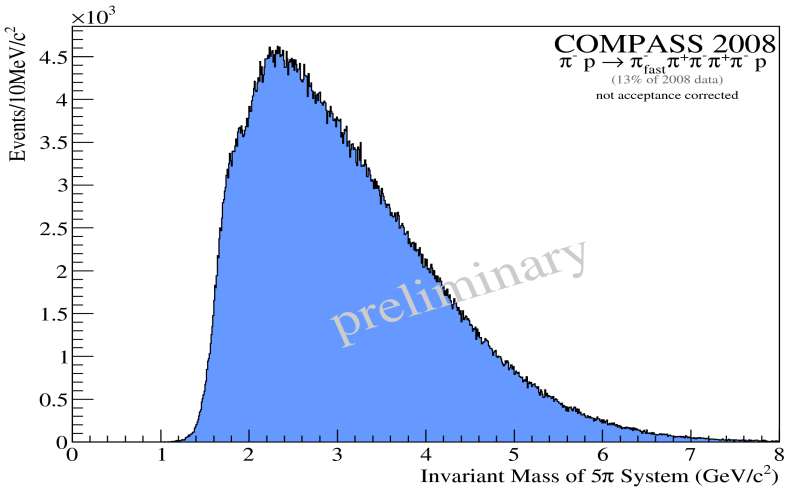


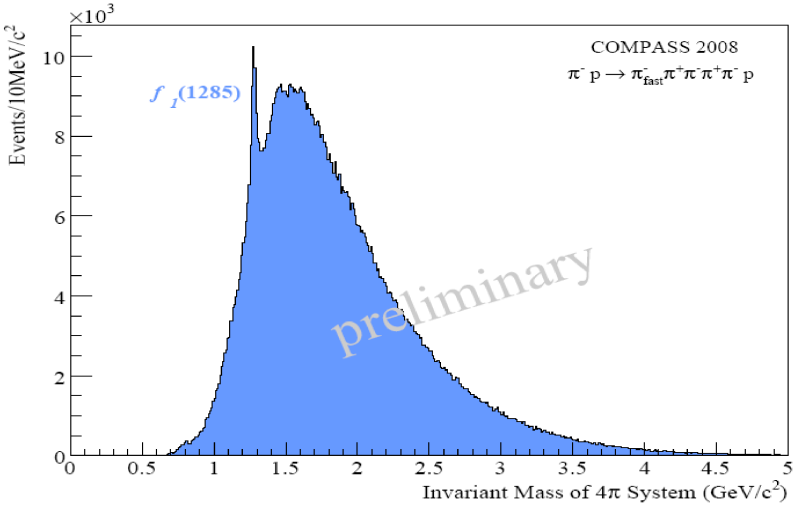
$pp \to p_{fast}\,\eta\eta p_{slow}\ at\ 450\ GeV$

