Meson Spectroscopy Experiments

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From nucleon structure to nuclear structure and compact astrophysical objects
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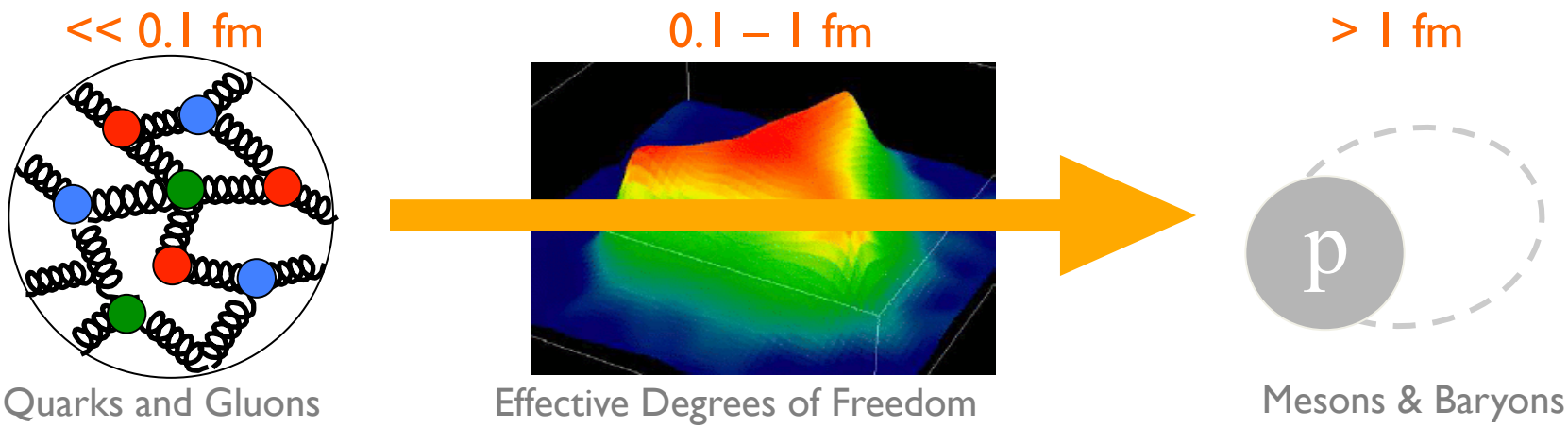
Outline

- Why meson spectroscopy
- Mesons in the quark model and beyond
- Recent results in the light quark sector:
  - Scalars mesons and glueballs
  - The $\pi_1(1600)$ and the search for hybrids
- Future perspectives
- New Challenges and Summary

Why Hadron Spectroscopy

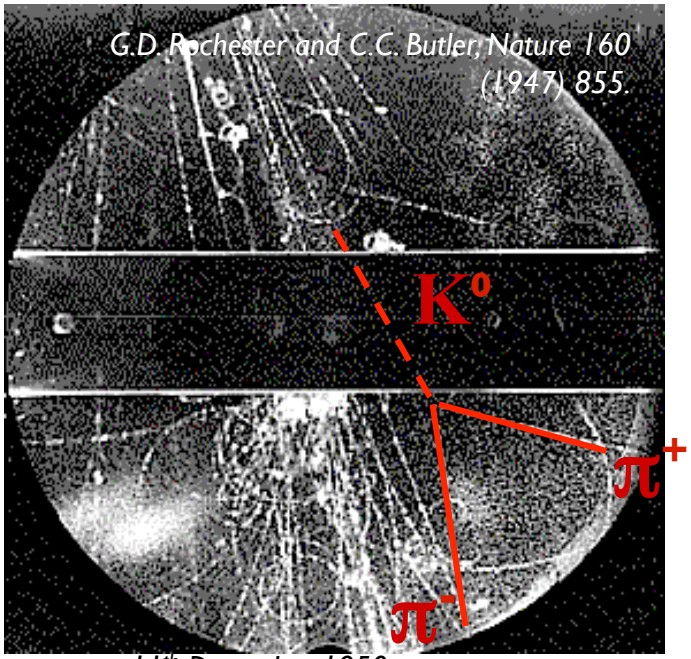
- QCD is responsible for most of the mass of matter that surrounds us
- Understanding the origin of this mass, i.e. the mass of hadrons, is a necessary step to reach a deep understanding of QCD
  - Revealing the nature of the mass of the hadrons
  - Identify the relevant degrees of freedom
  - Understand the role of gluons
  - Investigate the origin of confinement
- Meson spectroscopy is a key tool to investigate these issues



Meson Spectroscopy

Mesons are the simplest quark bound state, i.e. the best benchmark to understand how quarks interact to form hadrons and what the role of gluons is

Historically, the study of meson properties led to some of the most relevant discoveries in particles physics



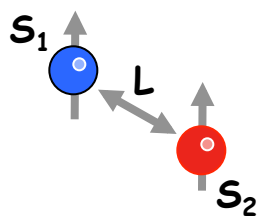
11th December 1950

- in 1947 the discovery of the pion by Powell, Occhialini and Lattes
- in the same year, the discovery of strange particles by Rochester and Butler
- the interpretation of the ϕ decay to KK by Zweig and others in 1963
- the discovery of the J/ψ in 1974
- …

After many years, meson spectroscopy remains a very active field and a precious source of information for the understanding of quark-gluon interaction

Mesons in the Quark Model

In the quark model meson are quark-antiquark bound states.



