In-medium properties of the ω-meson near the productionthreshold

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for the A2 collaboration

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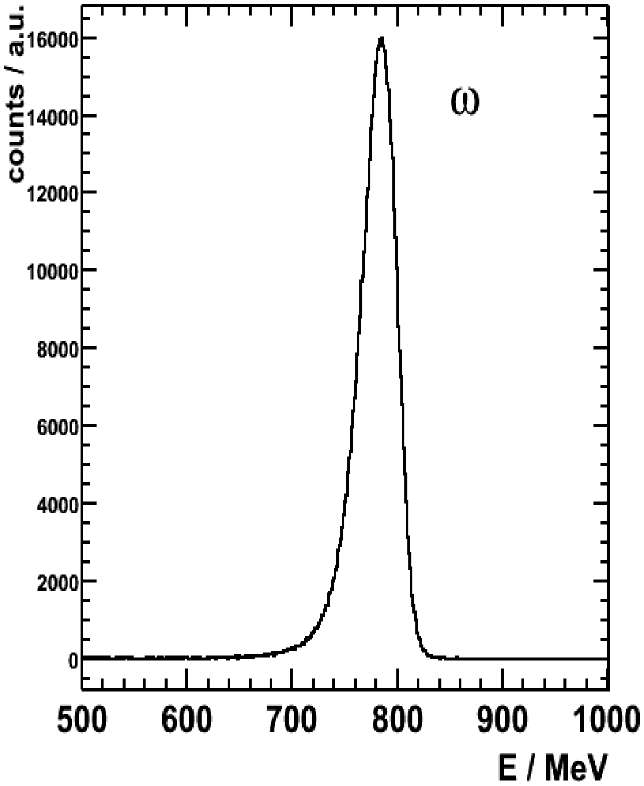
properties of the ω meson

well known for ρ=0:



m=782.65 MeV
Γ=8.49MeV

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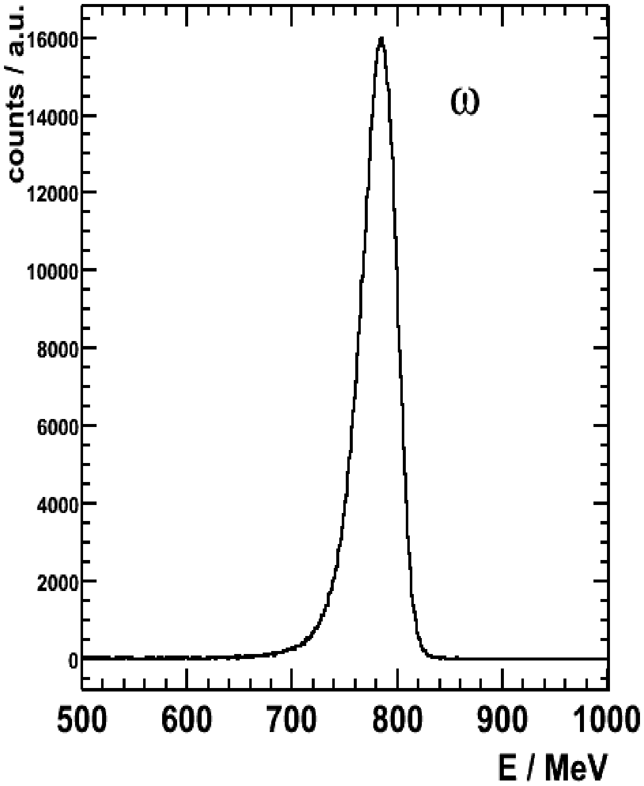

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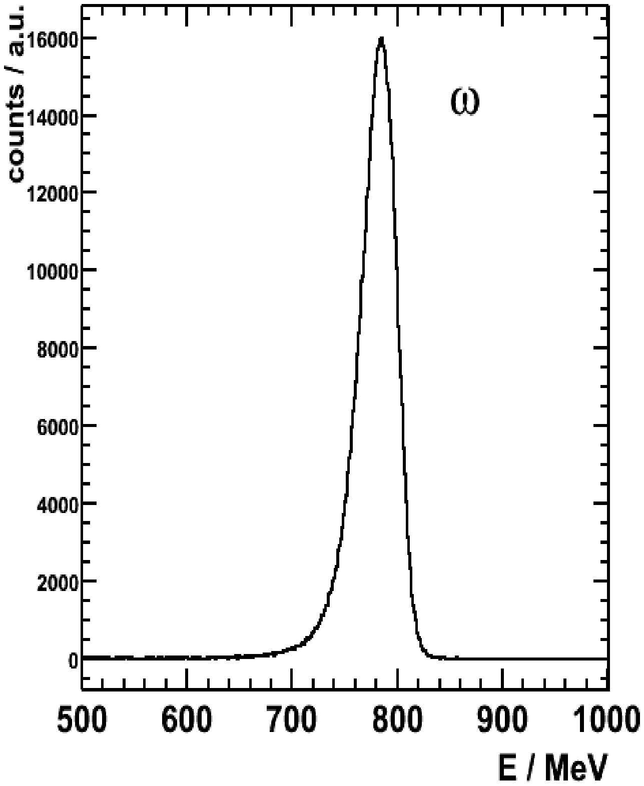
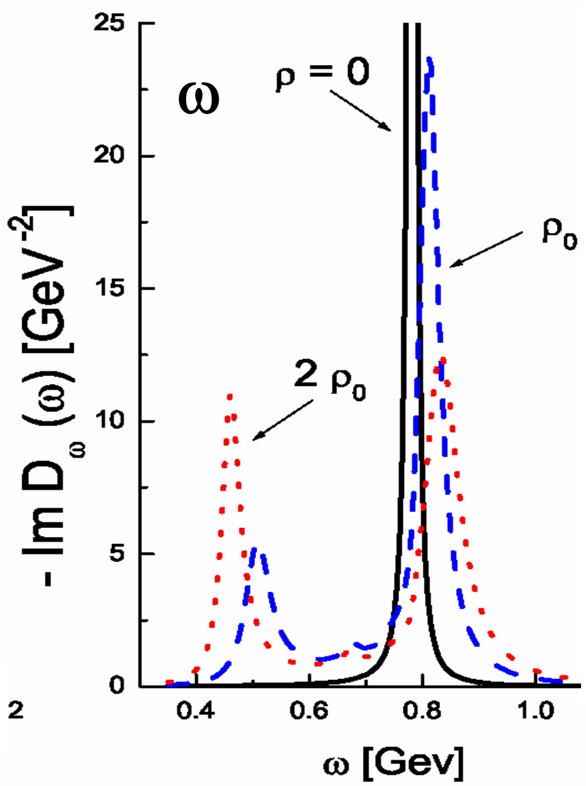
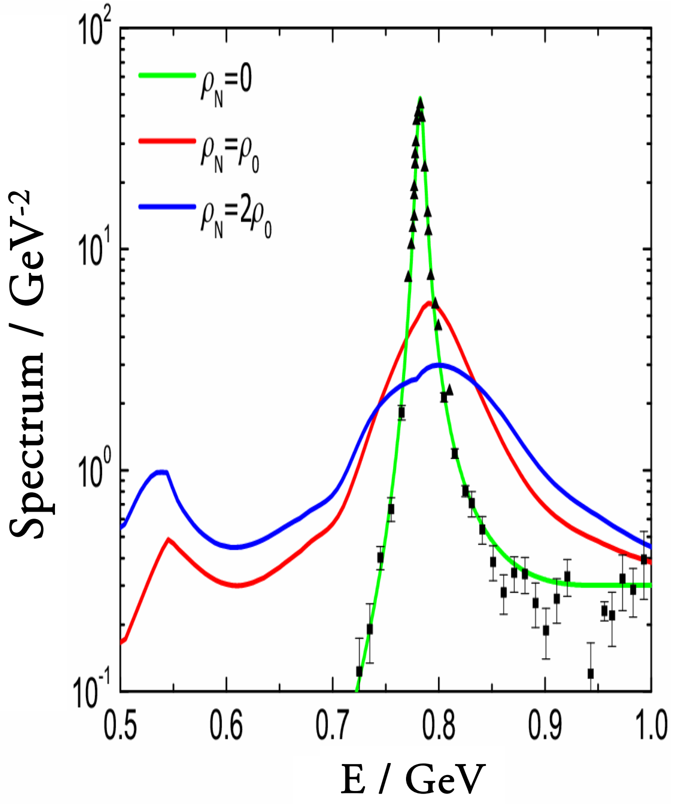




M. Lutz et al.
NPA 706 (2002) 431



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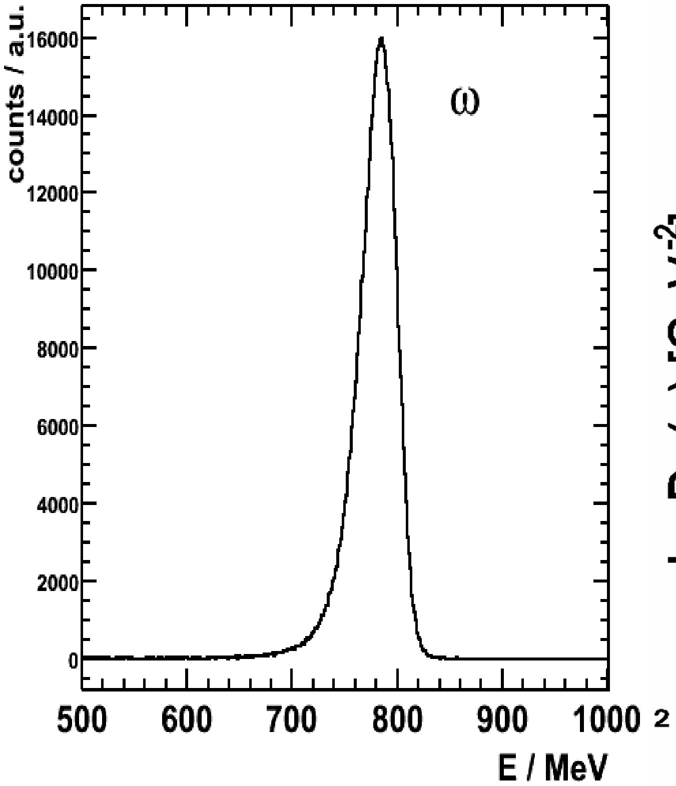

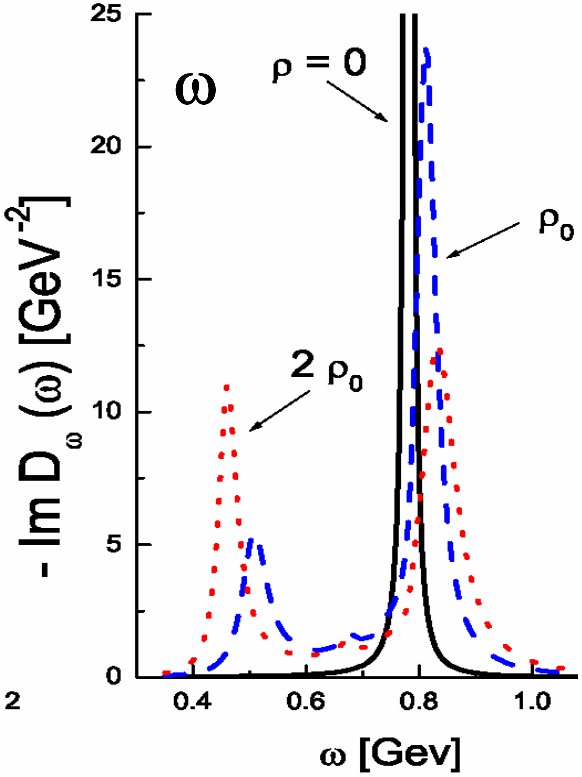

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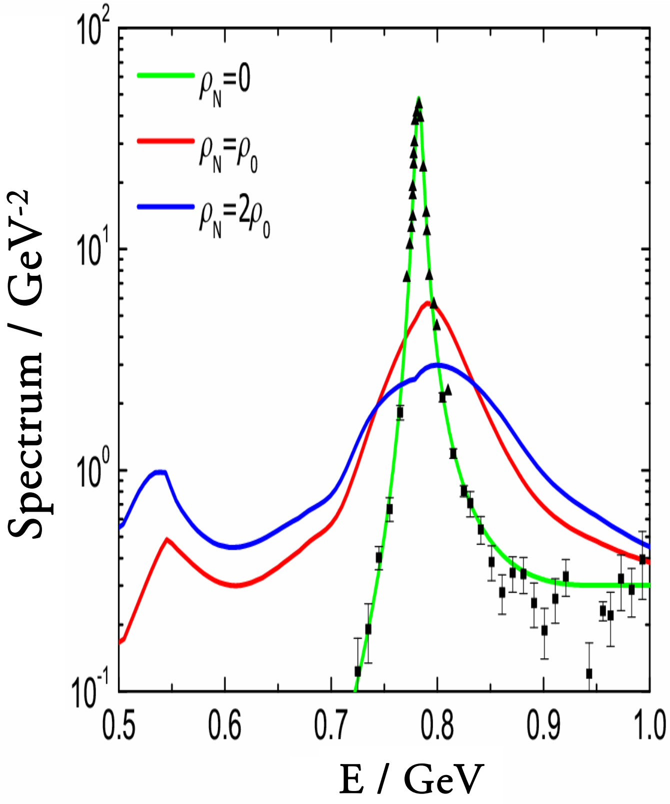

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m=782.65 MeV
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➡ what happens in a medium?

mass shift?
broadening?
structures?
} experimental task

exp. approaches for studying in-medium effects

- measurement of the meson lineshape: $\mathbf{H \rightarrow X_1 + X_2}$

  reconstruction of invariant mass
  from 4-momenta of decay products: $\mu(\vec{\mathbf{p}}, \rho, \mathrm{T}) = \sqrt{\mathbf{p}_1 + \mathbf{p}_2}$

  ➡ ensure that decays occur in the medium:
  - select shortlived mesons: $s = \beta\gamma \cdot c\tau \approx 1.3\ \mathrm{fm}(\rho);\ 23\ \mathrm{fm}(\omega);\ 46\ \mathrm{fm}(\phi)$
  - cut on low meson momenta for ω and ϕ mesons

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  sensitive to nuclear density at decay point!

