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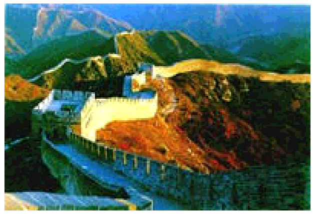
Session 6: QCD Soft Interactions



Inclusive Photoproduction of Mesons and Anti-Deuterons at HERA

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on behalf of

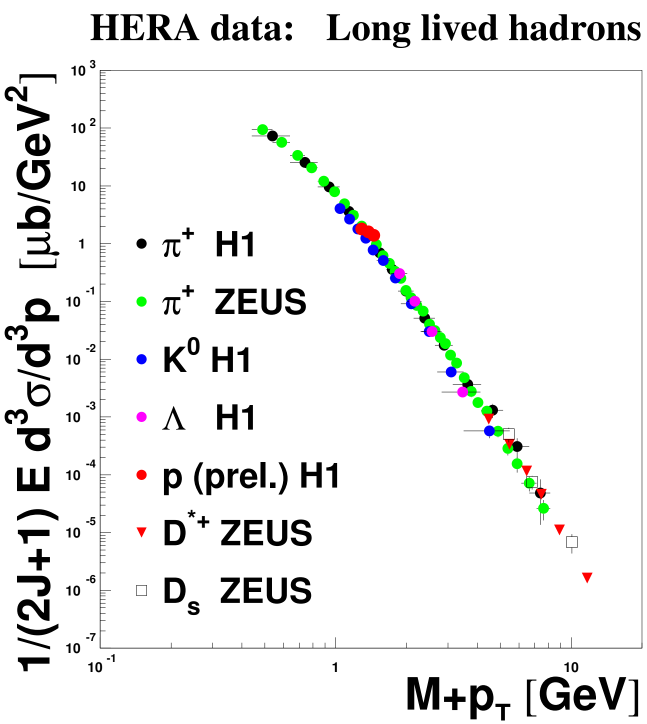
Ref. *Abstracts:* **6-0155, 6-0184**

Motivation

- Soft QCD processes represent a major theoretical challenge $\Rightarrow$ no firm predictions from first principles

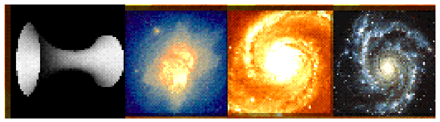
- Look for regularities which may indicate universal underlying mechanisms (see e.g. this figure $\Rightarrow$ Question: **would resonances spoil the picture?**)

- Characteristics of observed final state must reflect the properties of the **initial "fireball"**

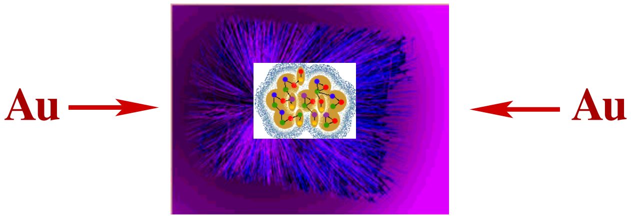


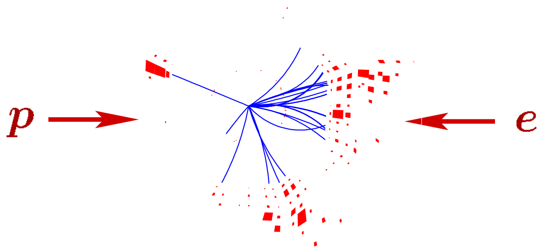
- Especially interesting (in a context of heavy ion collisions and astrophysics) is production of **complex (anti)matter species**

Bang!



QGP ?