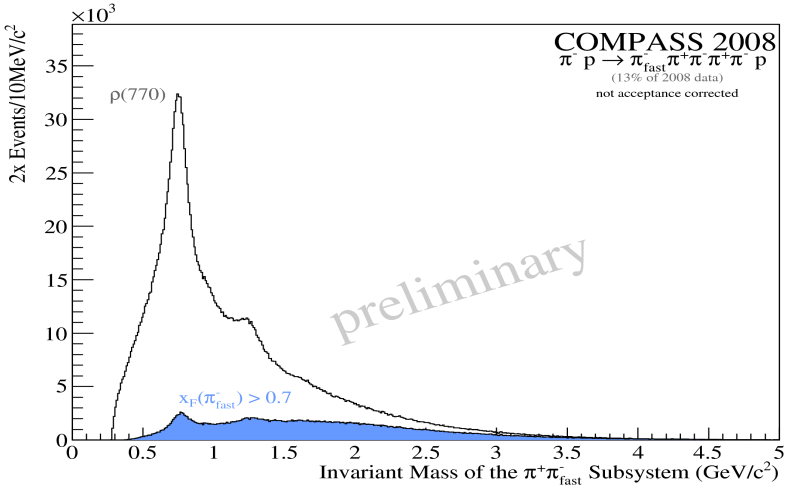


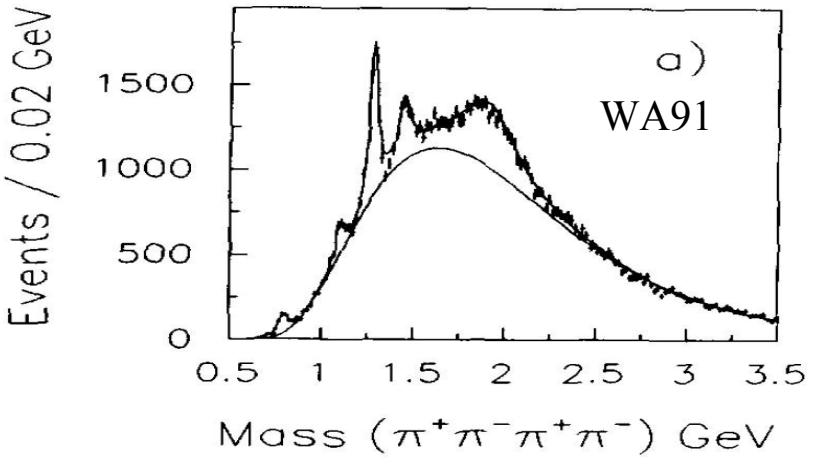


All charged channel: $\pi^- p \to 5\pi p$



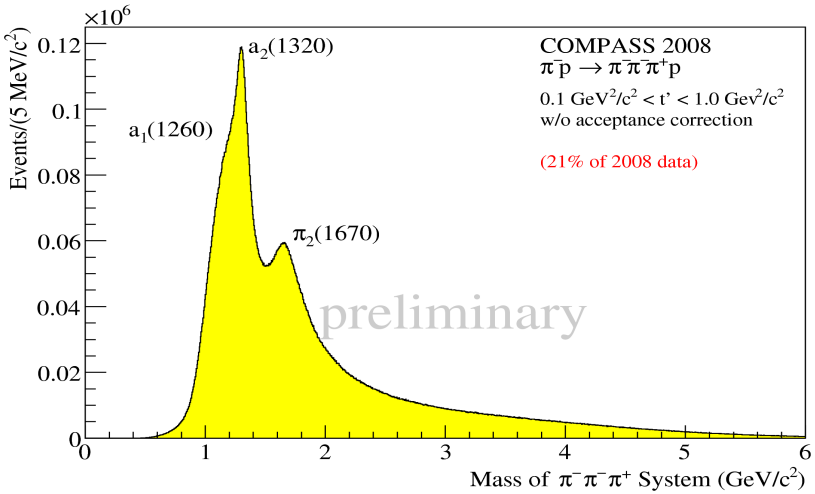


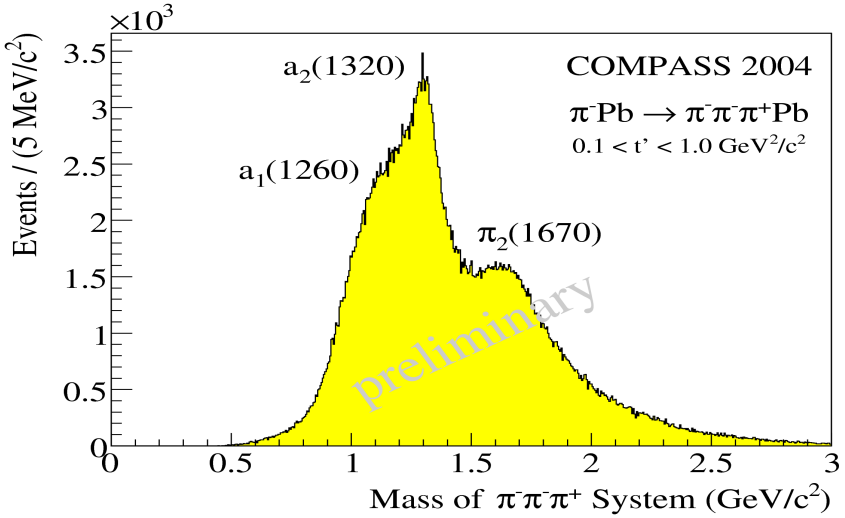