- measurement of the momentum distribution:

  in case of a dropping in-medium mass:
  when leaving the nucleus hadron has to become on-shell;
  mass generated at the expense of kinetic energy;

  sensitive to nuclear density at production point!

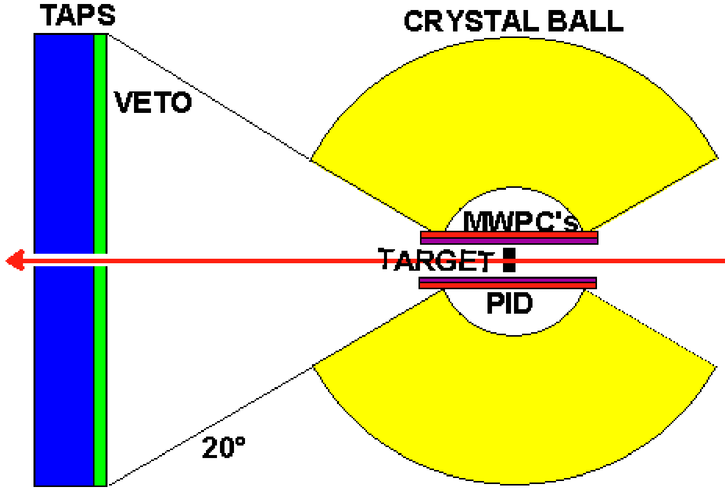
  ➡ *advantage: independent of meson lifetime!*

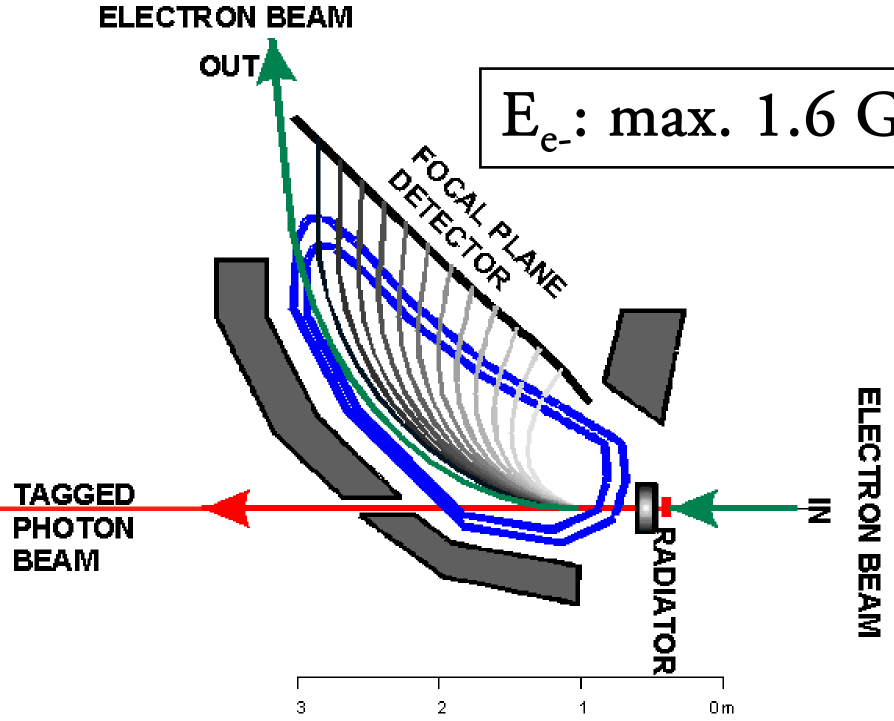
Crystal Ball and TAPS @ MAMI, Mainz

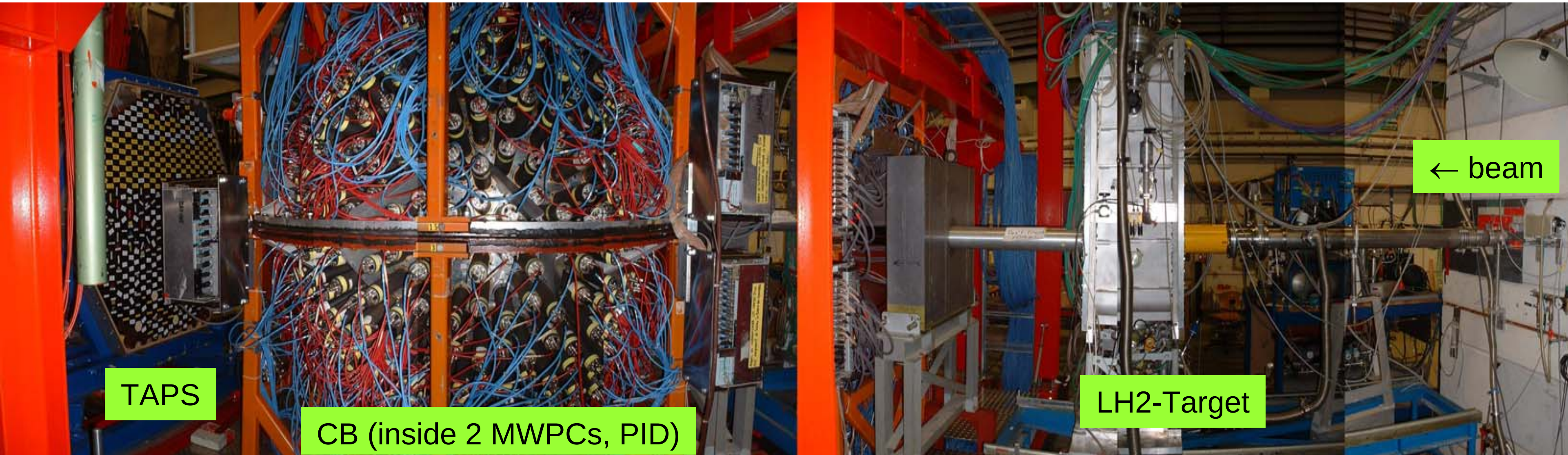
- ❖ TAPS ϑ coverage: 1° - 20°
- ❖ CB ϑ coverage: 20° - 160°

➡ 4π setup

E_{e-}: max. 1.6 GeV







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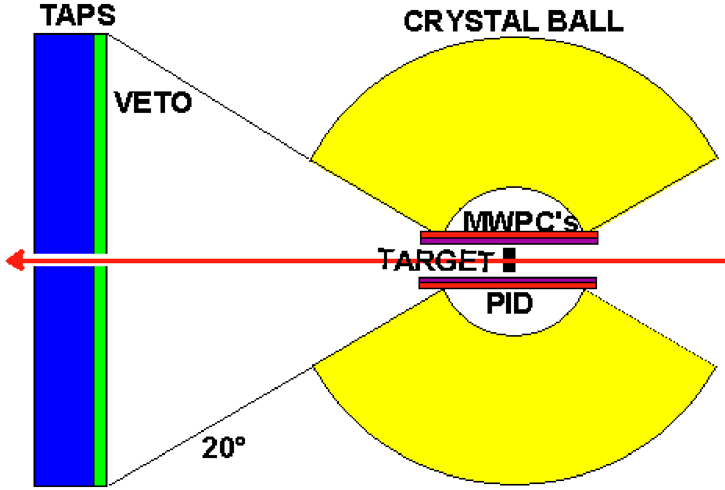
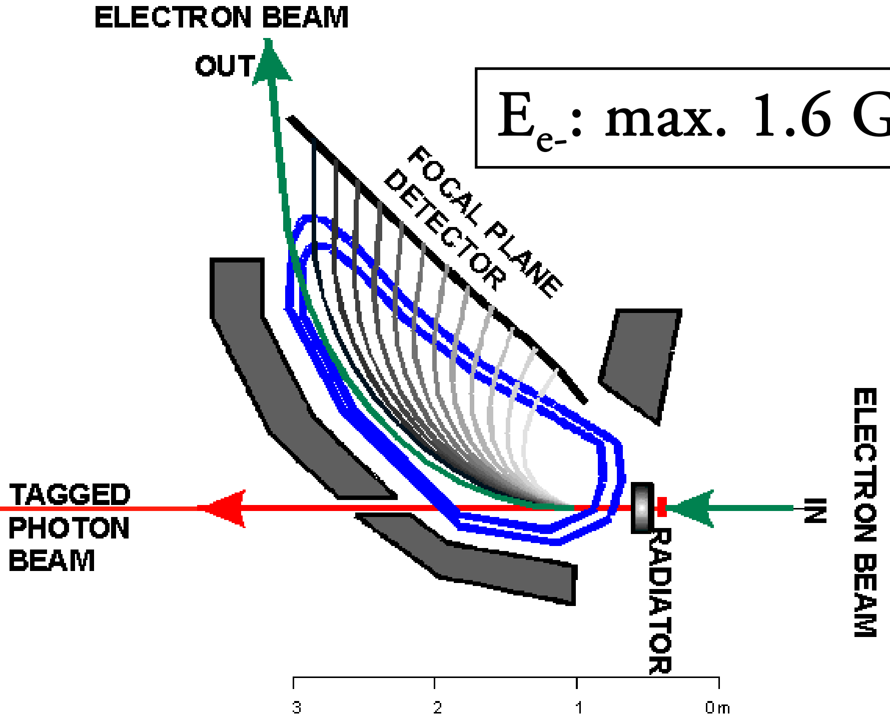
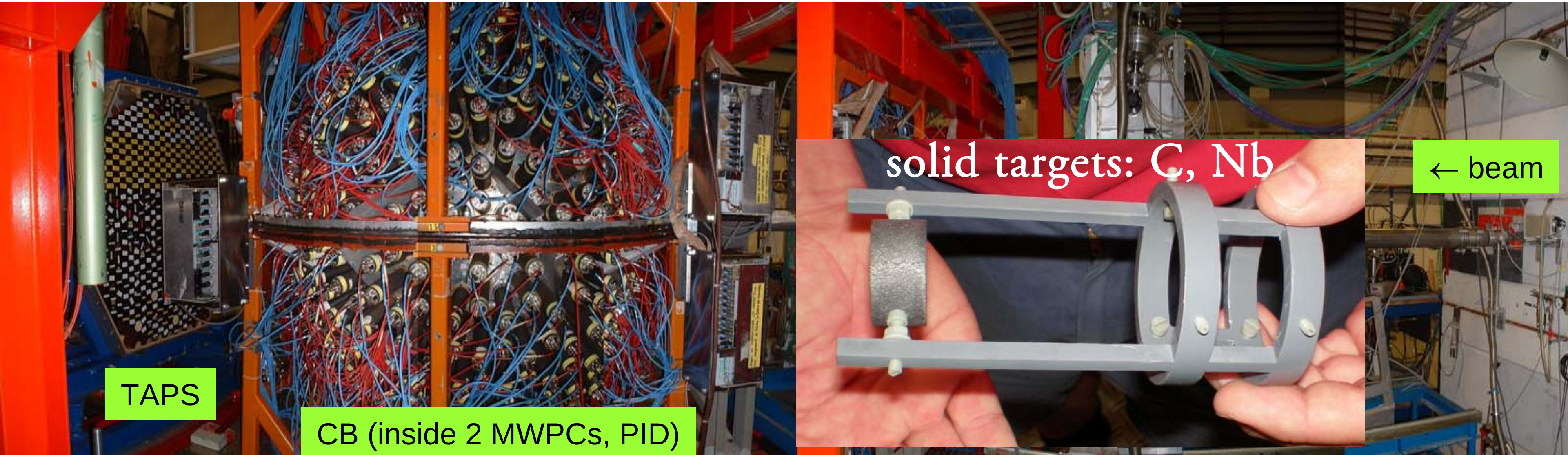
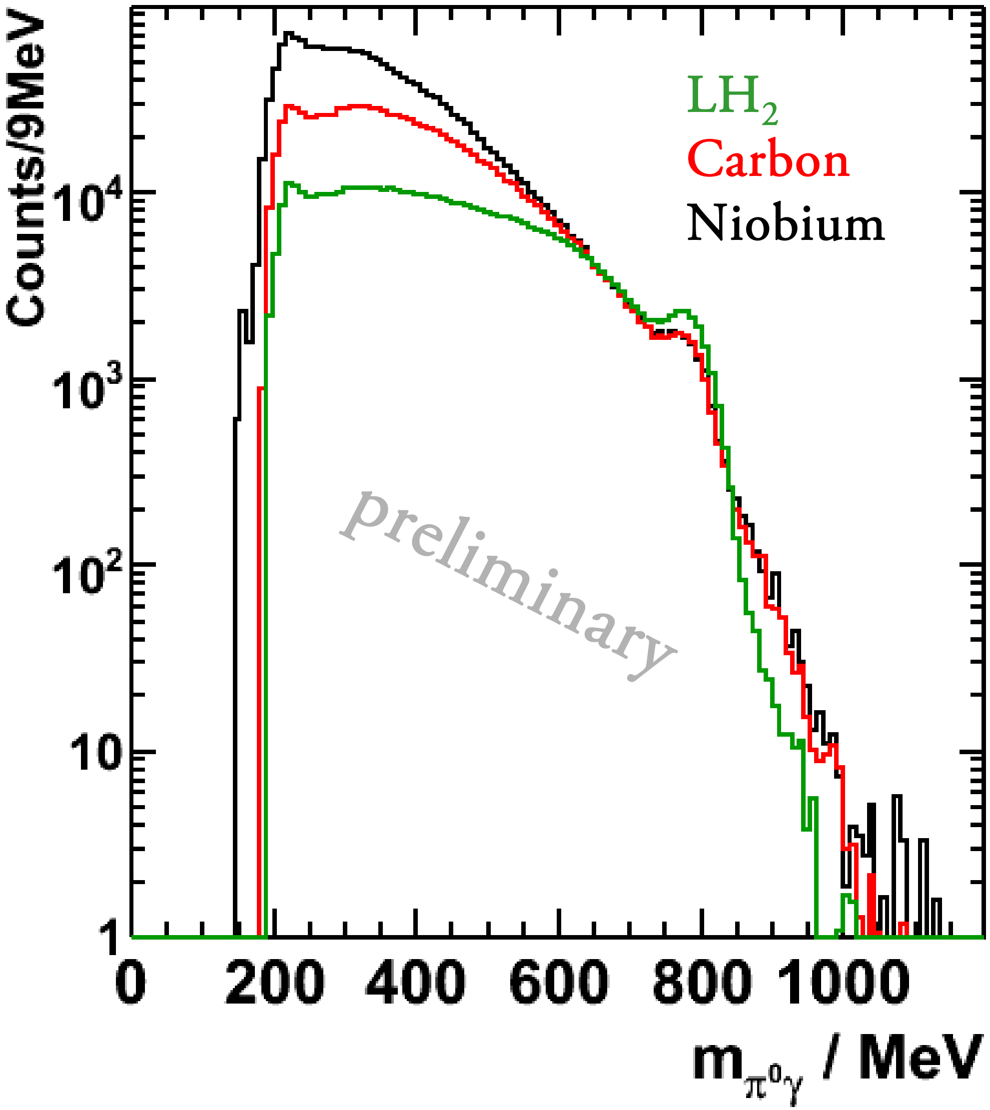