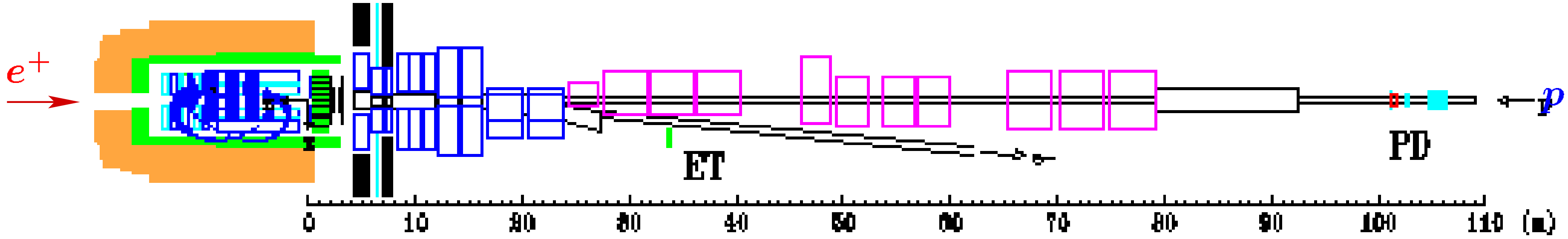




Data samples

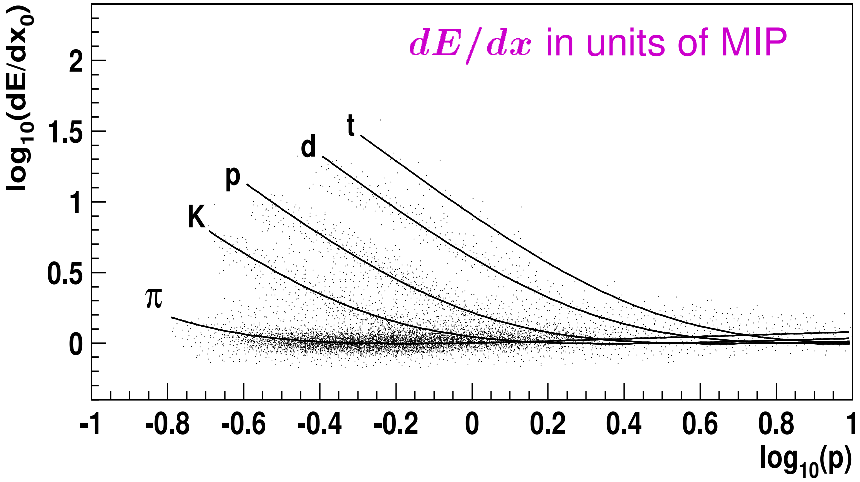
Photoproduction (using e-tagger): $e^+p \to e^+X$ ($\theta_e < 5$ mrad $\to$ $\langle Q^2\rangle \simeq 10^{-4}$ GeV^2)

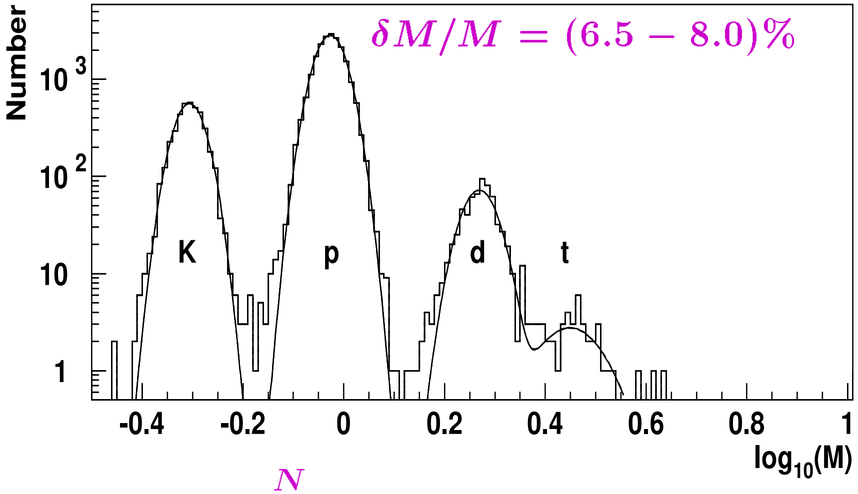
Trigger: (e^+ in ET) $\times$ (> 2 tracks in Central Tracker)



Measurement	abstract 6-0155		abstract 6-0184	
	$\bar{p}$	$\bar{d}$	ρ^0, f_0, f_2	η
Signature	dE/dx		$\pi^+\pi^-$-decay	$\gamma\gamma$-decay
Data sample	1996 (5.5 pb^{-1})		2000 (38.7 pb^{-1})	
Trigger eff.	0.72 ± 0.04	0.78 ± 0.04	0.72 ± 0.04	
A(e-tagger)	0.46 ± 0.02		0.485 ± 0.024	
$\langle W_{\gamma p}\rangle$/GeV	$200\ (0.3 < y_e < 0.7)$		$210\ (0.3 < y_e < 0.65)$	

Anti-Deuterons: dE/dx





$$L = \prod_i^N P(dE/dx_i|dE/dx_0)$$

Track selection

- soft selection ($p/\bar{p}$)
  - ▷ $N_{hits} > 10$
  - ▷ $R_{start} < 30$cm, $l_R > 10$cm
  - ▷ $\log_{10}(dE/dx) > 0.3$

$$\overline{\epsilon_{\bar{p}}} = 0.864 \pm 0.032$$

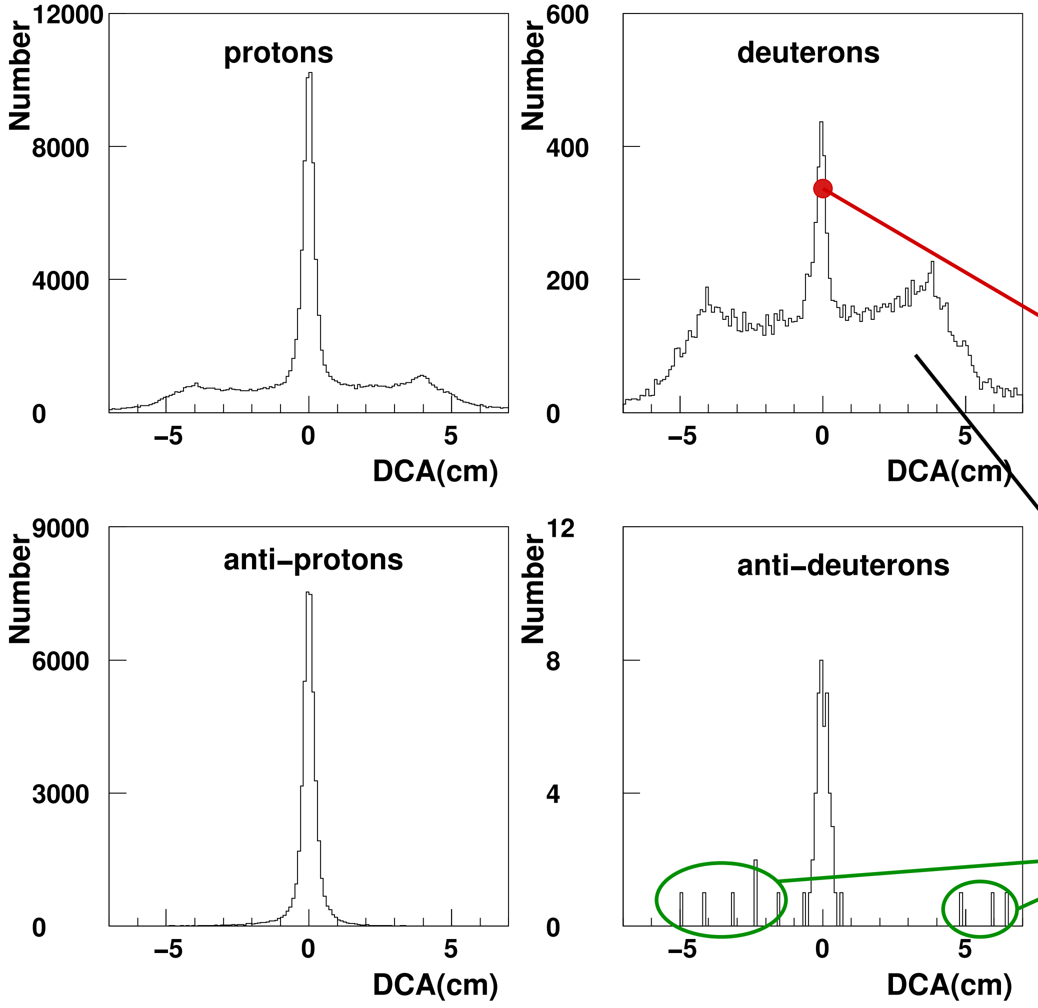
- hard selection ($d/\bar{d}$)
  - ▷ $N_{hits} > 40$
  - ▷ $R_{start} < 30$cm, $l_R > 35$cm
  - ▷ $\log_{10}(dE/dx) > 0.4$