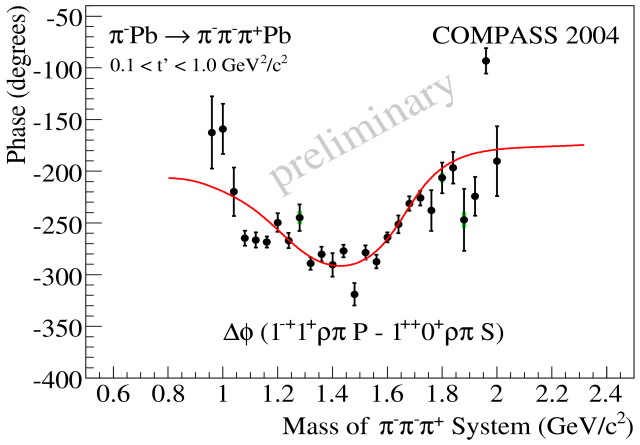


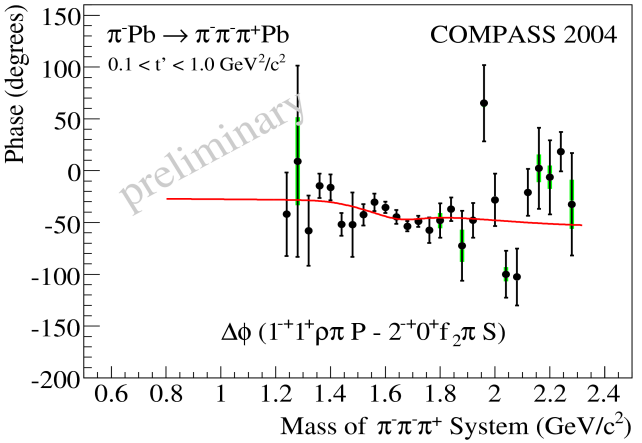
$M \sim 1450, f_0(1370) \to 4\pi ?$

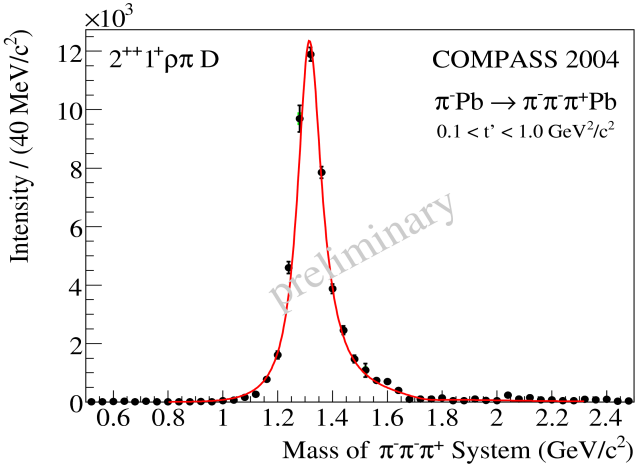
$\pi^- p \to \pi^- \pi^+ \pi^- p$ 2008 vs. $\pi^- Pb \to \pi^- \pi^+ \pi^- Pb$ 2004