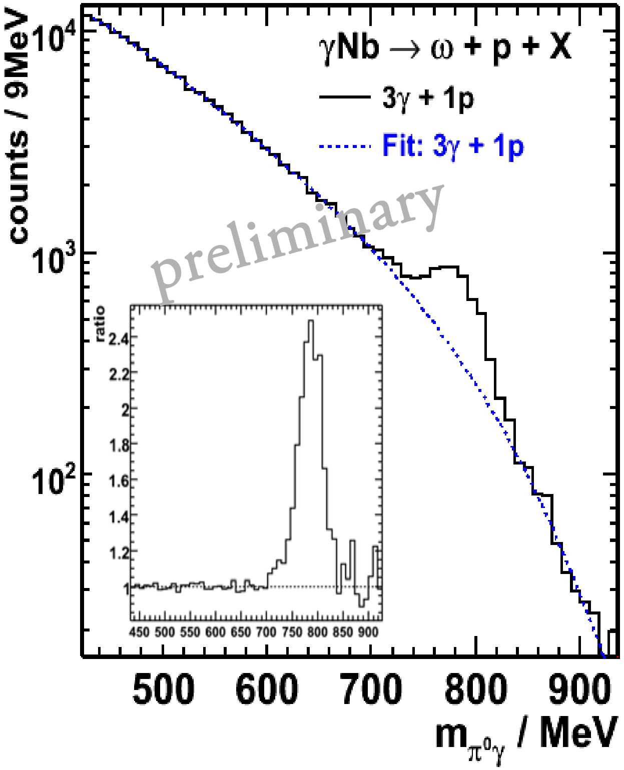
$\omega \rightarrow \pi^0\gamma$ invariant mass spectrum

hadronic decay channel: $\gamma A \rightarrow (A-1)\omega p \rightarrow (A-1)\pi^0\gamma p \rightarrow (A-1)\gamma\gamma\gamma p$



background determination: 2 approaches

background determined by fitting



average deviation from 1.0 in the mass range 430 – 650 MeV: 1%

background determination: 2 approaches

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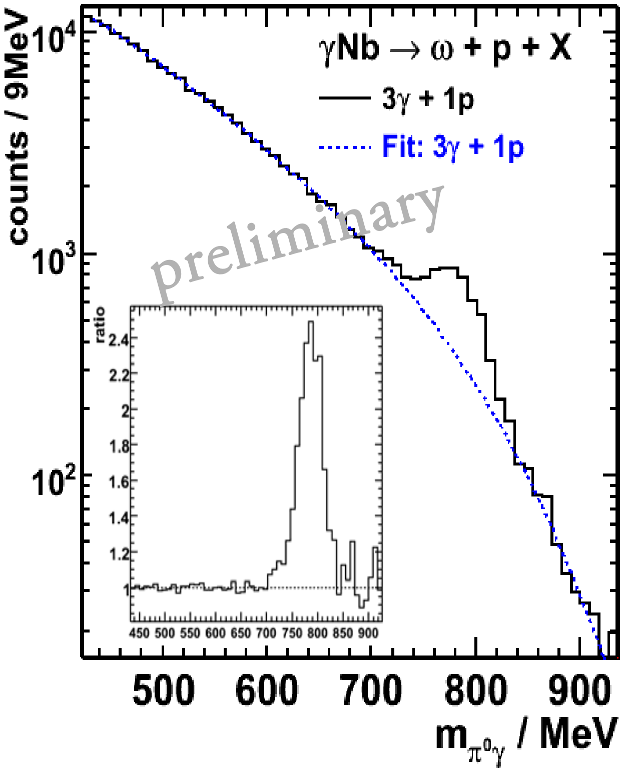
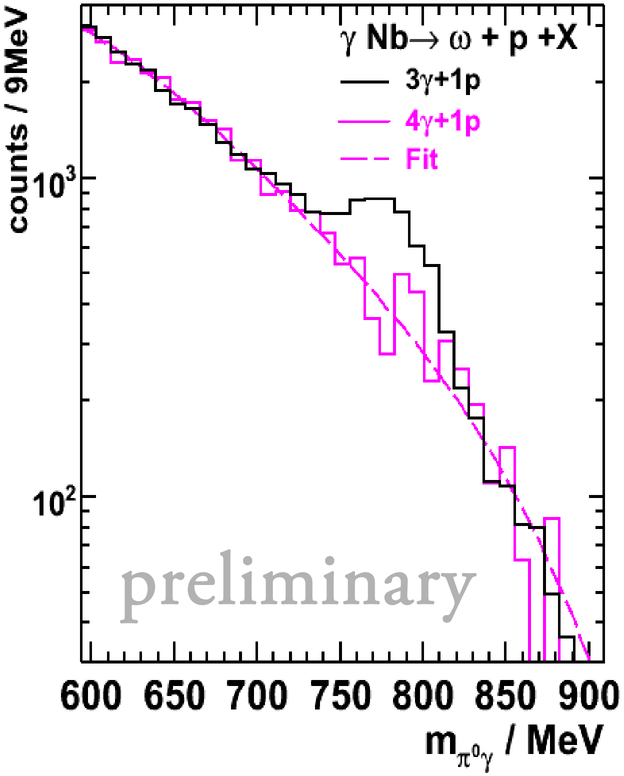


average deviation from 1.0 in the mass range 430 – 650 MeV: 1%

background determined from data



selecting 4γ and 1proton, omitting 1γ randomly

(M. Nanova et al., PRC 82 (2010), 035209)

background determination: 2 approaches

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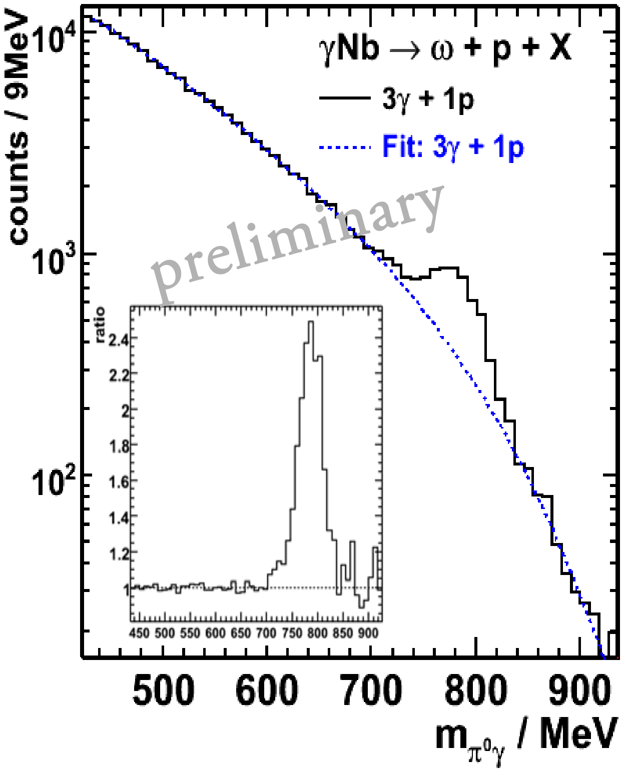

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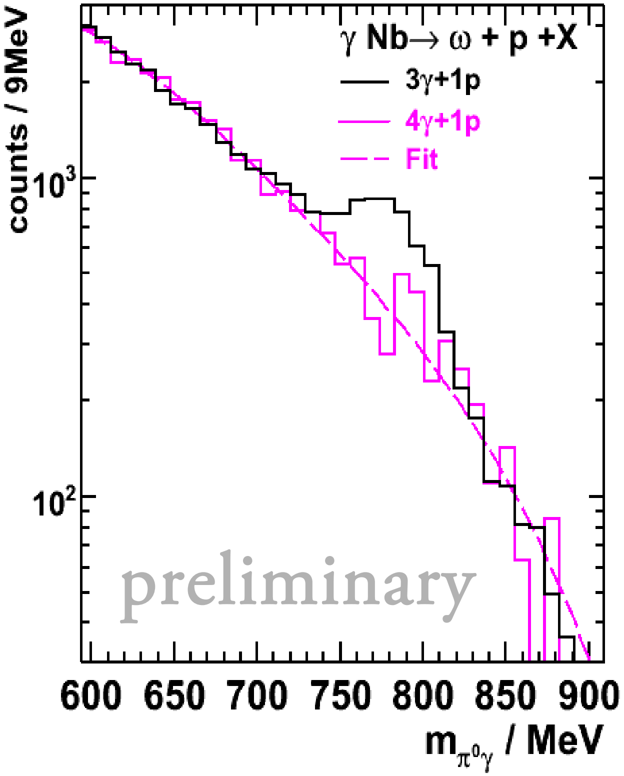