$$\overline{\epsilon_{\bar{d}}} = 0.676 \pm 0.078$$

Measurement region $\bar{d}(\bar{p})$

$$0.2(0.3) < p_t/M < 0.7 \quad |y_{lab}| < 0.4$$

Anti-Deuterons: background rejection



- Background rejection using
  - DCA to the primary vertex
  - event z – vertex position
  - track timing wrt event t_0

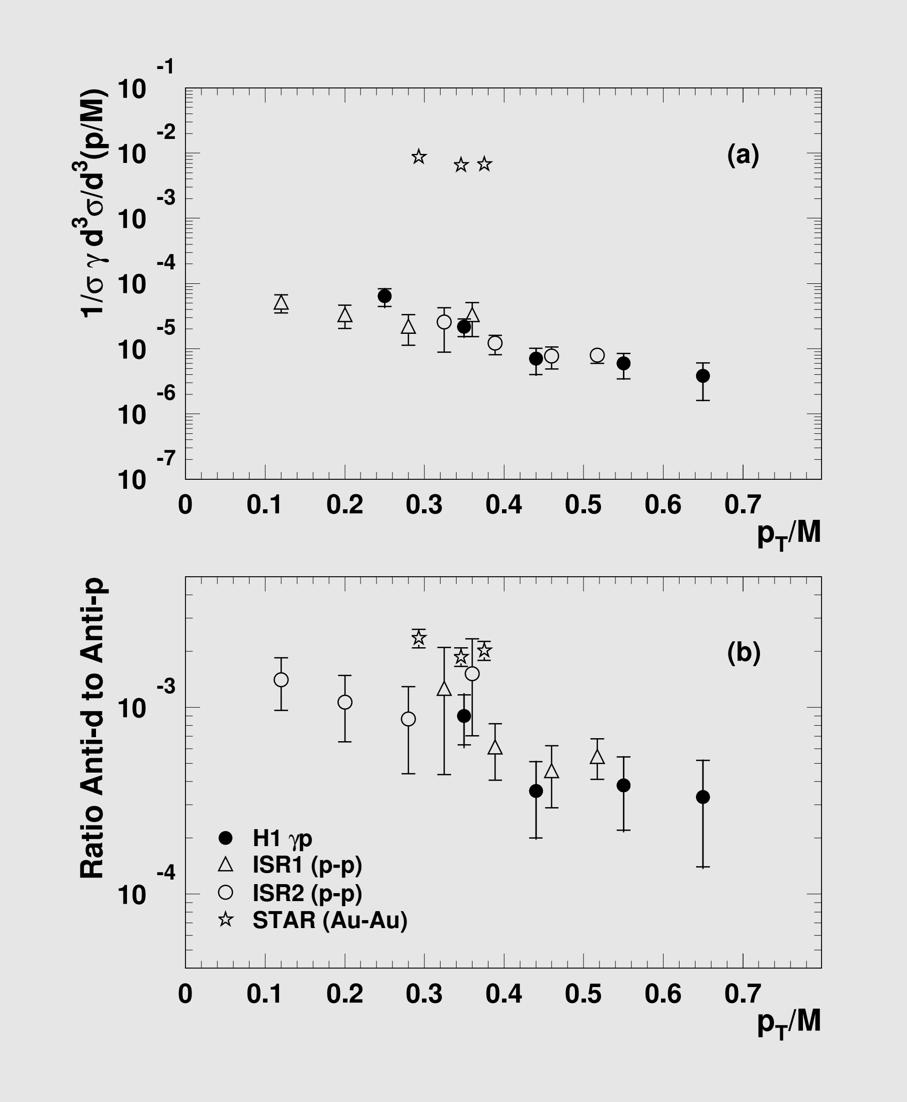
primary tracks
(ep and beam-gas distinguished by $z_{\rm vx}$)

secondary tracks from detector material

albedo deuterons (rejected by timing cut)