The two constituents can pair giving total spin S=0 (singlet) or S=1 (triplet) and have a non zero orbital angular momentum L

The resulting bound states are classified according to their J^{PC} where

$$P=(-1)^{L+1}$$
$$C=(-1)^{L+S}$$

Not all the J^{PC} combinations are allowed:

0^{++} 0^{+-} 0^{-+} 0^{--} 1^{++} 1^{+-} 1^{-+} 1^{--} 2^{++} 2^{+-} 2^{-+} 2^{--} 3^{++} 3^{+-} 3^{-+} 3^{--} …

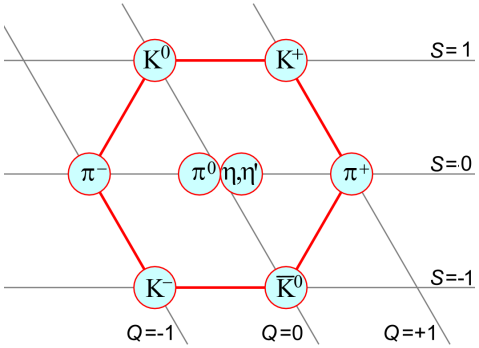
For each combination of J^{PC}, SU(3) flavor symmetry predicts the existence of a nonet ($8\oplus 1$) of degenerate states

$J^{PC}= 0^{-+} \Rightarrow (\pi, K, \eta, \eta')$

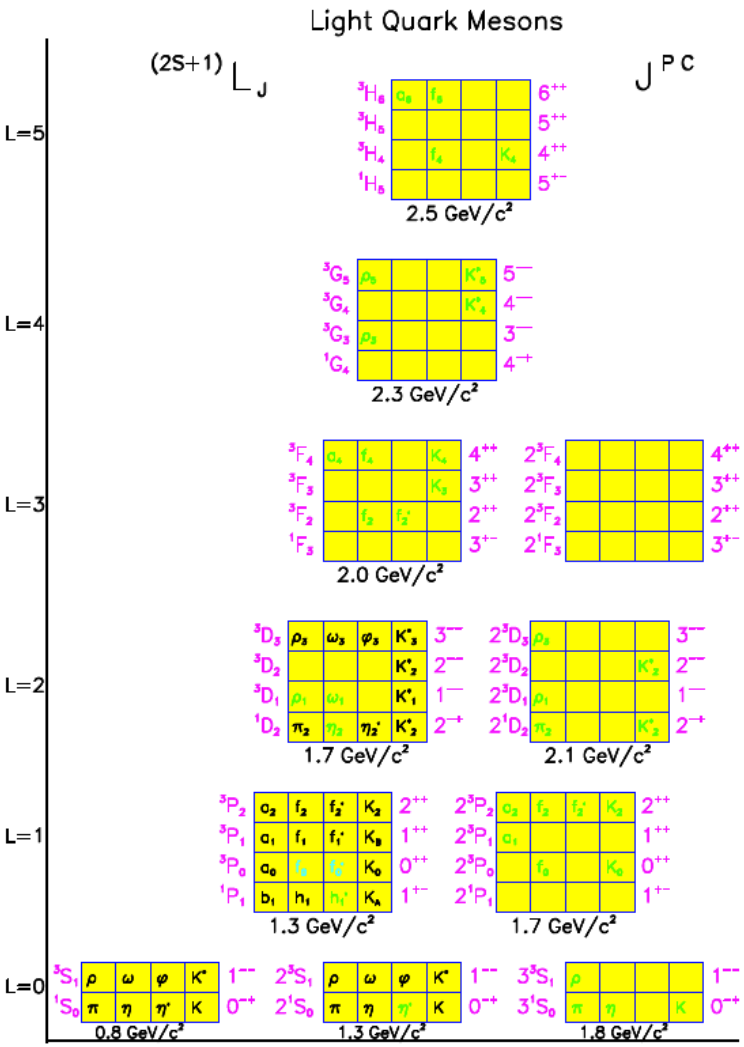
$1^{--} \Rightarrow (\rho, K^*, \omega, \Phi)$

$1^{+-} \Rightarrow (b_1, K_1, h_1, h_1')$

…



Spectrum and Missing States



Yellow: expected nonets of meson states as a function of the mass and angular momentum

Black: established states

Green: tentative assignments

A number of predicted states is not experimentally observed and assignments are uncertain:

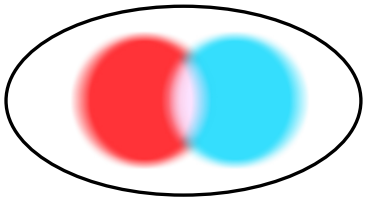
- failure of the model?
- limitations in the experimental techniques?
- states are too wide to be clearly identified?
- …