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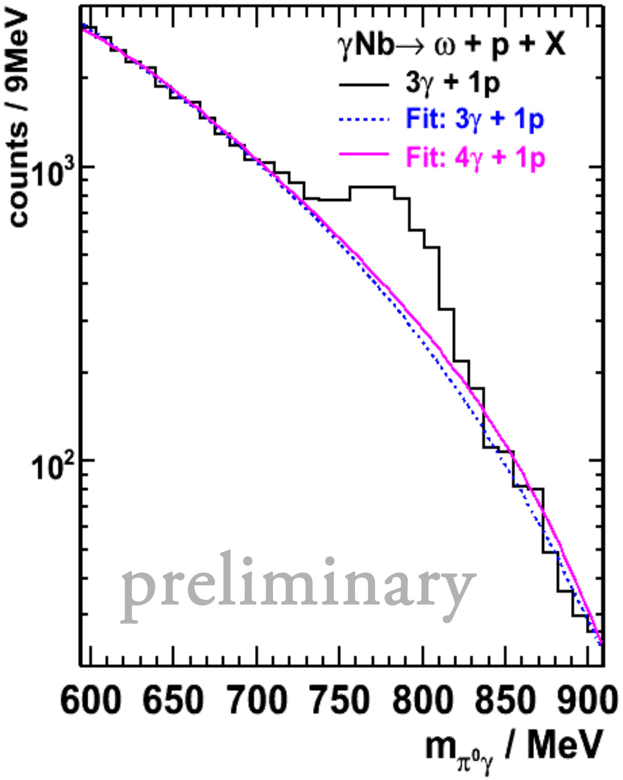
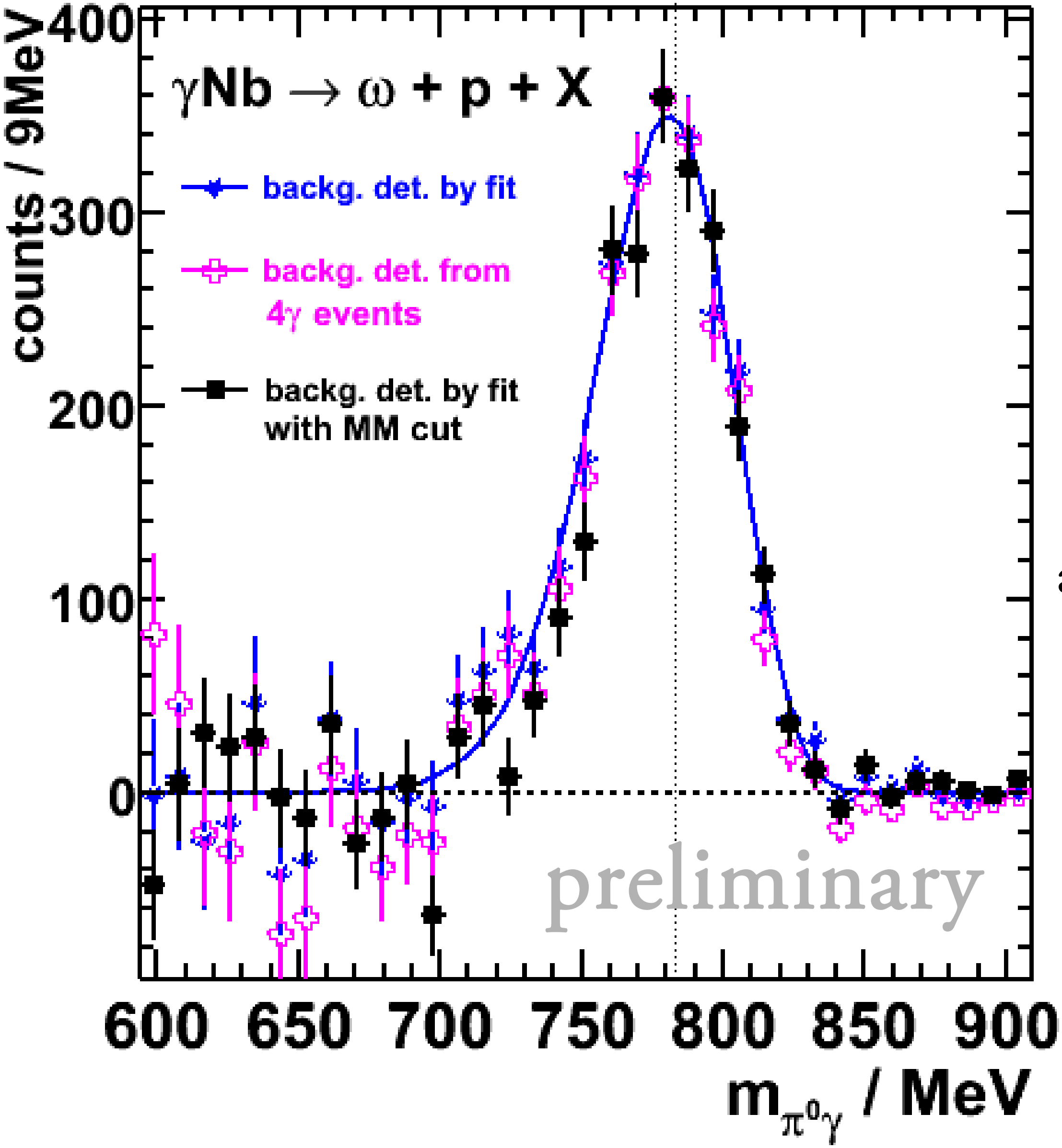
comparison of both approaches



agreement within 2%
in the lower
mass range
near the ω signal

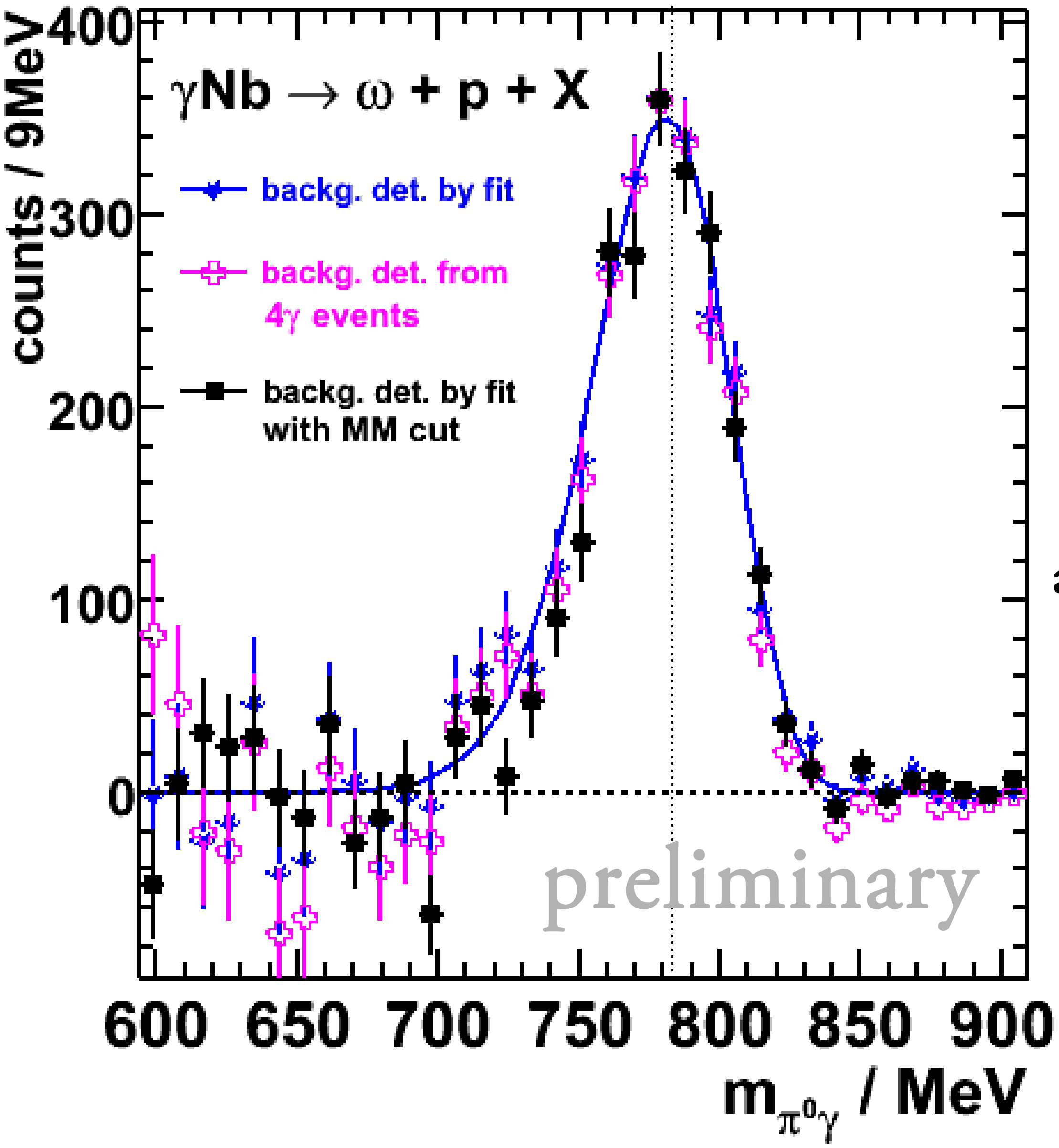
comparison of ω signal lineshapes



ω signal lineshapes
in good agreement
for the two different
background
determination methods

in addition:
applying a missing-mass cut
and determine the background
by a fit

comparison of ω signal lineshapes



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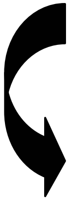
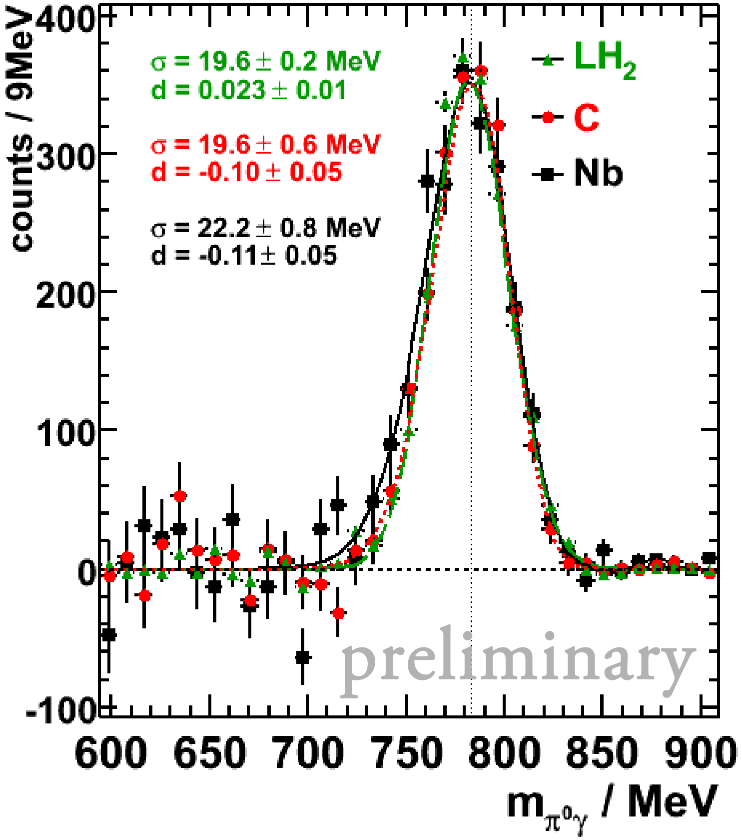