$\Rightarrow$ Antiparticle samples are cleaner

Anti-Deuterons: yield



- $\sigma(\bar{d}) = 2.7 \pm 0.5 \pm 0.2$ nb

  $\sigma(M_- > M_{\bar{d}}) < 0.19$ nb
  $\sigma(M_+ > M_t) < 0.19$ nb

  $(0.2 < p_t/M < 0.7, \; |y| < 0.4)$

- Invariant $\bar{d}$ cross sections are similar in pp and γp reactions, and both are way below then in heavy ion collisions

- Ratio $\bar{\mathrm{d}}/\bar{\mathrm{p}}$ only slightly smaller in ”elementary” reactions than at RHIC

Anti-Deuterons: Fireball size

- Coalescence model parameter

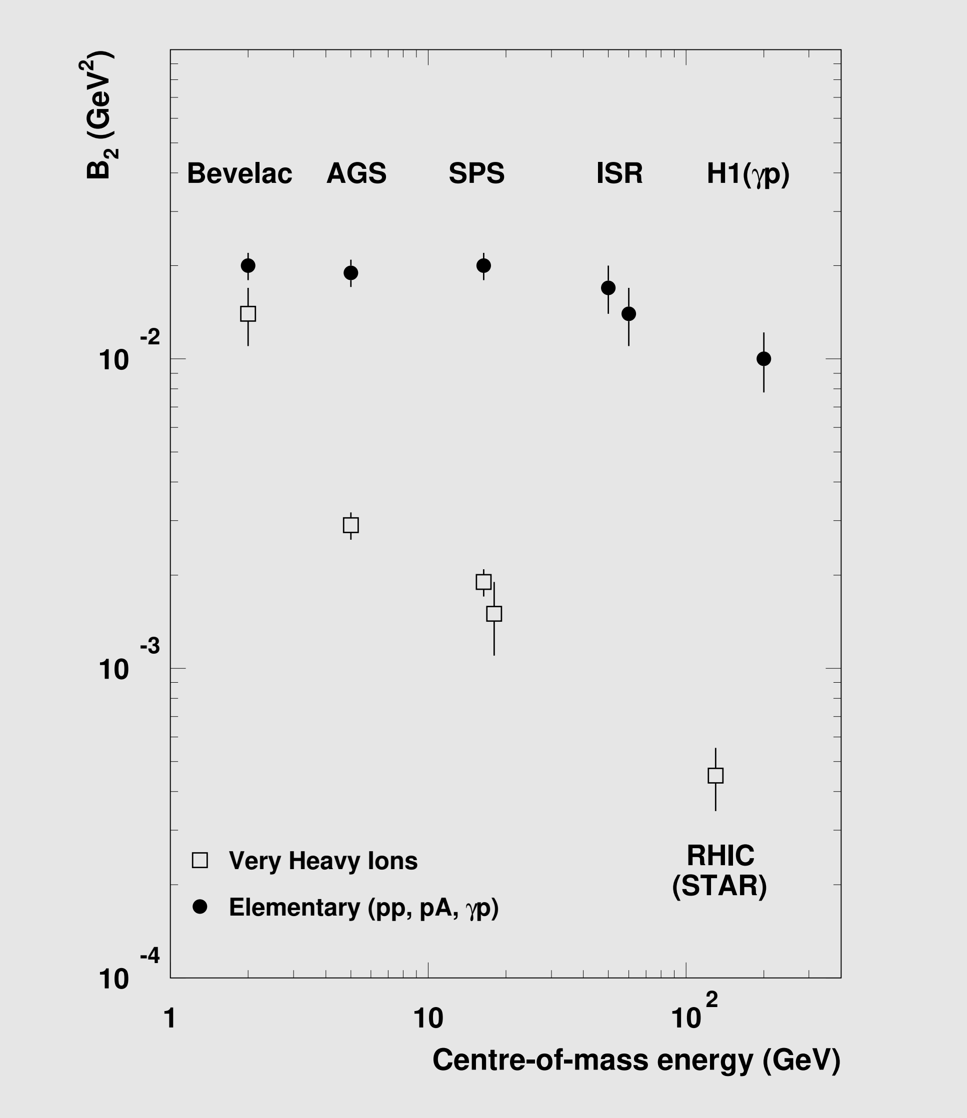
$$B_2 = \left(\frac{1}{\sigma}\frac{E_d d^3\sigma_d}{d^3P_d}\right) / \left(\frac{1}{\sigma}\frac{E_N d^3\sigma_N}{d^3p_N}\right)^2$$

  is inversly proportional to the size of interaction region (IR) at "freeze-out"

- Size of IR in γp and pp is smaller than in heavy ion collisions:

  $(\langle R_{(\mathrm{Au-Au})}\rangle / \langle R_{\gamma p}\rangle \simeq 5)$

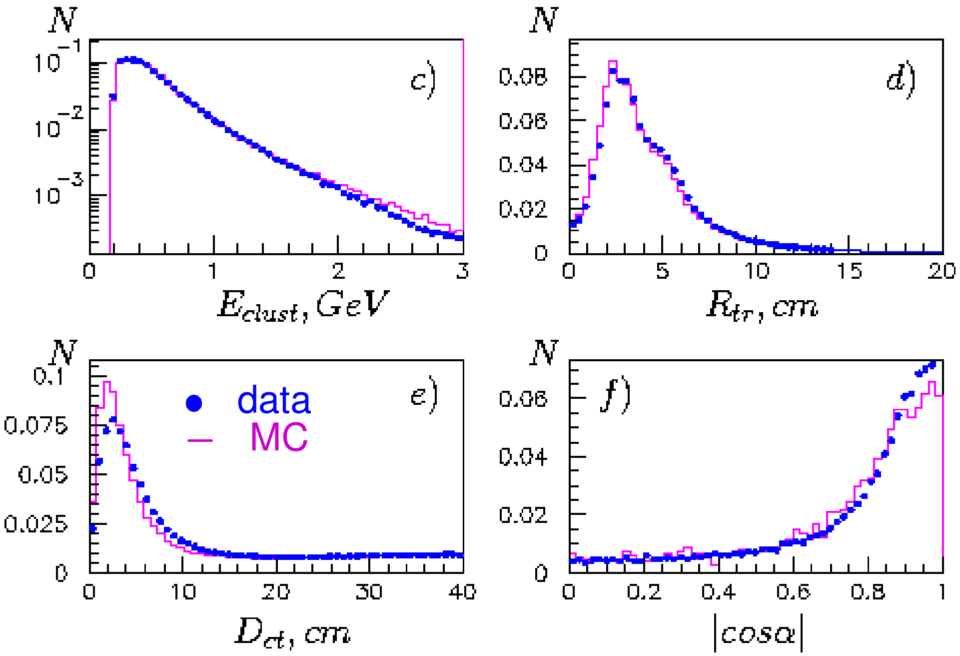
  and its increase with $c.m.s.$ energy is slower

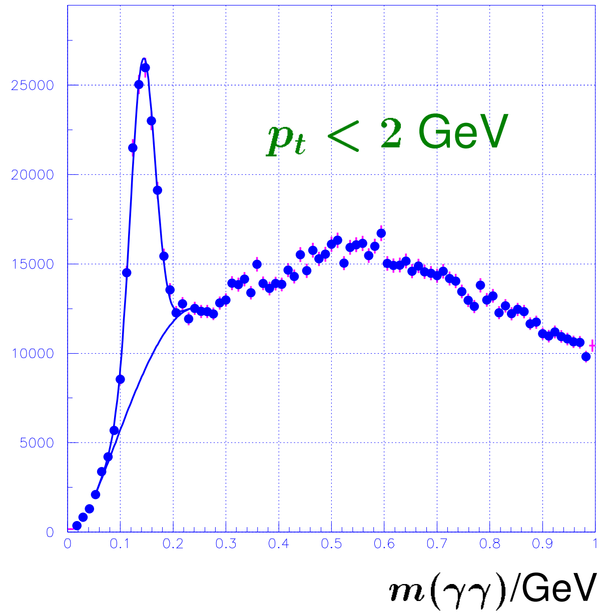


η-meson: Selecting γ's

Select photon candidates

- $\triangleright$ $E_{clust} > 200$ MeV ($E_{em}/E_{tot} > 0.9$)
- $\triangleright$ $0.5 < \theta_{lab} < 2.6$ ($|y_{lab}| < 1.0$)
- $\triangleright$ $R_{tr} <$ 8cm (compact cluster: e.m. nature)
- $\triangleright$ $D_{CT} >$ 15cm (no track associated)
- $\triangleright$ $|cos\alpha| < 0.7$ (decay angle cut against comb.bgr.)