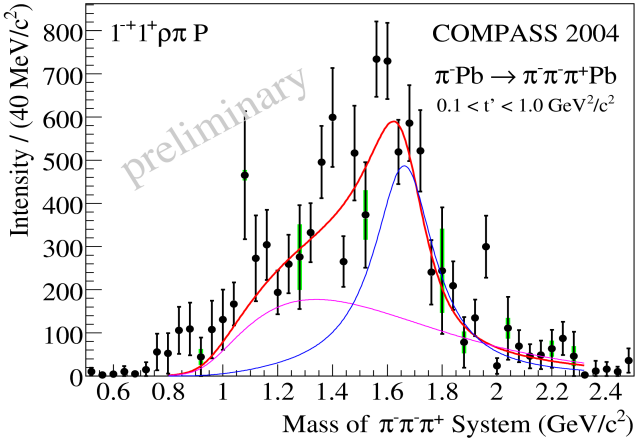








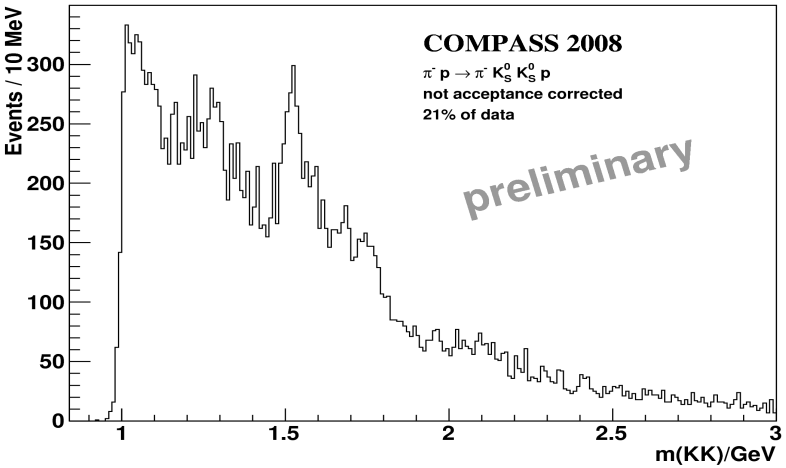


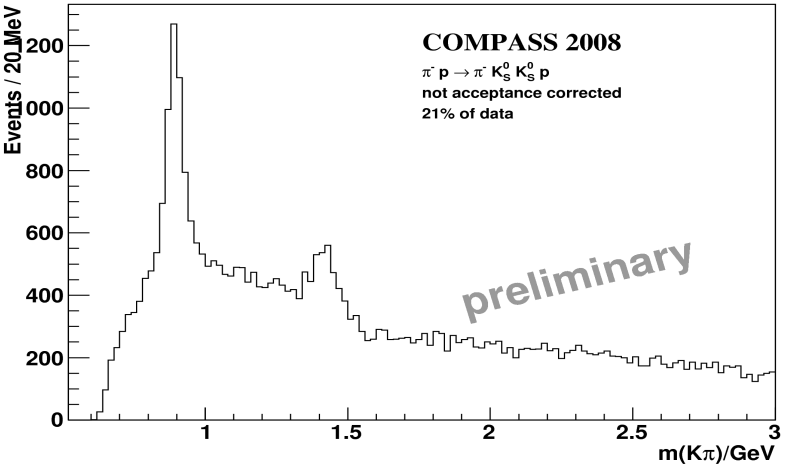


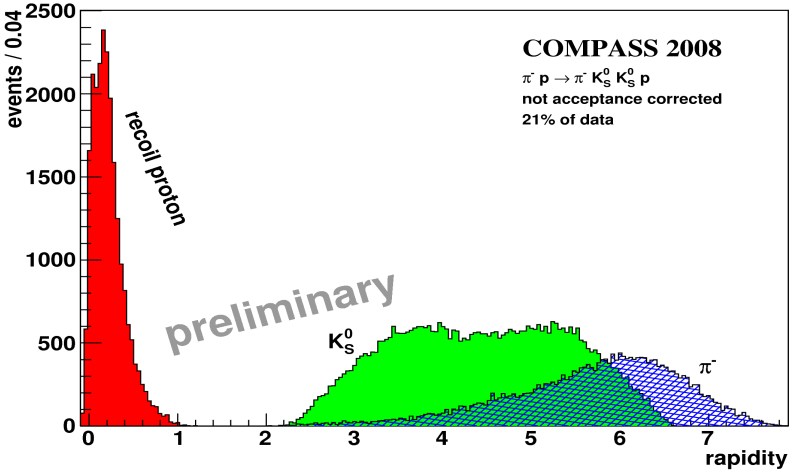
there will be also $\pi^- Pb \to \pi^- \pi^+ \pi^- Pb$ data in 2009!

$\pi^- p \to \pi^- K_s K_s p$

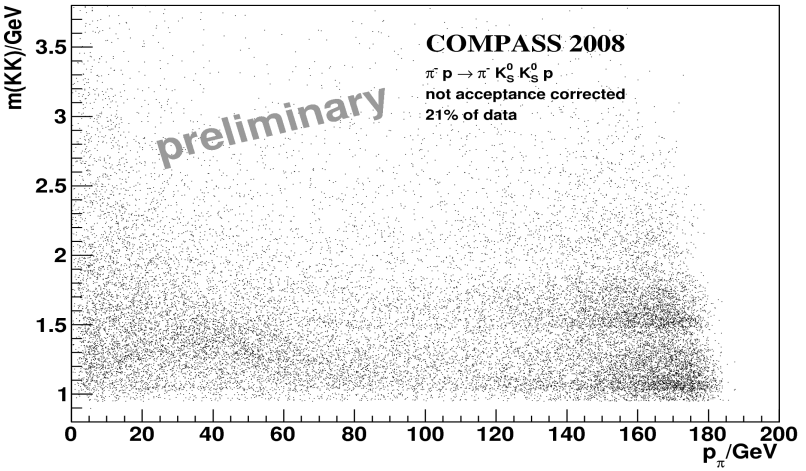
I=0,1, J=0^{++},2^{++},4^{++},...