Beyond the quark model…Exotics

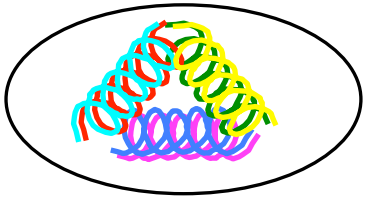
Understanding the role of gluons and the origin of confinement is crucial to complete our picture of strong interaction

- At high energy experimental evidence is found in jet production
- At lower energies the hadron spectrum carries information about the gluons that bind quarks
- Can we find hints of the glue in the meson spectrum?

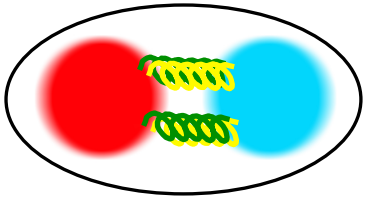
Search for non-standard states with explicit gluonic degrees of freedom



regular meson



glueball



hybrid

- Most intriguing unconventional states are glueballs (gg, ggg,…) and hybrids ($q\bar{q}g$)
- Predicted by different models and lattice QCD calculations

Glueballs

- Having **color charge**, gluons can interact with each other forming bound, color-singlet objects
- Historically, glueballs were first studied in the **bag model**, where gluon fields can be in:
  - Transverse electric (TE) mode: $P=(-1)^{J+1}$
  - Transverse magnetic (TM) mode: $P=(-1)^{J}$

gg and ggg

Mode	J^{PC}	*Mass (GeV)*
TE^2	$0^{++},2^{++}$	0.96
TE·TM	$0^{-+},1^{-+},2^{-+}$	1.29
TE^3	$0^{+-},1^{++},2^{+-},3^{++}$	1.49
TM^2	$0^{++},2^{++}$	1.59

R. Jaffe and J. Jhonson, Phys. Lett. B69 (1976) 201

- Predicted quantum number are the same as for conventional mesons: glueballs can mix with conventional states
- Glueballs decays should be flavor blind; from SU(3) symmetry (isoscalar factors)

$$(glueball)_{|1\rangle} \rightarrow \begin{pmatrix} K\bar{K} & \pi\bar{\pi} & \eta\eta & \bar{K}K \end{pmatrix}_{|8\rangle\times|8\rangle} = \frac{1}{\sqrt{8}}\begin{pmatrix} 2 & 3 & -1 & -2 \end{pmatrix}^{1/2}$$

  - Couplings of a flavor singlet glueball to ππ, KK and ηη: 3:4:1
  - Decay to ηη' is forbidden (independent of the mixing angles)
  - Decay to η'η' can not be related to other decays by symmetry

Glueballs

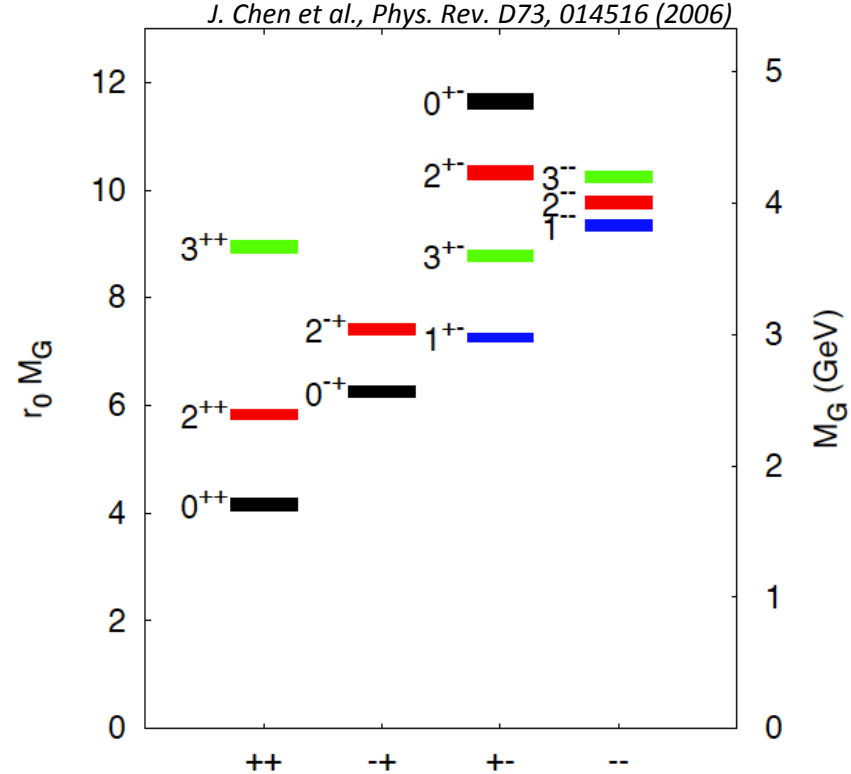
Glueballs have been studied in many different models:

- flux tube model
- QCD Sum Rules
- …

Possible existence of glueballs is also confirmed by Lattice QCD calculations:

- Most calculations performed in quenched approximation
- Lower mass glueballs are scalar (0^{++}) and tensor (2^{++}) states
- Mass of the lightest glueball around 1.5-1.7 GeV
- Recent calculation using anisotropic lattice, indicated the lightest state to be 0^{++} with M~1.7 GeV, followed by a 2^{++} with M~2.4 GeV with uncertainties of~100 MeV

J. Chen et al., Phys. Rev. D73, 014516 (2006)



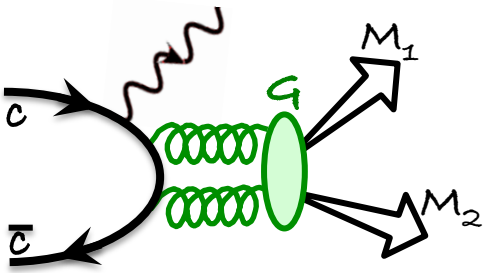
Mass spectrum of glueballs
(r_0=410 MeV)

Glueballs Searches

Production of glueballs is expected to be favored in **glue-rich** channels:

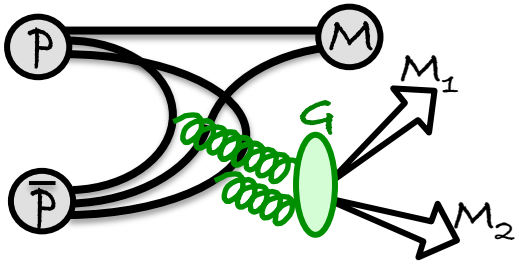
1. J/Ψ radiative decay

After emission of a photon, the $c\bar{c}$ pair annihilates into gluons. Radiative decays are of the order of 6% of the total width. BES experiment in Bejiing.



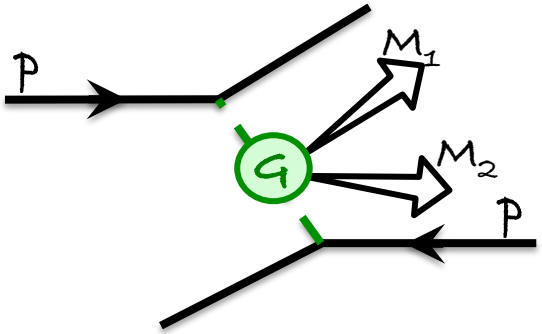
2. Proton-antiproton annihilation

Annihilations usually involves quark rearrangements but can also produce several gluons. Crystal Barrel experiment at CERN.



3. Central Production

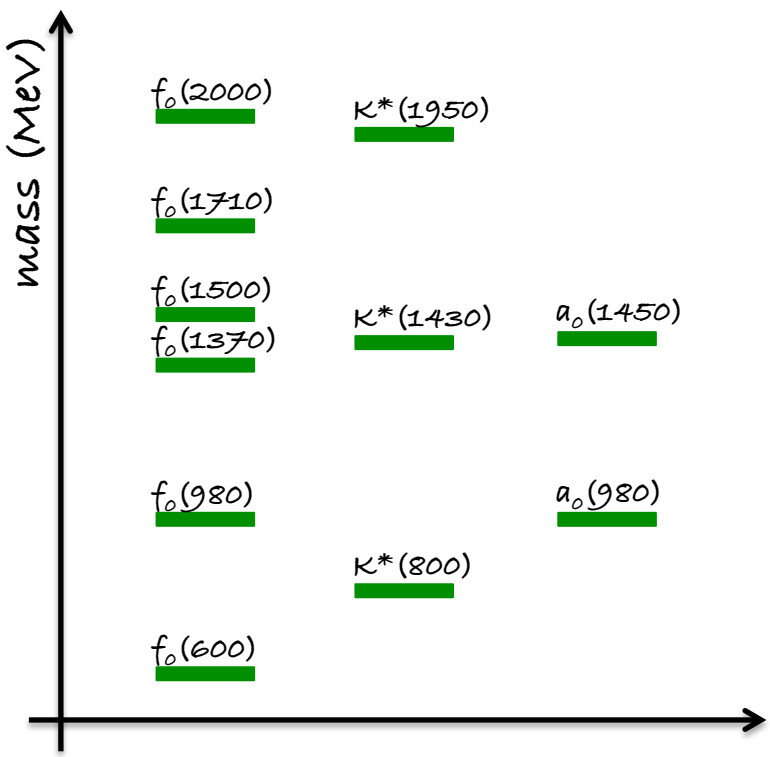
The two initial particles exchange virtual particles remaining unchanged. At high energy the process become diffractive and is dominated by exchange of pomerons, effective particles with high gluonic content.
WAXX experiments at CERN and GAMS in Protvino