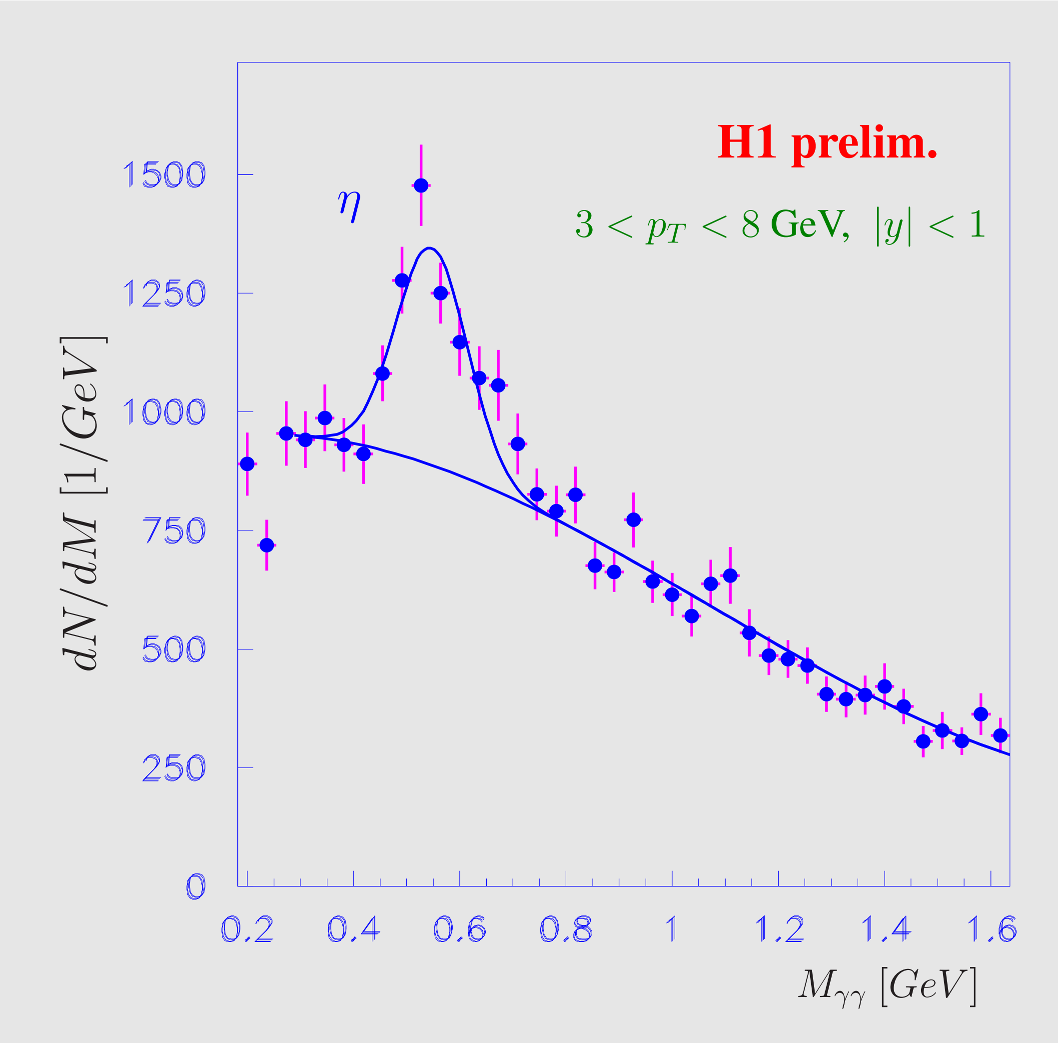




Use $\pi^0 \to \gamma\gamma$ signal to calibrate the calorimeter and to check π^0 yield vs $\pi^{+/-}$ $\Rightarrow$ OK

Determine $\epsilon_{rec}(\eta) = 29\% - 36\%$ from detailed MC simulation

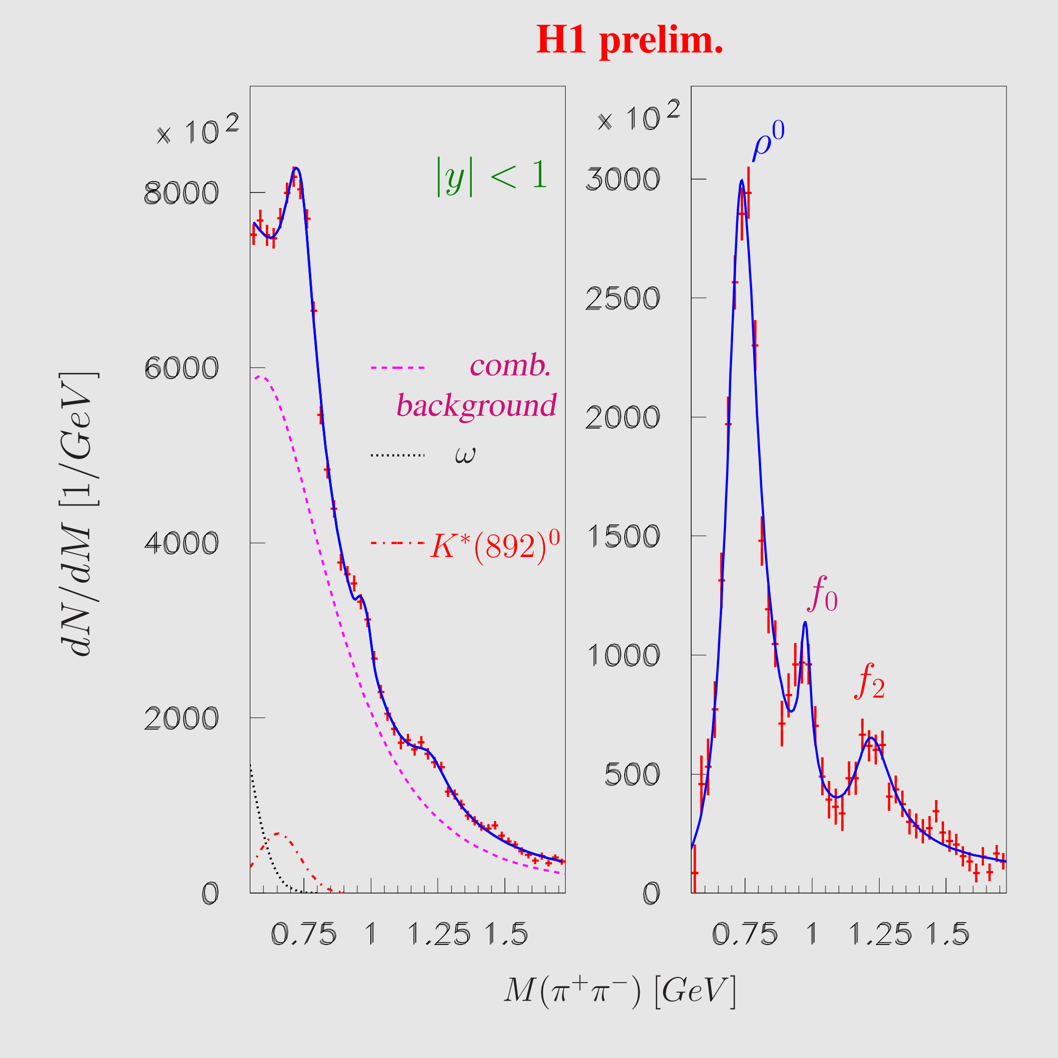
$\eta \to \gamma\gamma$ signal



Measurement range:
$3 < p_t < 8$ GeV/c, $|y_{\rm lab}| < 1$

- Low $p_t < 3$ GeV/c:
  large combinatorial background
- High $p_t > 8$ GeV/c:
  photon clusters start to merge
- Fit: Gaussian + polinomial bgr.
  with $M_\eta = M$(PDG) and σ(MC)