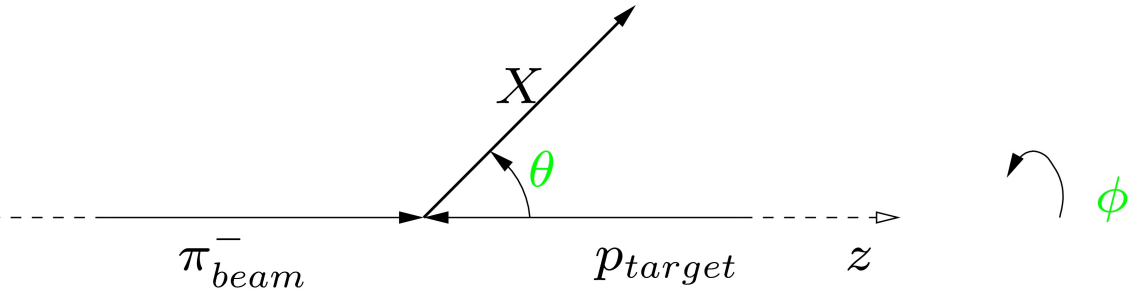


all KsKs: invariant mass of KK vs p_π



Production amplitude for central X(MC)

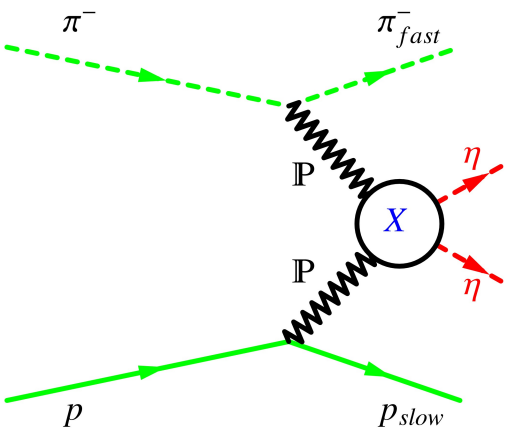
- M_X uniform [$2m_\eta$,2.5 GeV]
- flatrapidity y_X [-1,1]
- t_π , t_p as e^{-t}, b~6.0 [0,1]
- ϕ_π , ϕ_p uniform [0,2π]

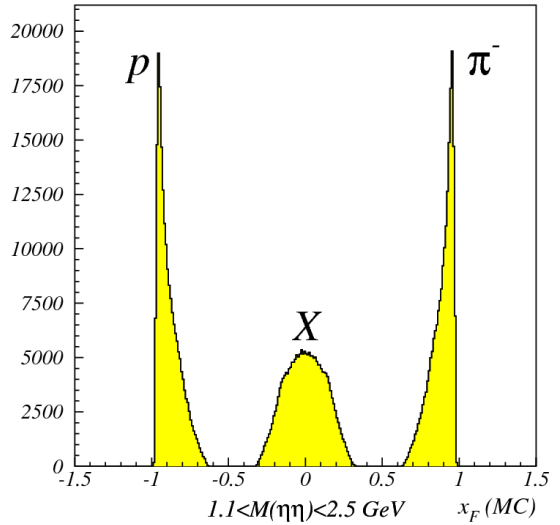


$$M_X^2 = -x_{P_\pi} x_{P_p} s$$

$$p_{T,\pi}^2 \sim -t_\pi , p_{T,p}^2 \sim -t_p$$

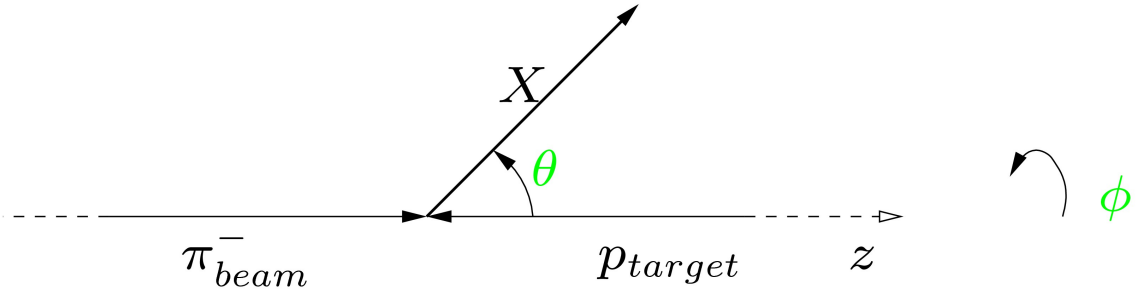
$$x_p + x_\pi + x_X = 0$$





Production amplitude for diffractive X(MC)