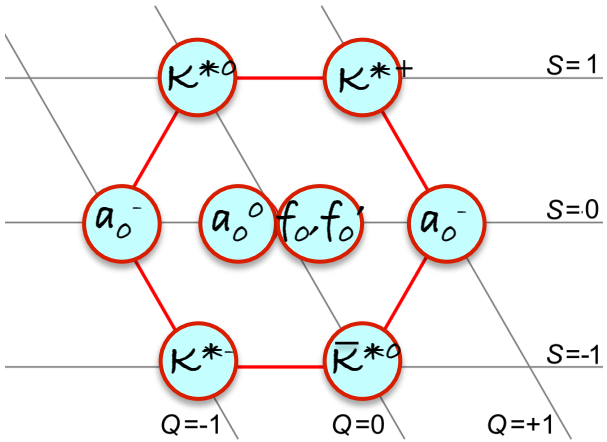


Scalars and Glueballs

The scalar meson nonet should be composed by a_0(I=1),K* (I=1/2), f_0 and f_0'(I=0)

At present, given the I=1 and I=1/2 states that have been identified, there is an excess of I=0 states





- For masses below 2 GeV, there two I=1 and two I=1/2 states that are (reasonably) well identified and could be part of two nonets.
- In the same mass range there are 5 I=0 states. 4 could complete the nonets leaving a glueball candidate

Experimental Evidence

The lightest glueball is expected to be a scalar ($J^{PC}=0^{++}$)

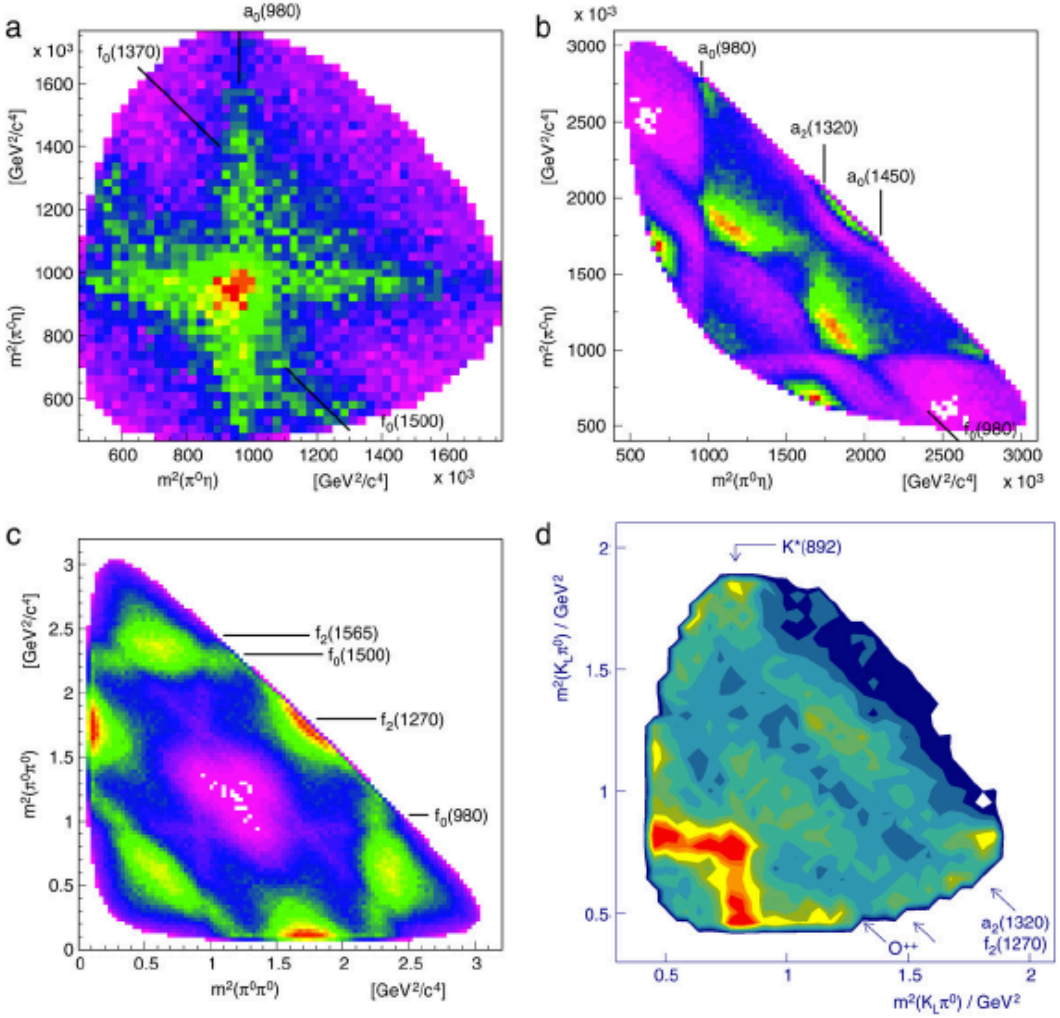
One of the most significant results in this sector obtained by Crystal Barrel Collaboration at LEAR

$$p\bar{p} \rightarrow \pi^0\eta\eta$$
$$p\bar{p} \rightarrow \pi^0\pi^0\eta$$
$$p\bar{p} \rightarrow \pi^0\pi^0\pi^0$$
$$p\bar{p} \rightarrow \pi^0 K_L K_L$$