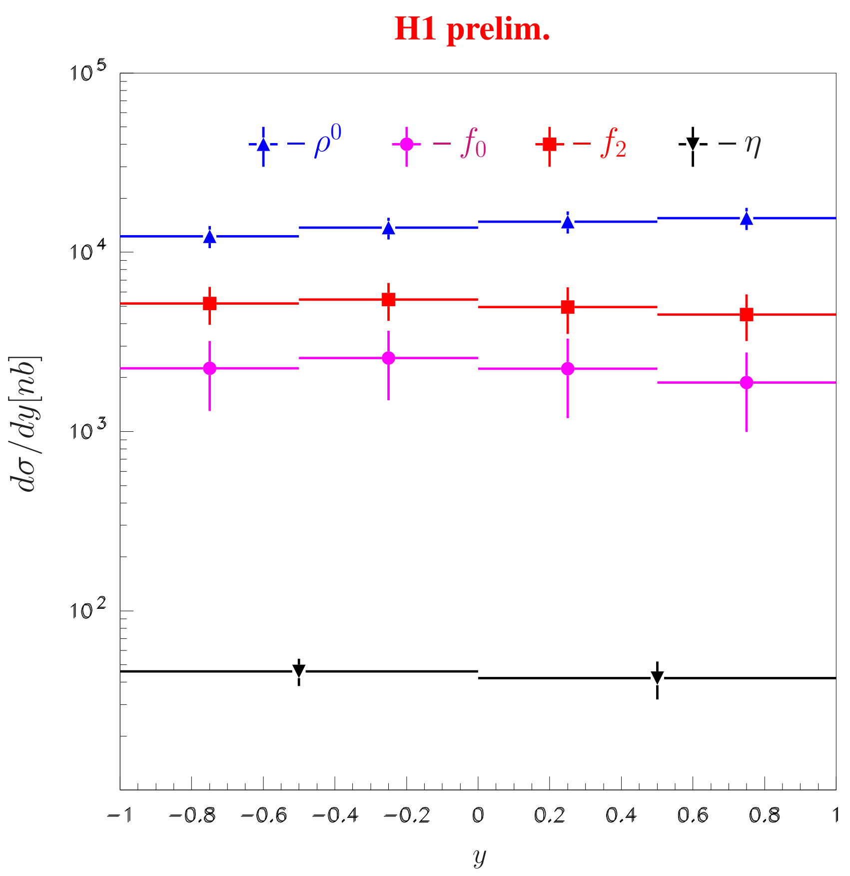
$\pi^+\pi^-$ mass spectra

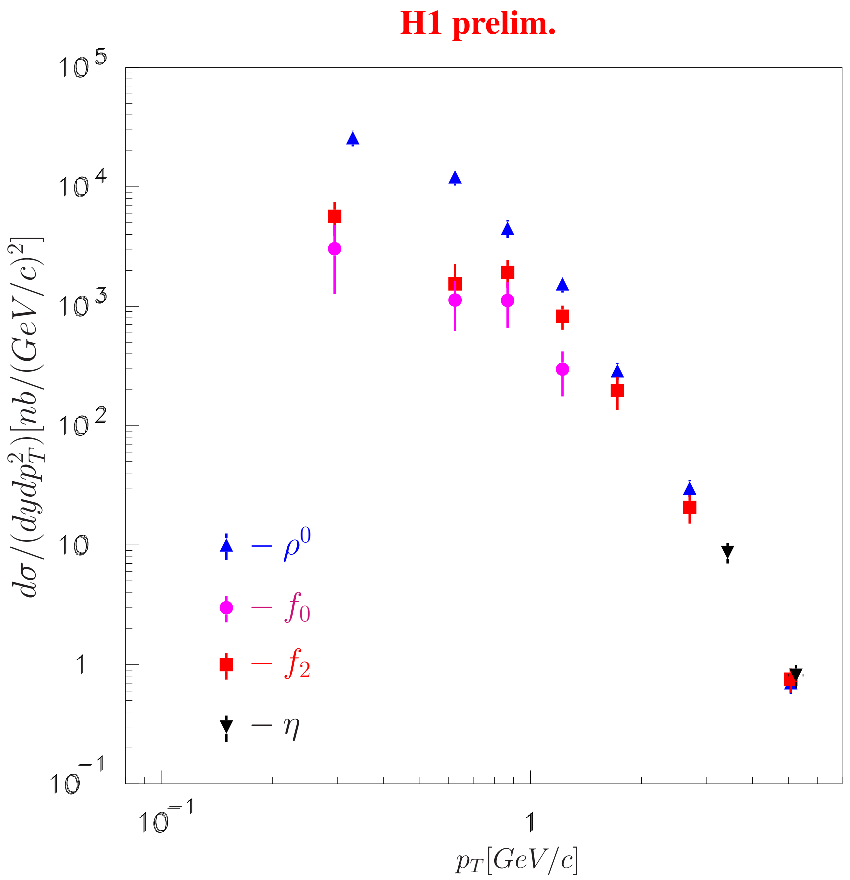


- Primary vertex fitted tracks:
  $p_t > 150$ MeV/c, $0.5 < \theta < 2.6$
- Subtract like-sign combinations:
  $f(m) = M(\pi^\pm\pi^\mp) - M(\pi^\pm\pi^\pm)$
- f(m)=BG(m)+$\sum$BW(m)+$\sum$Ref(m)
  (ρ^0, f_0, f_2 masses are fitted)
- Major reflections:
  $K^*(982) \rightarrow K^\pm\pi^\mp$ (K taken as π)
  $\omega(782) \rightarrow \pi^\pm\pi^\mp\pi^0$ (π^0 is lost)
- $\epsilon_{rec}(\pi^\pm\pi^\mp) = 50\% - 82\%$