the signal obtained
with missing-mass cut
has slightly better
resolution

comparison of ω signal for different nuclei

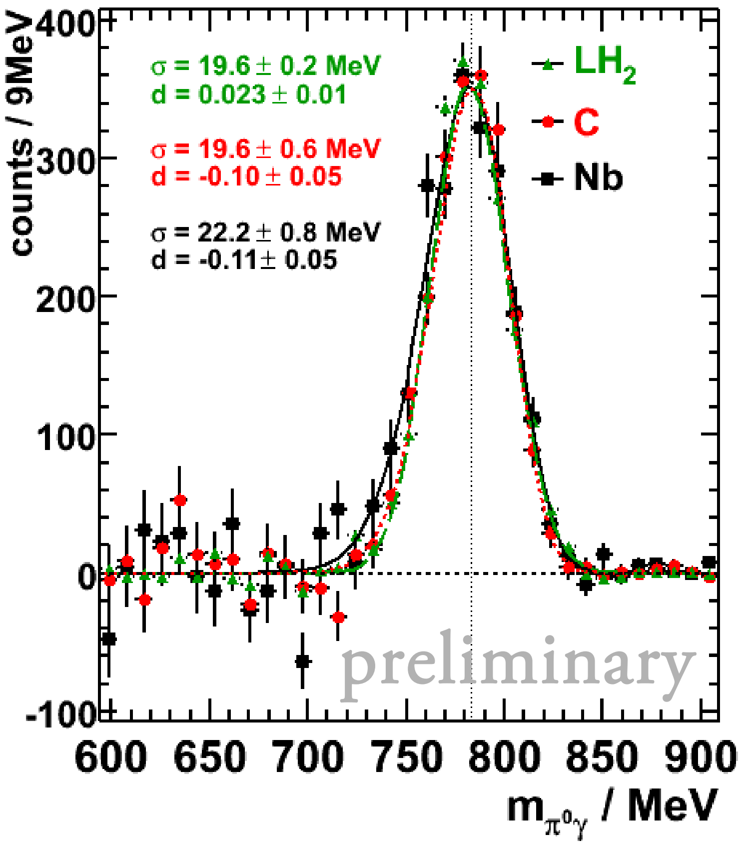


with missing-mass cut

ω-meson lineshape in good agreement for C und Nb target slightly broader compared to LH$_2$ signal

comparison of ω signal for different nuclei

with missing-mass cut



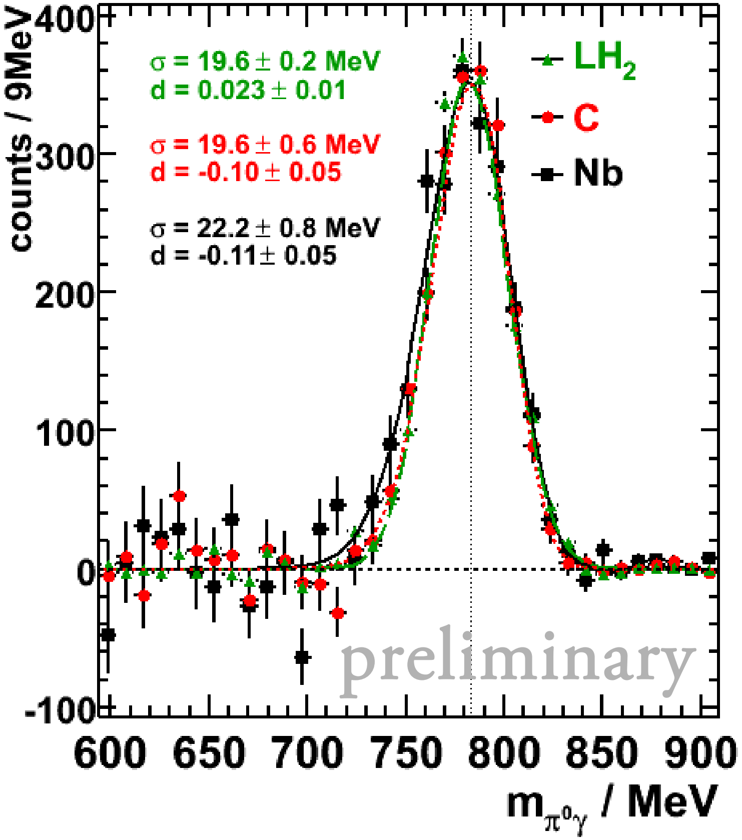
ω-meson lineshape in good agreement for C und Nb target slightly broader compared to LH_2 signal

➡ is this consistent with an in-medium broadening ($\Gamma_{med} \approx 150$ MeV) determined from the Transparency ratio?

(M. Kotulla et al., PRL 100 (2008), 192302)

comparison of ω signal for different nuclei

with missing-mass cut



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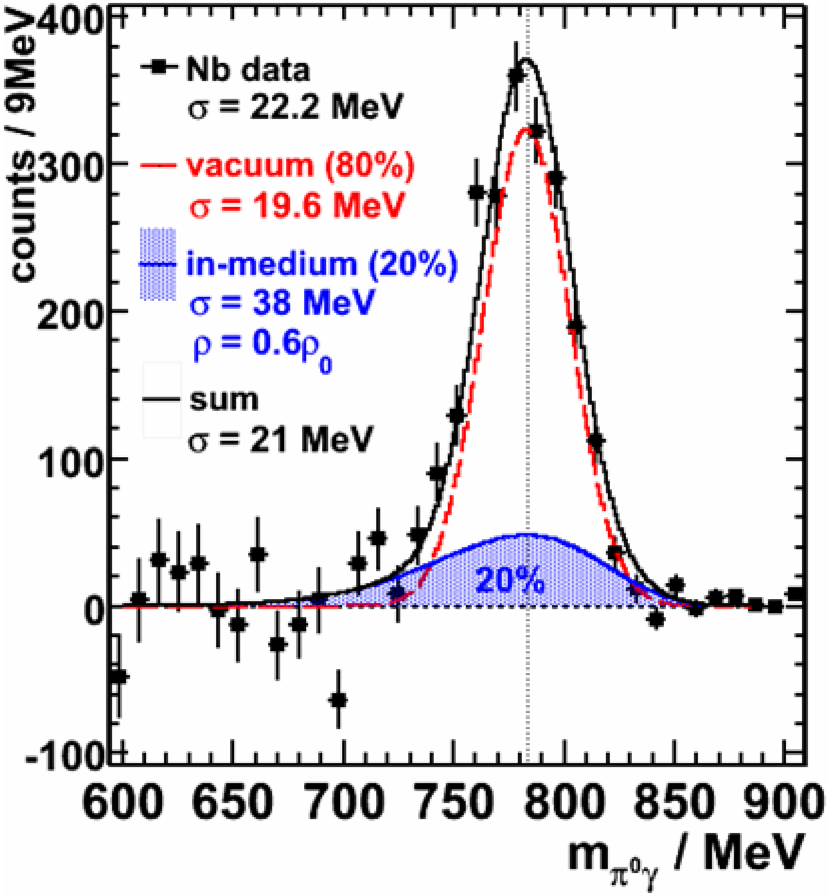
test on the sensitivity to in-medium signal



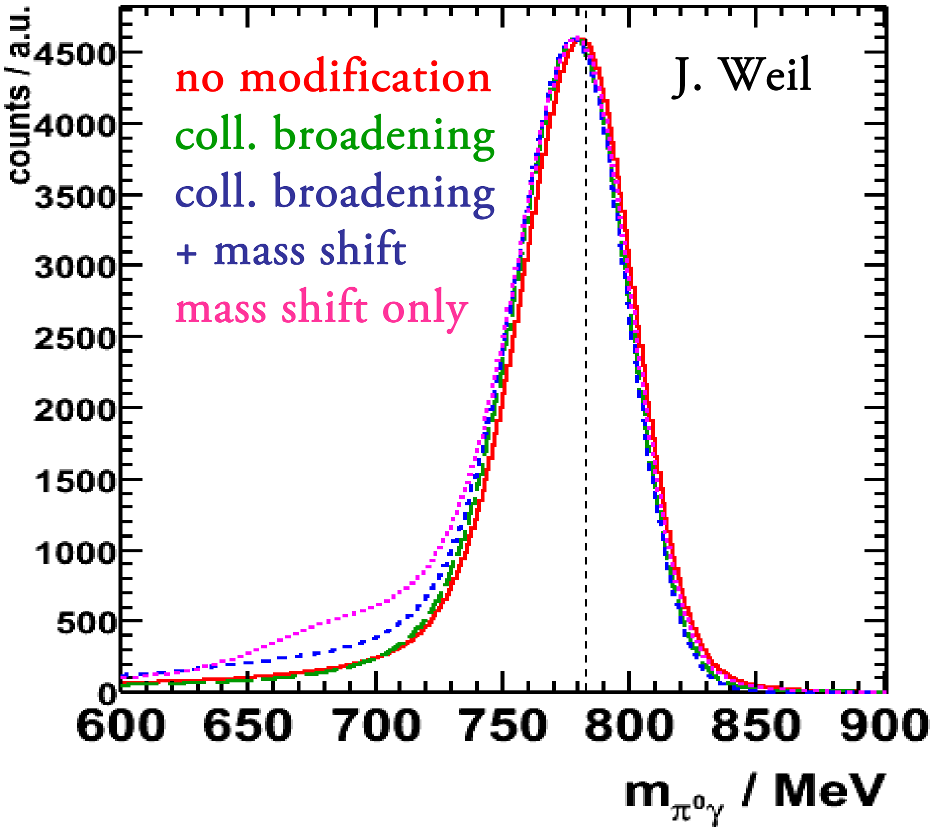
GiBUU simulations (J. Weil)

energy range: 900 – 1300 MeV (E_{thresh} = 1108 MeV)

4 scenarios:
- ❖ no in-medium modification
- ❖ collisional broadening (Γ_{med} = 150MeV)
- ❖ coll. broadening plus mass shift
- ❖ mass shift (-16%)

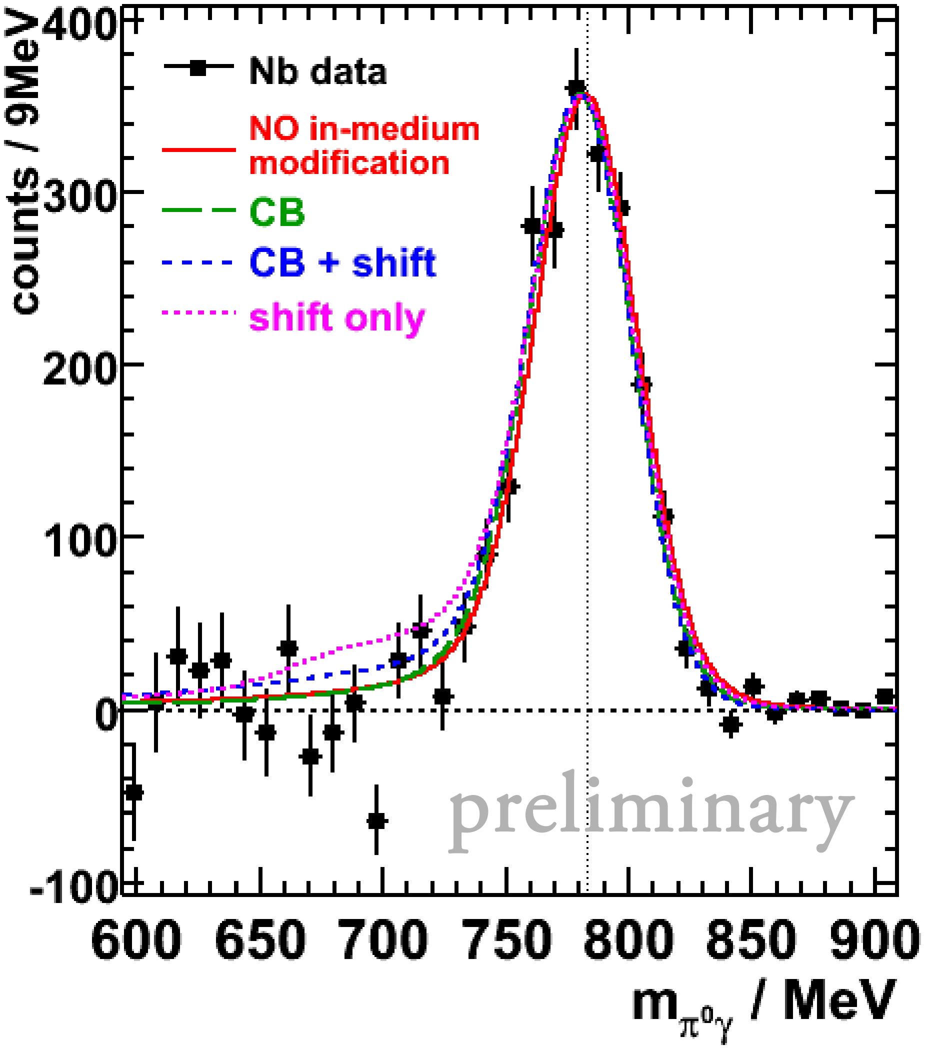
$$m = m_0\left(1+\alpha\frac{\rho}{\rho_0}\right)$$

with α = -0,16



only small difference
in lineshape
for the 4 scenarios

comparison exp. data to GiBUU (J. Weil / U. Mosel)