In case of two identical pseudo-scalar meson in the final state, these can combine to give

$I^G J^{PC}=(0^+)(0^{++})$ and $(0^+)(2^{++})$

i.e. f_0 and f_2 states

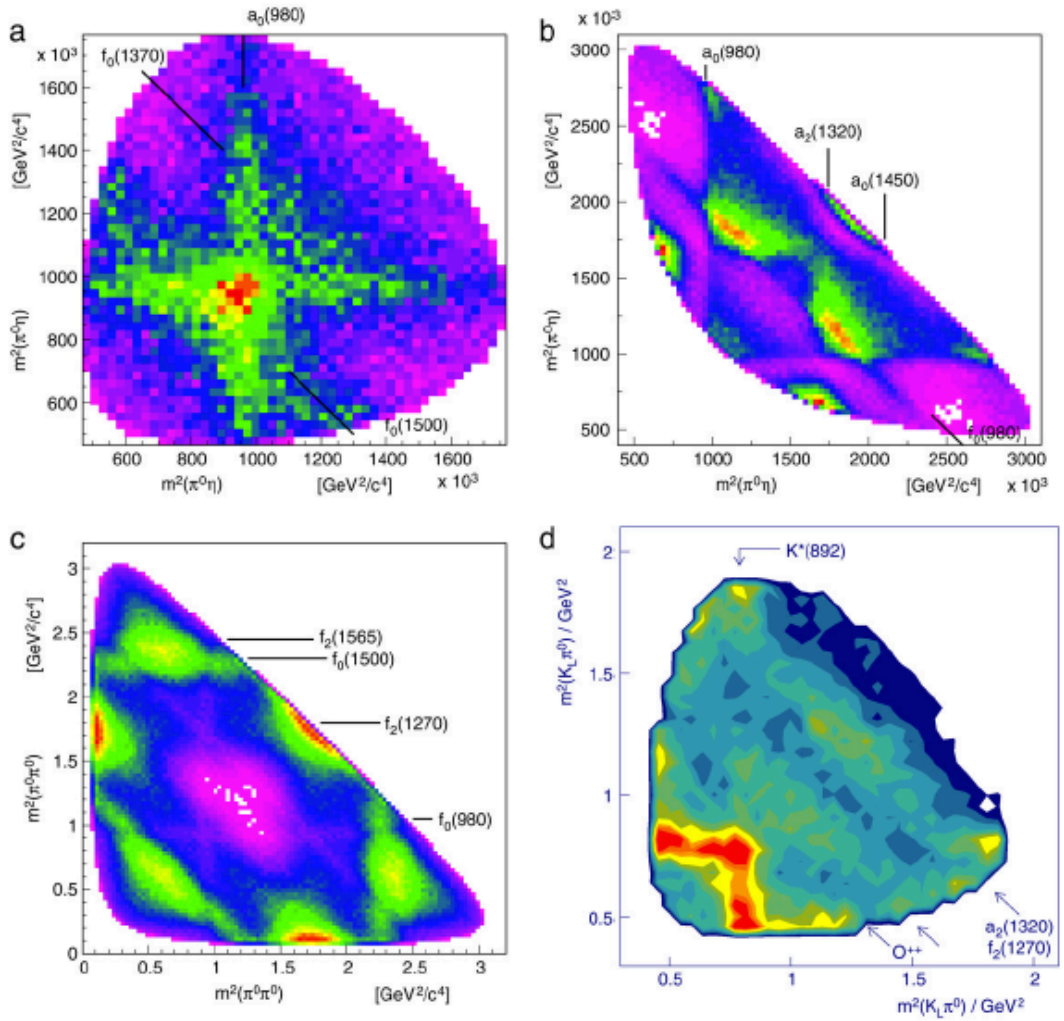


Experimental Evidence

Good description of the 4 Dalitz plot with two isoscalar states:

	$f_0(1370)$	$f_0(1500)$
Γ_{tot}	275±55	130±30
$\Gamma_{\pi\pi}$	21.7±9.9	44.1±15.4
$\Gamma_{\eta\eta}$	0.41±0.27	3.4±1.2
$\Gamma_{\eta\eta'}$		2.9±1.0
Γ_{KK}	5.2-28.4	8.1±2.8
$\Gamma_{4\pi}/\Gamma_{tot}$	0.80±0.05	0.76±0.08

- Partial decays seems inconsistent with the glueball picture but also with regular meson expectations
- Large branch to 4π is indicative of $n\bar{n}$ nature



Experimental Evidence

Central production at CERN WA102

Confirmation of the $f_0(1370)$ and $f_0(1500)$ and evidence for the **$f_0(1710)$**, previously seen by Crystal-Ball at SLAC in radiative J/y decays.