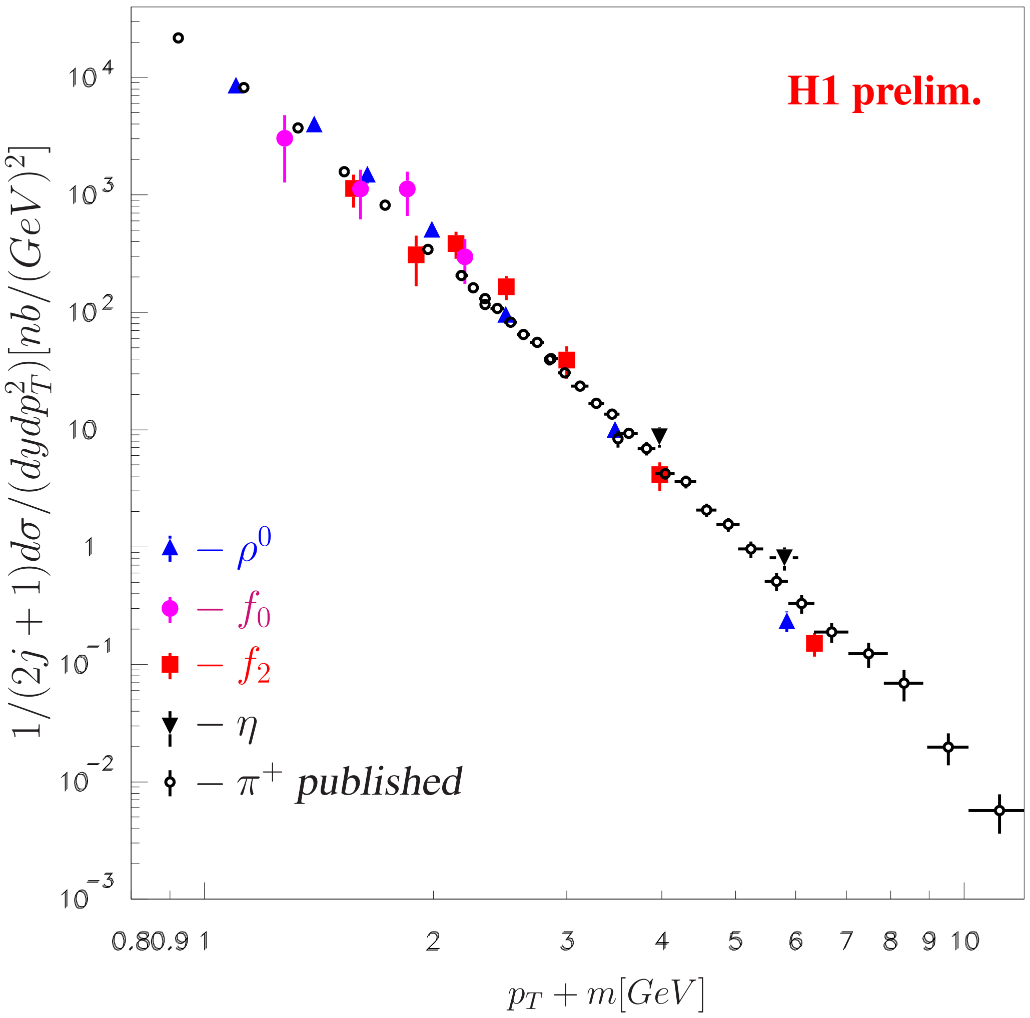
Light meson resonanses: Differential cross sections

$$\sigma_{\gamma p}(i) = \frac{N_{ep}(i)}{\mathcal{L}} \cdot \frac{1}{\mathcal{F}_\gamma} \cdot \frac{1}{A_{etag} \cdot \epsilon_{trig} \cdot \epsilon_{rec} \cdot Br(i)}$$





Scaling wrt $(p_t + m)$



- Light meson resonanses display same universal dependence as charged pions
- Photoproduction rate of hadrons found to be largely independent on their internal structure, except mass and spin
- Same production mechanism?
- Universal power law spanning from low to high p_t is non-trivial $\rightarrow$ thermodynamics?

Summary

- Photoproduction of Anti-Deuterons is measured for the first time
  - **Relative yield $R(\bar{d}/\bar{p})$ is found to be similar in γp and pp reactions and two times smaller than in heavy ion collisions**
  - **Coalescence model parameter B_2 indicates that the size of the interaction volume is smaller than in AA collisions and its increase with centre-of-mass energy is slower**

- Inclusive photoproduction of light meson resonances η, ρ^0, f_0 and f_2 is measured for the first time at HERA
  - **same scaling behaviour in dependence on $m + p_t$ is observed as for the long lived hadrons**
  - **universal power law suggests thermodynamic picture of particle production at high energies**

- These results are essential for the assesment of various experimental observations in heavy ion collisions in context of quark-gluon plasma formation