GiBUU (for Nb target):

- no in-medium modification
- collisional broadening (Γ_{med} = 150 MeV)
- collisional broadening plus mass shift (Γ_{med} = 150 MeV, α = -0.16)
- mass shift only (α = -0.16)

data disfavour „mass shift only“ scenario

limited sensitivity to in-medium signal

- experimentally observed mass distribution = convolution of spectral function with branching ratio into channel being studied

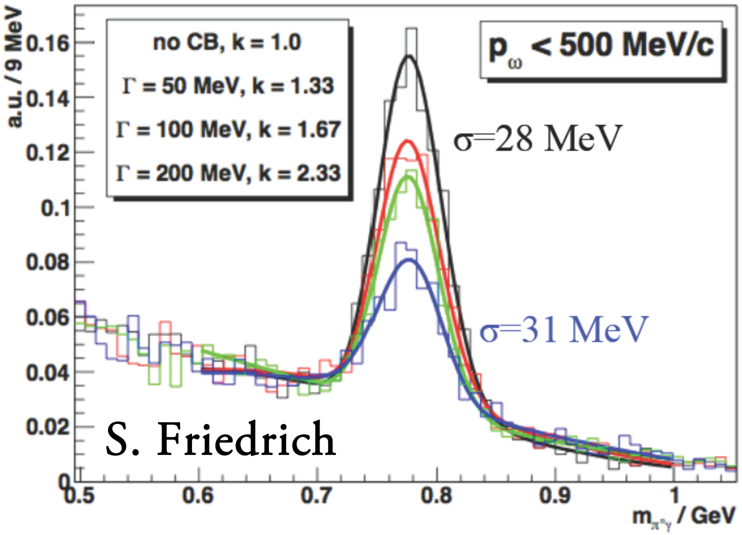
$$\frac{d\sigma_{H\to X_1X_2}}{d\mu} \sim A(\mu)\cdot\frac{\Gamma_{V\to\text{final state}}}{\Gamma_{tot}} = \frac{\mu\cdot\Gamma_{tot}}{\left(\mu^2-m_V^2\right)^2+\mu^2\Gamma_{tot}^2}\cdot\frac{\Gamma_{V\to\text{final state}}}{\Gamma_{tot}}$$

(F. Eichstaedt et al., Prog. Theo. Phys. Suppl. 168 (2007) 495)

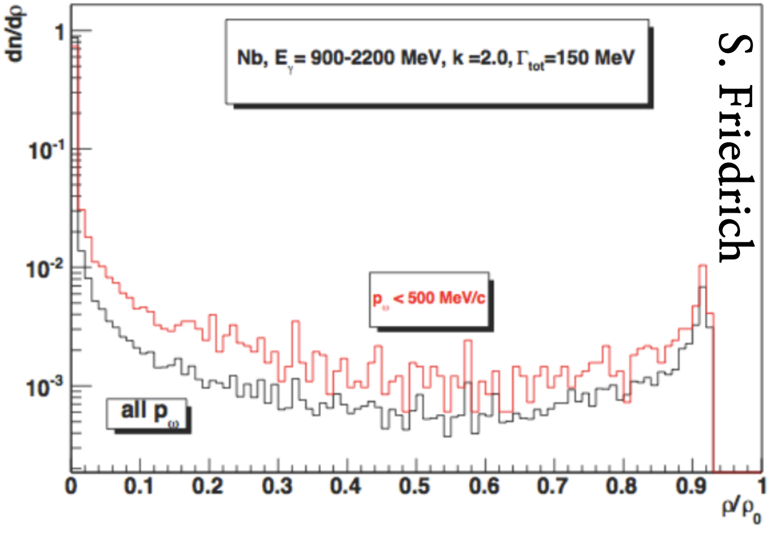
3 effects limit sensitivity:

- ω yield reduced by increase of in-medium width ($\Gamma_{med} \approx 16\cdot\Gamma_{vac}$)
- spread out in mass
- only 20% of all ω decays occur at $\rho > 0.1\rho_0$

(M. Kotulla et al., PRL 100 (2008), 192302)



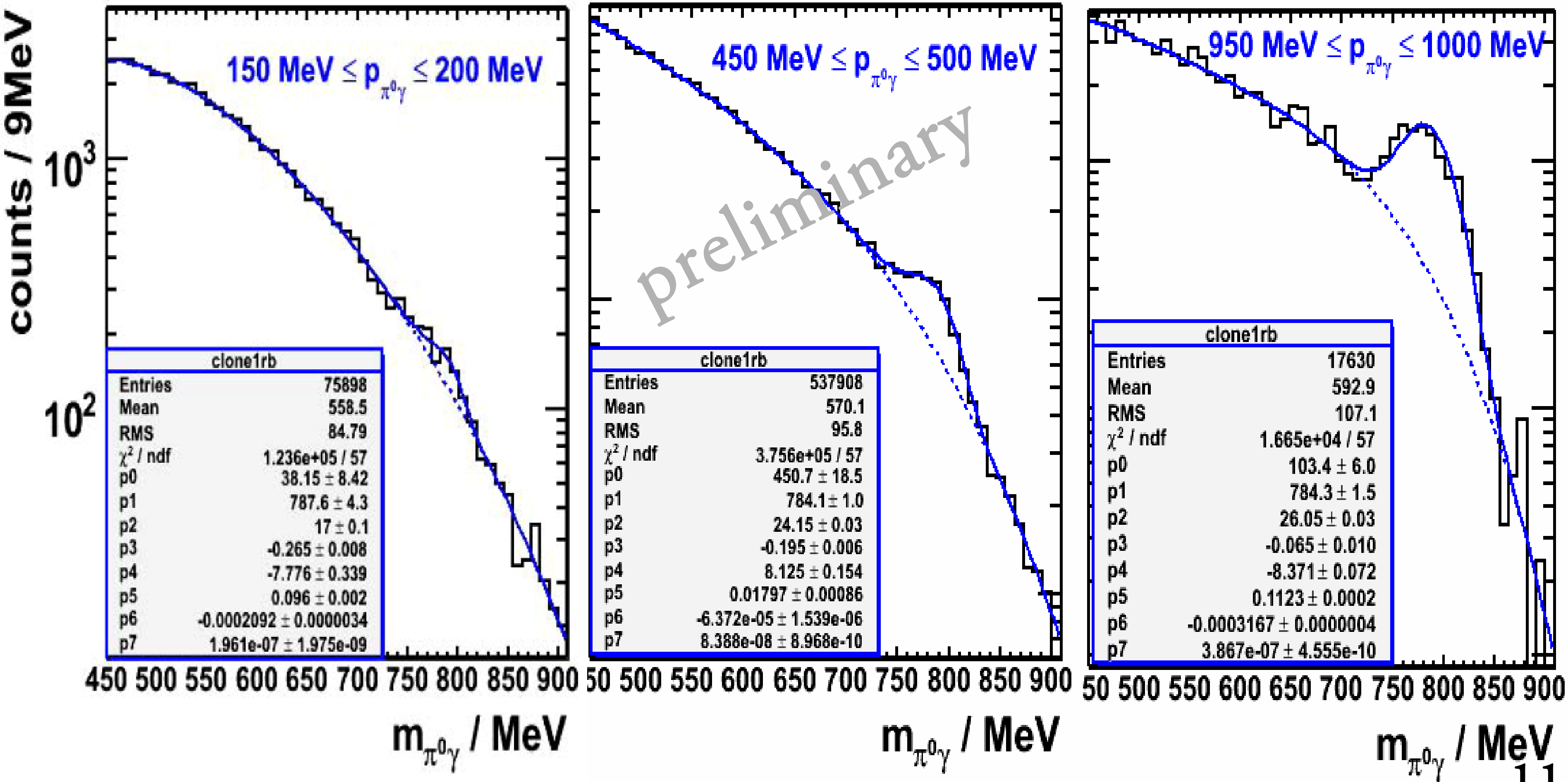
S. Friedrich



S. Friedrich

measurement of the momentum distribution

- carbon beamtime
- analysis with exactly 3γ (+0,1,2,… charged) final state
- ω yield in different momentum bins

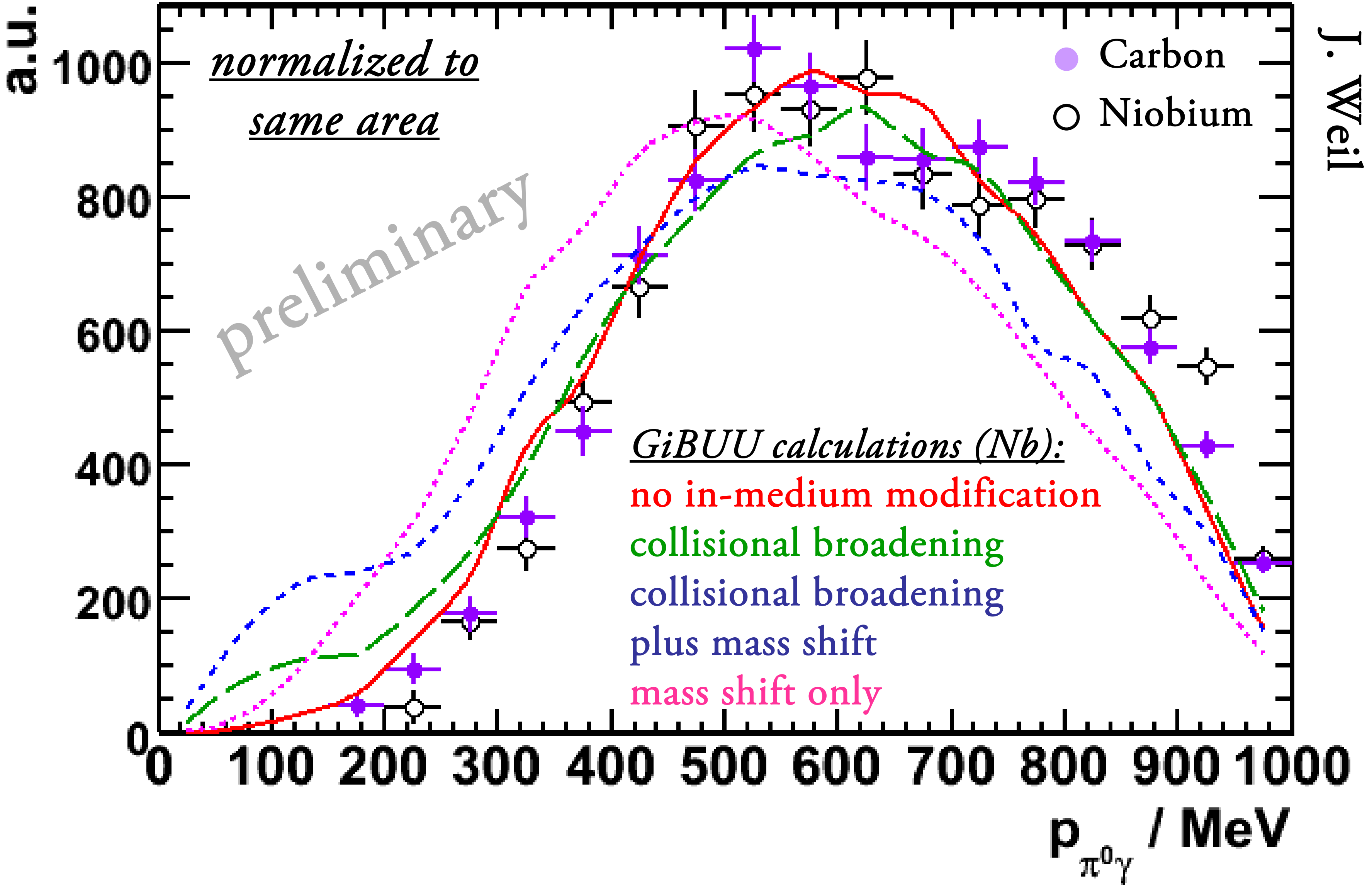


clone1rb	
Entries	75898
Mean	558.5
RMS	84.79
χ^2 / ndf	1.236e+05 / 57
p0	38.15 ± 8.42
p1	787.6 ± 4.3
p2	17 ± 0.1
p3	-0.265 ± 0.008
p4	-7.776 ± 0.339
p5	0.096 ± 0.002
p6	-0.0002092 ± 0.0000034
p7	1.961e-07 ± 1.975e-09

clone1rb	
Entries	537908
Mean	570.1
RMS	95.8
χ^2 / ndf	3.756e+05 / 57
p0	450.7 ± 18.5
p1	784.1 ± 1.0
p2	24.15 ± 0.03
p3	-0.195 ± 0.006
p4	8.125 ± 0.154
p5	0.01797 ± 0.00086
p6	-6.372e-05 ± 1.539e-06
p7	8.388e-08 ± 8.968e-10

clone1rb	
Entries	17630
Mean	592.9
RMS	107.1
χ^2 / ndf	1.665e+04 / 57
p0	103.4 ± 6.0
p1	784.3 ± 1.5
p2	26.05 ± 0.03
p3	-0.065 ± 0.010
p4	-8.371 ± 0.072
p5	0.1123 ± 0.0002
p6	-0.0003167 ± 0.0000004
p7	3.867e-07 ± 4.555e-10

measurement of the momentum distribution



data disfavour „mass shift“ and „coll. broad. + mass shift“ scenario

conclusion and outlook

- ω-lineshape analysis
    - sensitive to nuclear density at decay point
    - signal sensitive to background determination
    - reduced sensitivity
    - favours scenarios without mass shift