A coupled analysis of ππ and KK final states indicated the dominance of the KK decay mode, suggestive of an ss nature

$$\frac{f_0(1710) \to \pi\pi}{f_0(1710) \to K\bar{K}} = 0.20 \pm 0.03$$

$$\frac{f_0(1710) \to \eta\eta}{f_0(1710) \to K\bar{K}} = 0.48 \pm 0.14$$

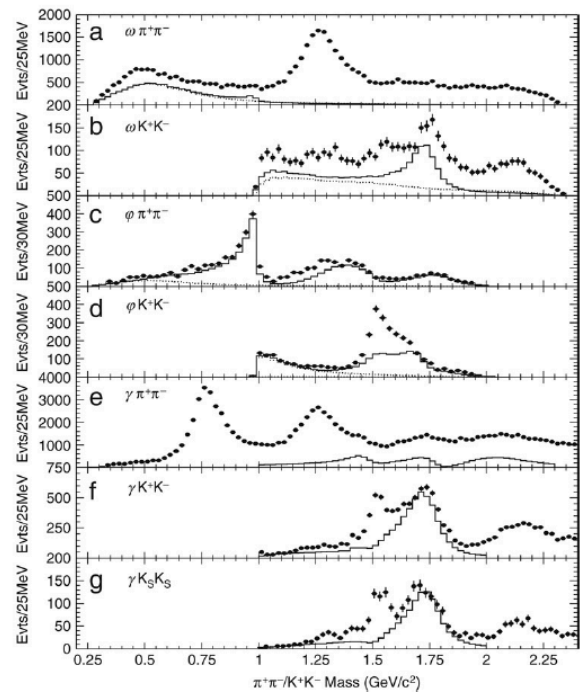
$$\frac{f_0(1710) \to \eta\eta'}{f_0(1710) \to \eta\eta} < 0.05(90\%cl)$$

J/Ψ decays at BES

Evidence for the $f_0(1500)$, $f_0(1710)$ and $f_0(2000)$

Study of J/ψ → ωX and J/ψ→ϕX (flavor tagging reactions):

- A possible signal for the $f_0(1710)$ is seen in ωKK and not in ϕKK.
- A broad signal in ϕππ around 1790 is found (??)



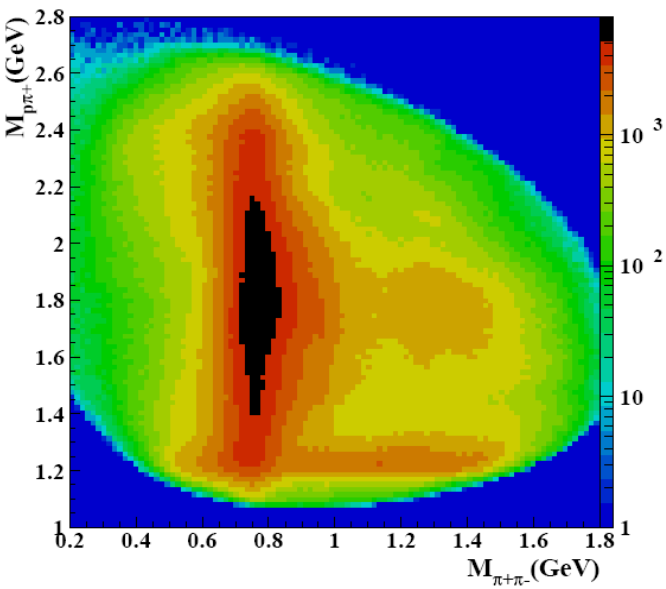
Scalars and Glueballs: summary

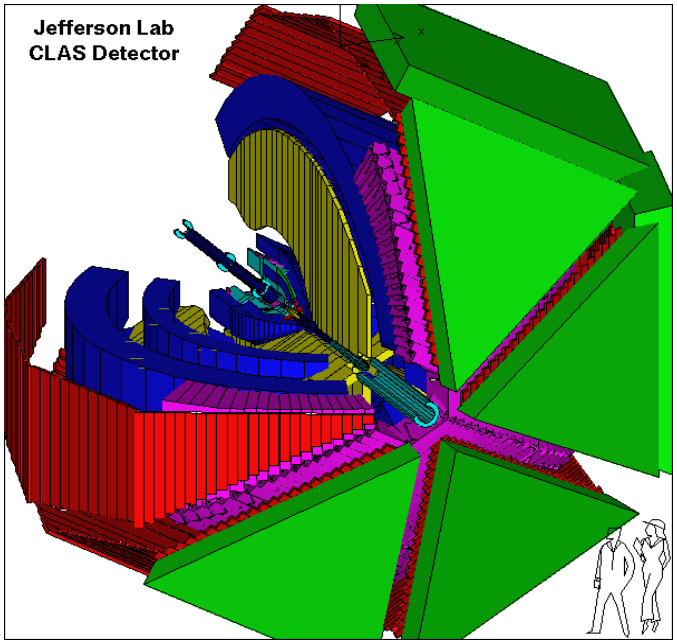
- Experimental study of scalar mesons has provided indication for the existence of a possible glueball
- Discrepancies between experiments and possible mixing between glueball and ordinary states make identification of the unconventional states and scalar nonet assignment difficult:
  - Need more high precision data for different decay channels and higher sophistication analyses to rule out ambiguities: data expected from BESIII in Beijing and Panda at GSI
  - Need better understanding of production process and decay patterns for conventional states in the scalar sector