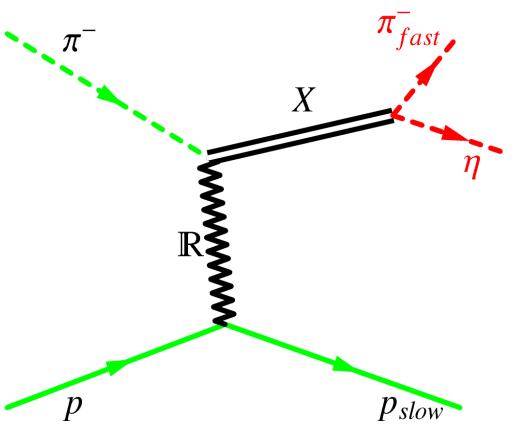
- M_X uniform [$m_\pi+m_\eta$,2.5 GeV]
- t_X as e^{-t}, b~6.0 [0,1]
- ϕ_X , ϕ_p uniform [0,2π]

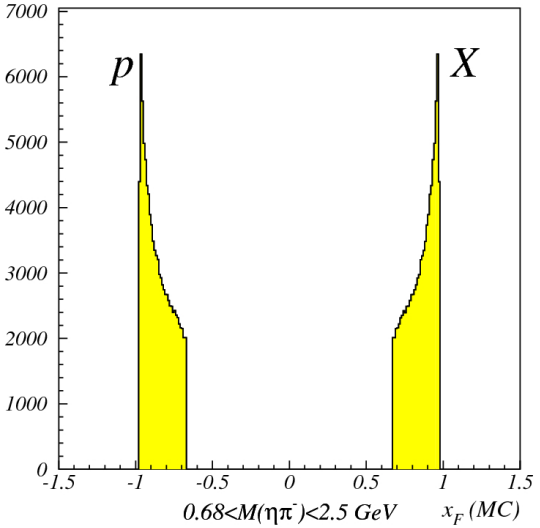


$$1-x_X \sim \frac{M_X^2-m_\pi^2}{s}$$

$$p_{T,X}^2 \sim -t_X$$

$$x_X + x_p = 0$$





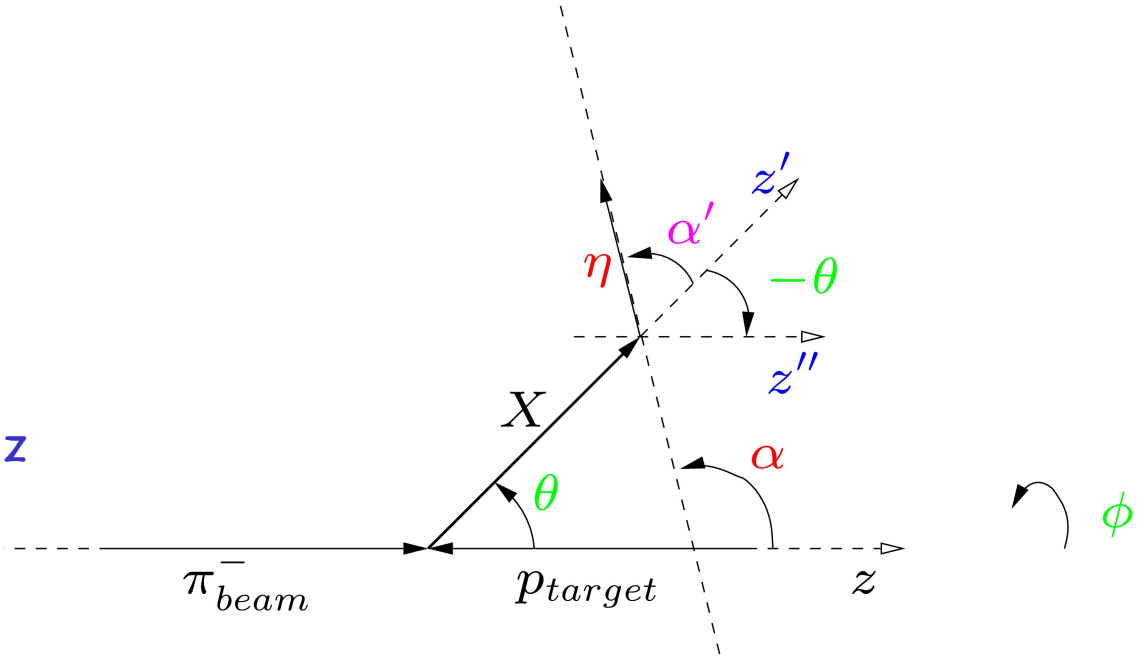
Decay amplitude for central or diffractive X

z axis defined by the beam.