- ω-momentum analysis
    - sensitive to nuclear density at production point
    - favours scenarios without mass shift
    - model dependent!

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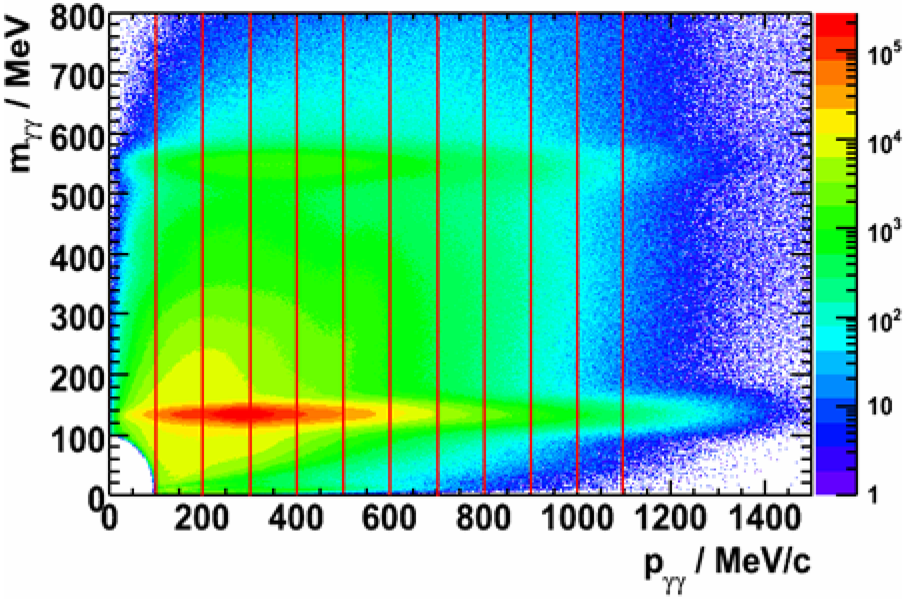
outlook:

- lineshape analysis: energy range $E_\gamma = 900 - 1100$ MeV
- cut on ω momentum: $p_\omega < 300$ MeV

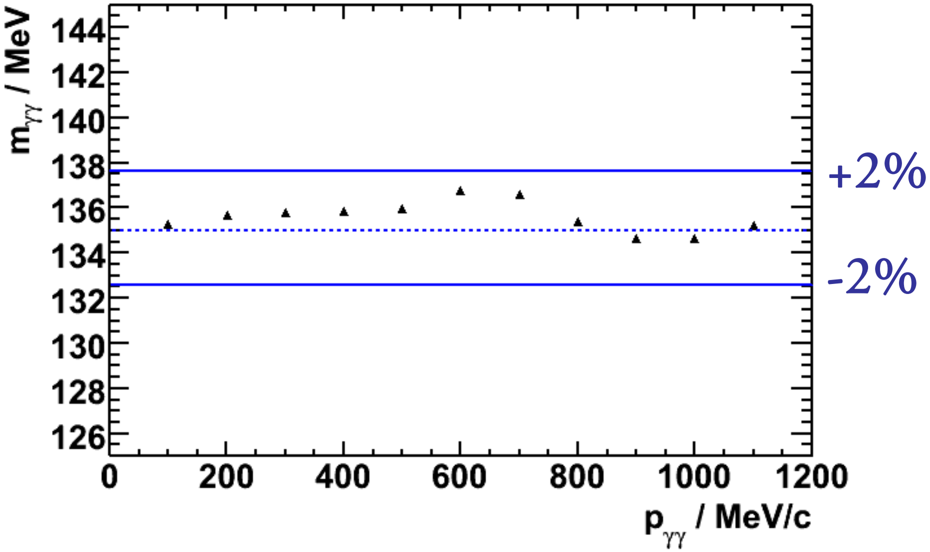
backup slides

backup slides

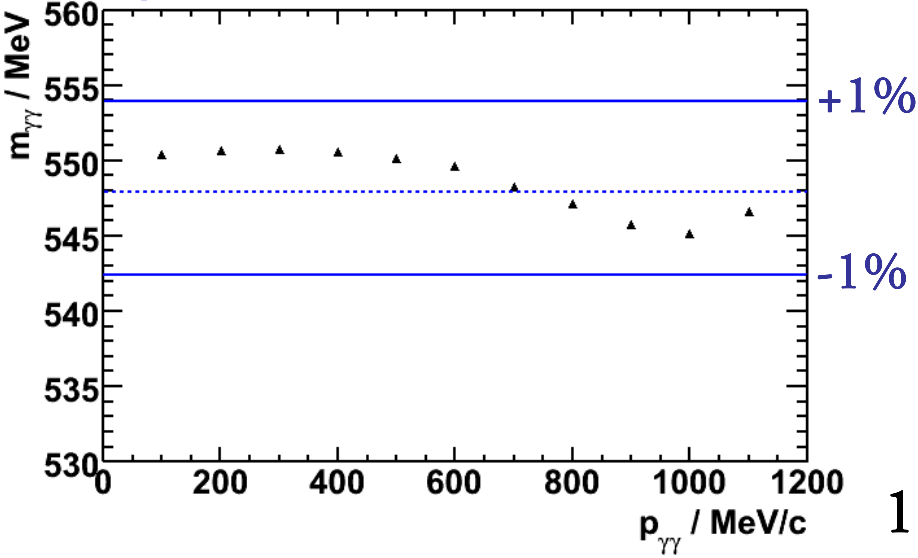
experiment requires very accurate energy calibration