- Boost to π^-p c.m. frame.
- Wick rotation by θ and ϕ
- Boost to X rest frame (x′,y′,z′)
- rotation back by $-\phi$ and $-\theta$

direction of x″,y″,z″ ≡ direction of x,y,z

η with final momenta different from those in the overall π^-p rest frame.



Decay amplitude: $$A_J = Ge^{i\delta}F_J(q)\frac{Y_J(\alpha)}{m_0^2 - s - im_0\Gamma(m)}$$

Intensity with two resonances $X_J(m_0)$, $Y_{J'}(m_0')$:

$$w(m, m_0, m_0') = |A_{X_J}(m, m_0)|^2 + |A_{Y_{J'}}(m, m_0')|^2 + 2\Re(A_{X_J}(m, m_0)A_{Y_{J'}}(m, m_0'))$$

Minimization

Standard log-likelihood definition:

$$L = \prod_{i=1}^{N_{events}} w(\alpha)$$

$$\alpha \equiv G_{\lambda}, \delta_{\lambda}, m_{0,} \Gamma_{0,} J^{PC}$$

$$S = -\ln L = -\sum_{i=1}^{N_{DATA}} \ln w_i + N_{DATA} \ln \left(\sum_{j=1}^{N_{MC}} w_j \right)$$

Minimization with FUMILI on event per event basis

old PWA: mass indipendent angular fit

+mass dependent log-likelihood fit

new PWA: mass dependent global fit

advantage: reduce the number of non-mathematical ambiguities

disadvantage: CPU time

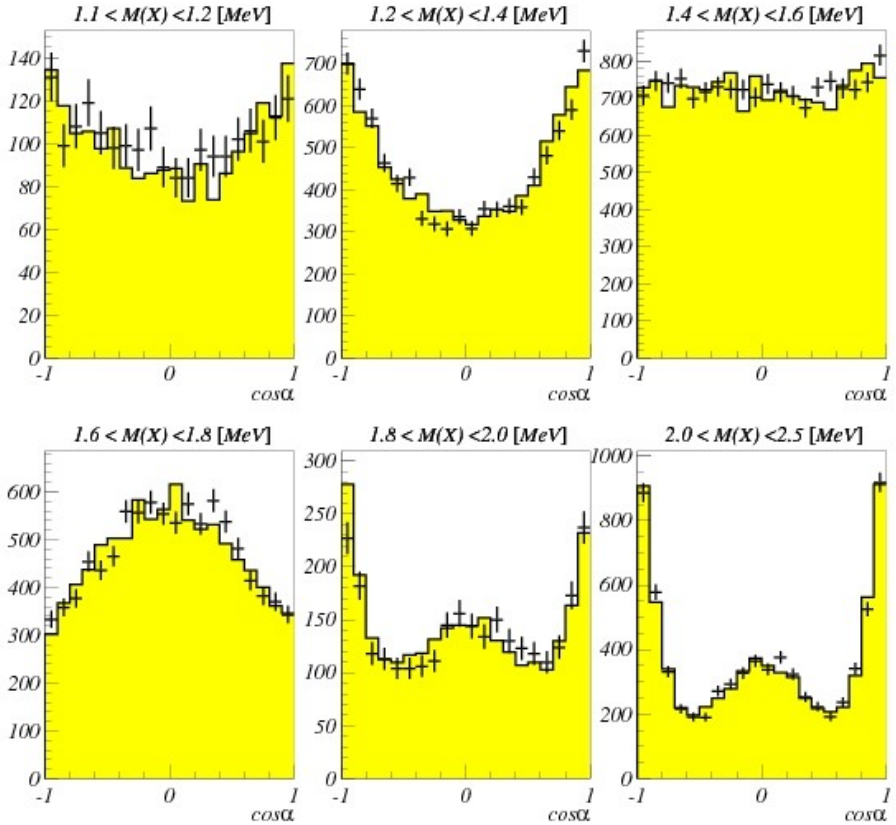
Simulation of Partial Waves

Ingredients of the simulations and fit

	Generated	Fit without detector effects	Fit after detector simulation
0^{++} total (including background)			
Rate [%]	78.2	76.8	84.0
$f_0(1370)$			
M [GeV/c^2]	1.312	1.310 ± 0.005	1.308 ± 0.004
Γ [GeV/c^2]	0.340	0.392 ± 0.019	0.415 ± 0.028
Rate [%]	21.3	21.8	26.0
$f_0(1500)$			
M [GeV/c^2]	1.502	1.507 ± 0.002	1.502 ± 0.002
Γ [GeV/c^2]	0.100	0.114 ± 0.004	0.130 ± 0.005
Rate [%]	13.2	13.9	17.9
$f_0(1710)$			
M [GeV/c^2]	1.727	1.726 ± 0.002	1.719 ± 0.003
Γ [GeV/c^2]	0.126	0.141 ± 0.005	0.129 ± 0.005
Rate [%]	14.2	15.0	13.1
incoherent S-wave background			
Rate [%]	29.5	26.1	27.0
2^{++} total			
Rate [%]	15.9	16.4	12.7
$f_2(1270)$			
M [GeV/c^2]	1.270	1.277 ± 0.011	1.304 ± 0.008
Γ [GeV/c^2]	0.170	0.193 ± 0.022	0.162 ± 0.019
Rate [%]	1.28	1.7	0.6
$f_2(2150)$			
M [GeV/c^2]	2.130	2.130 ± 0.003	2.093 ± 0.004
Γ [GeV/c^2]	0.270	0.257 ± 0.009	0.306 ± 0.014
Rate [%]	14.58	14.7	12.1

Comparison with the BNL program (Chung et al.) MC

Decay frame (PWA2)
after Wick rotations



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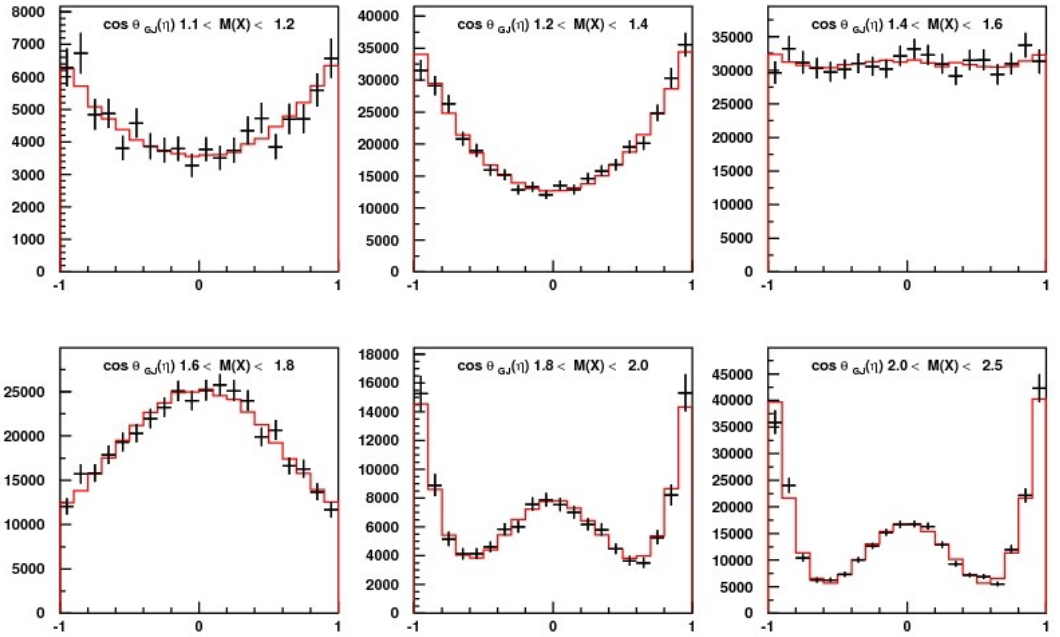
Gottfried-Jackson
frame (PWA1)



on average α shape is equivalent to θ_{GJ} shape

Conclusion and Outlook

- Exotic $\pi(1600)$ decaying to 3π has been observed.
- $f_0(1500)/f_2`(1525)$ decaying to $\eta\eta$ has been observed.
- COMPASS started massive amplitude analysis in the light quark sector.

  Goal: BNL and WA102 results with much higher statistics.
  Plus: centrally and diffractively produced resonances will be fitted simultaneously with two indipendent formalisms.