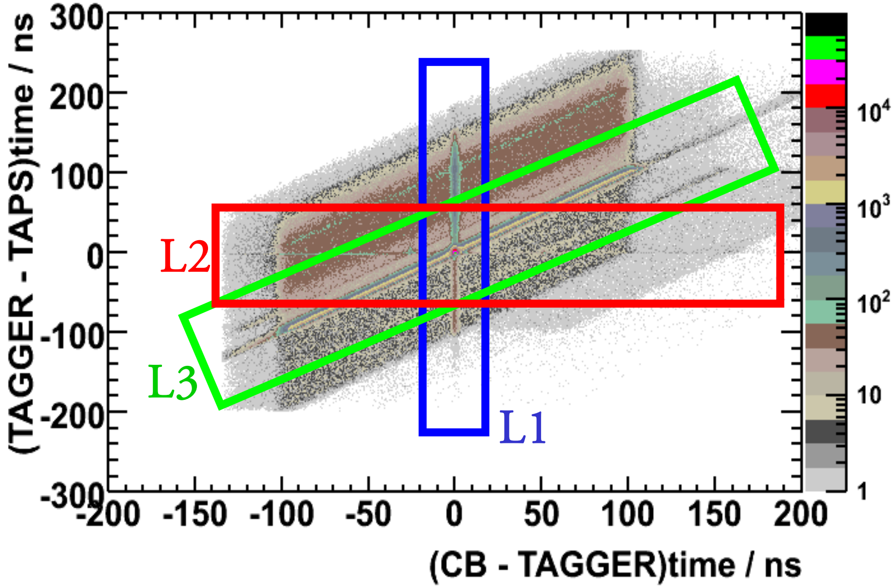
π^0 mass

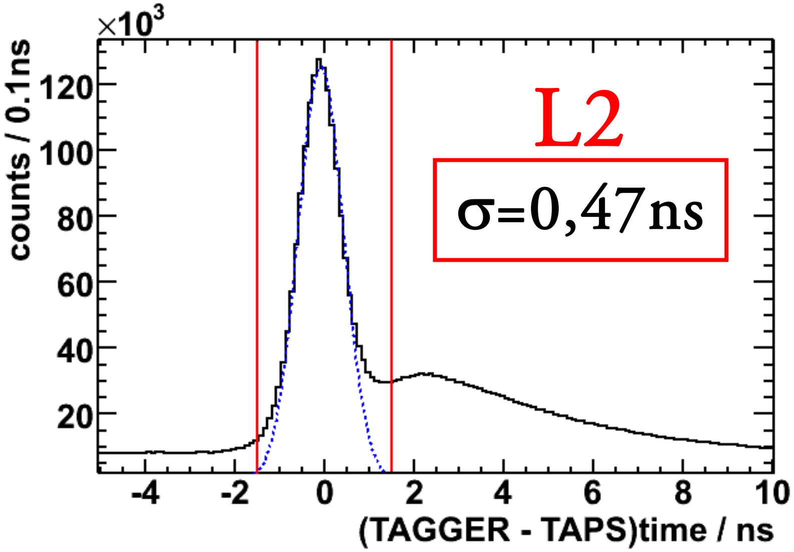


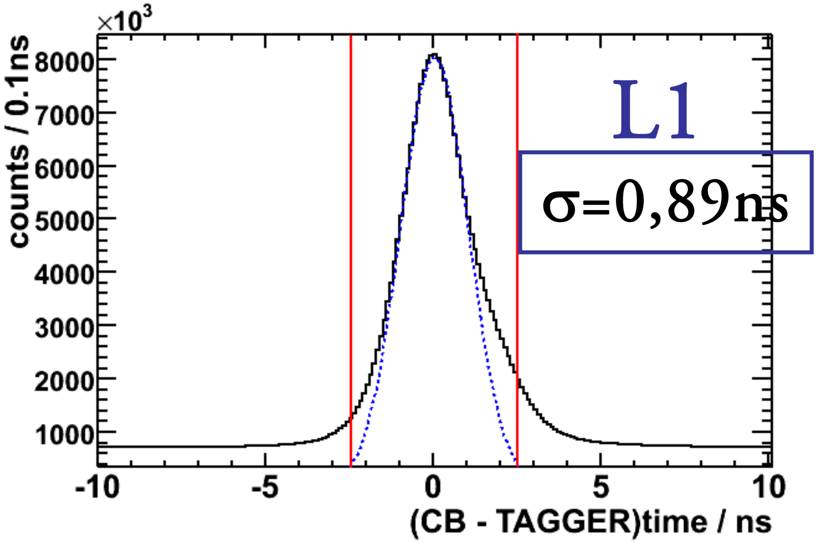
η mass

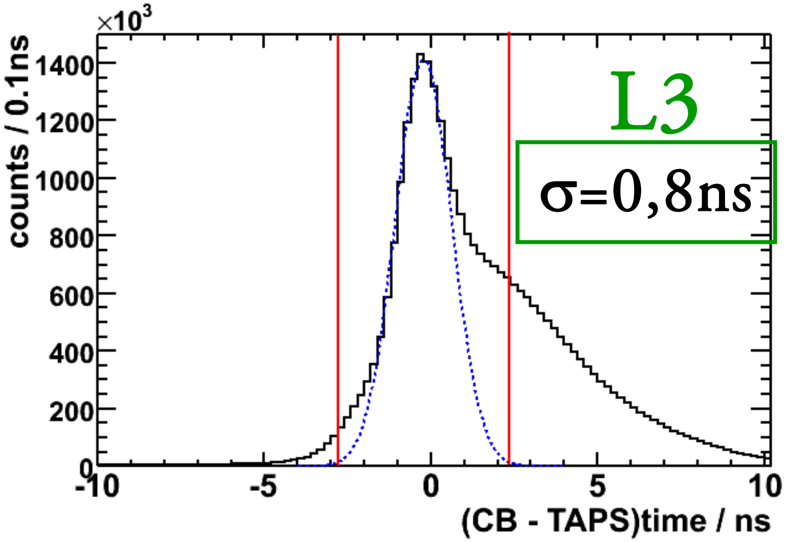


prompt time event selection



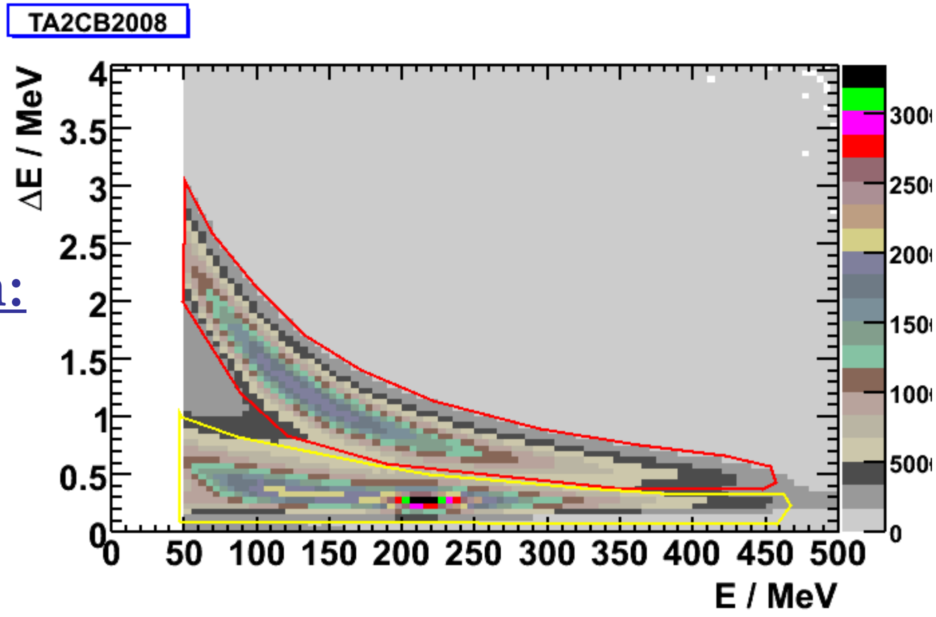






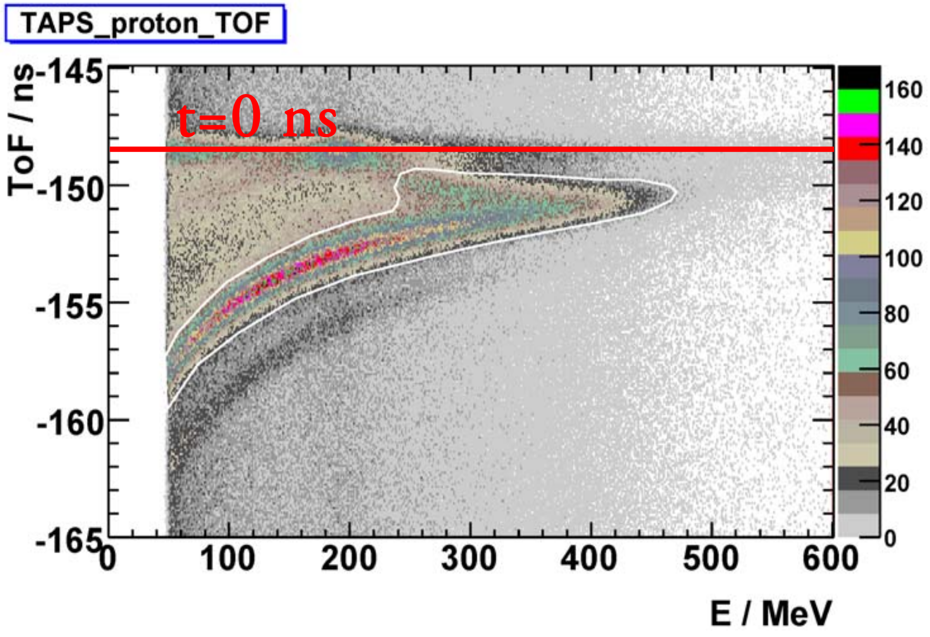
photon / particle separation possible using time-of-flight

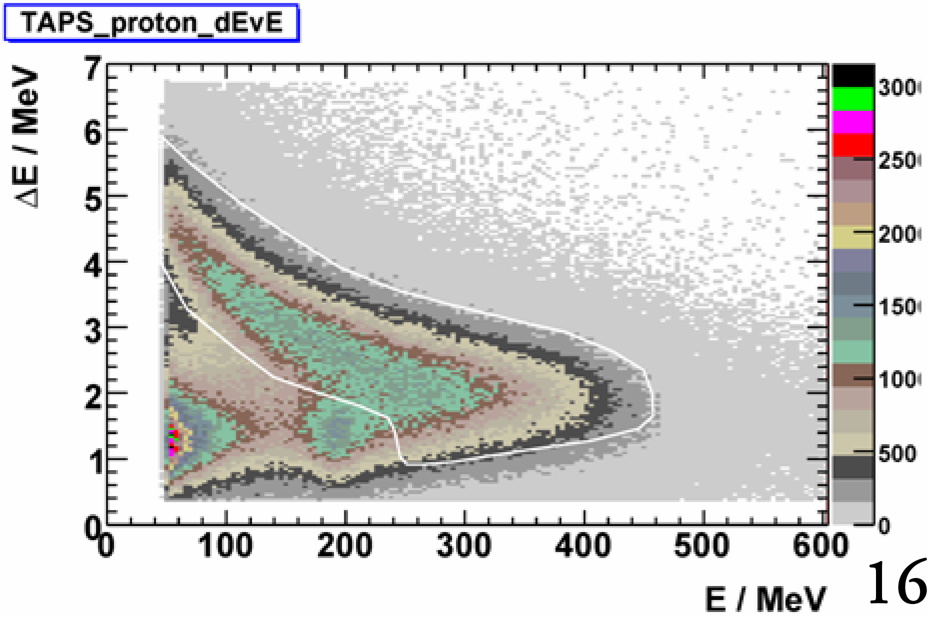
charged particle identification



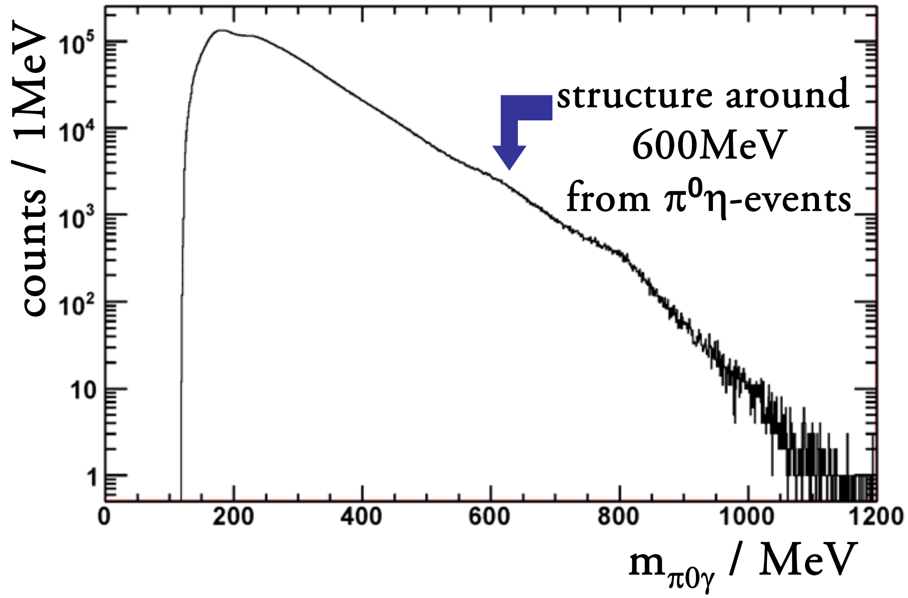
<u>identification of charged particles in:</u>

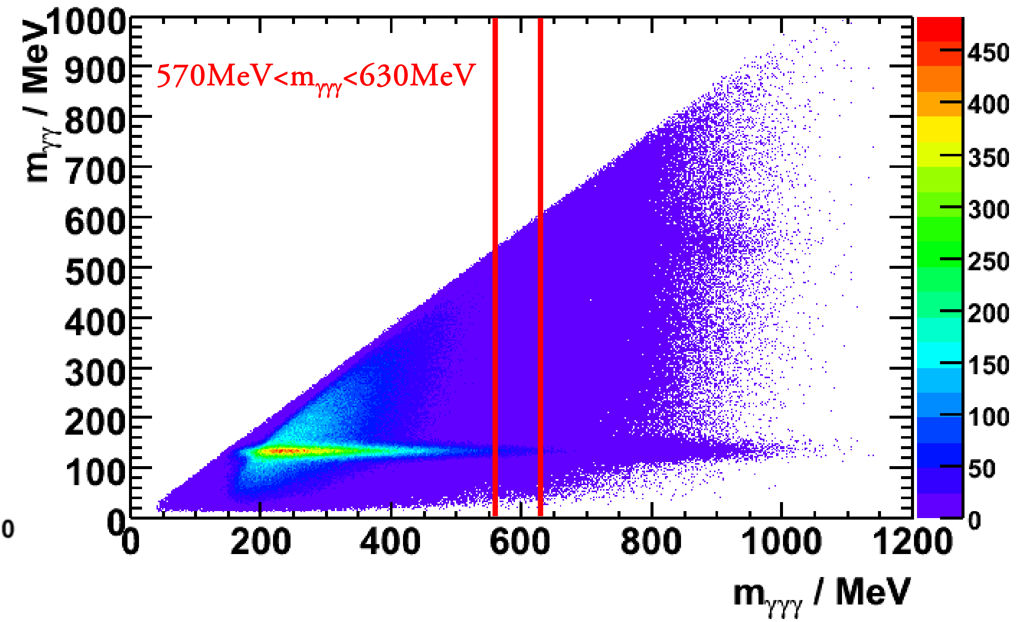
- ❖ PID (CB): ΔE vs E
- ❖ TAPS: ΔE vs E and E vs t

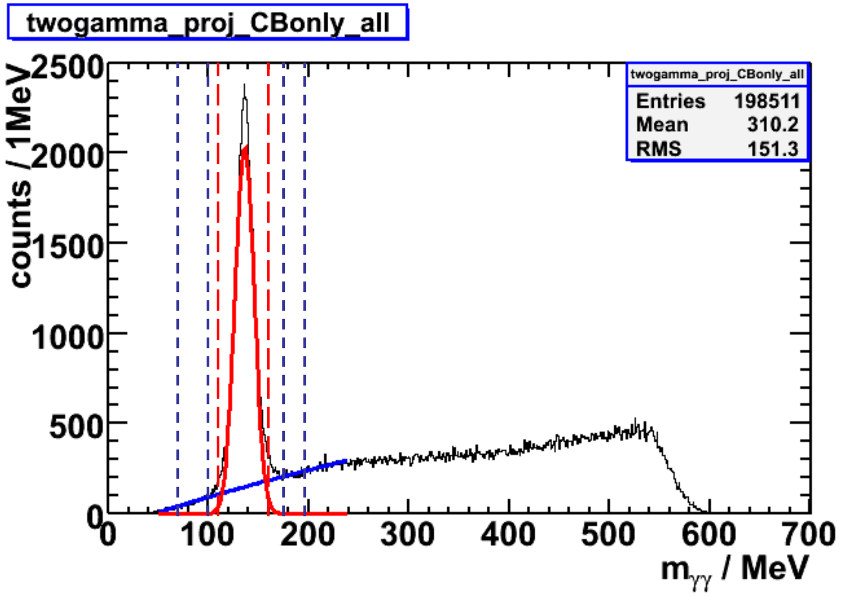




pion sideband subtraction







- remove background below π^0 peak by sideband subtraction
- removes structure around 600MeV!