The $f_0(980)$ at CLAS

Study of scalar mesons in photoproduction of pion pairs at CLAS

- Bremsstrahlung photon beam: 1.6-3.8 GeV
- 40 cm long liquid hydrogen target
- ~$7 \cdot 10^9$ triggers
- Integrated Luminosity ~ 80 pb^{-1}



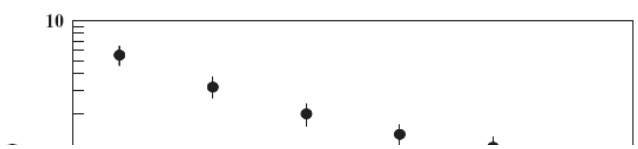


- Reaction $\gamma p \rightarrow p\pi^+(\pi^-)$ isolated via missing mass
- Analysis focused on high energy (3.0-3.8 GeV) and low –t (0.4-1.0 GeV^2) region

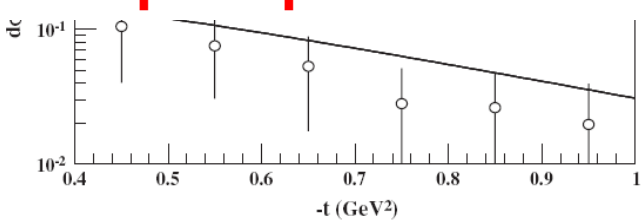
The $f_0(980)$ at CLAS

$\gamma p \rightarrow p\pi^+\pi^-$

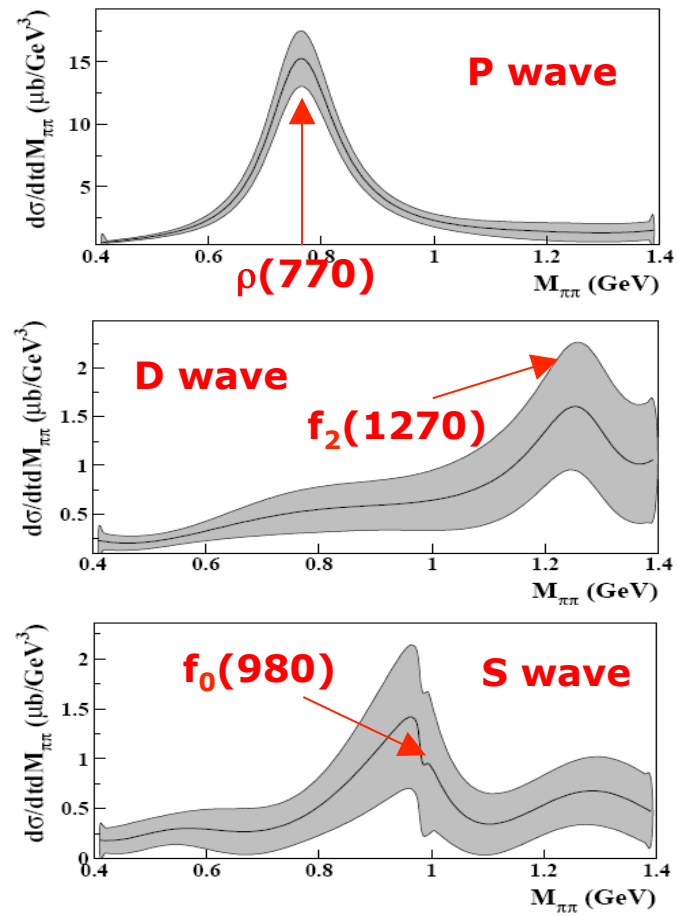
- M($\pi^+\pi^-$) spectrum below 1.5 GeV:
  - P-wave: ρ meson
  - D-wave: $f_2(1270)$
  - S-wave: σ, $f_0(980)$ and $f_0(1370)$
- Moments of the 2-pion angular distribution extracted via likelihood fit of data
- Partial Wave fitted to experimental moments
- **Known states well reproduced, e.g. ρ(770)**



First observation of $f_0(980)$ in photoproduction



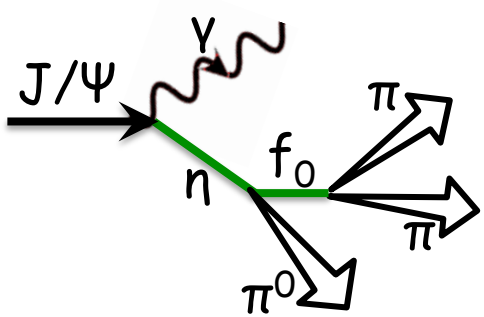
3.4 GeV < E_γ < 3.6 GeV
0.5 GeV² < -t < 0.6 GeV²

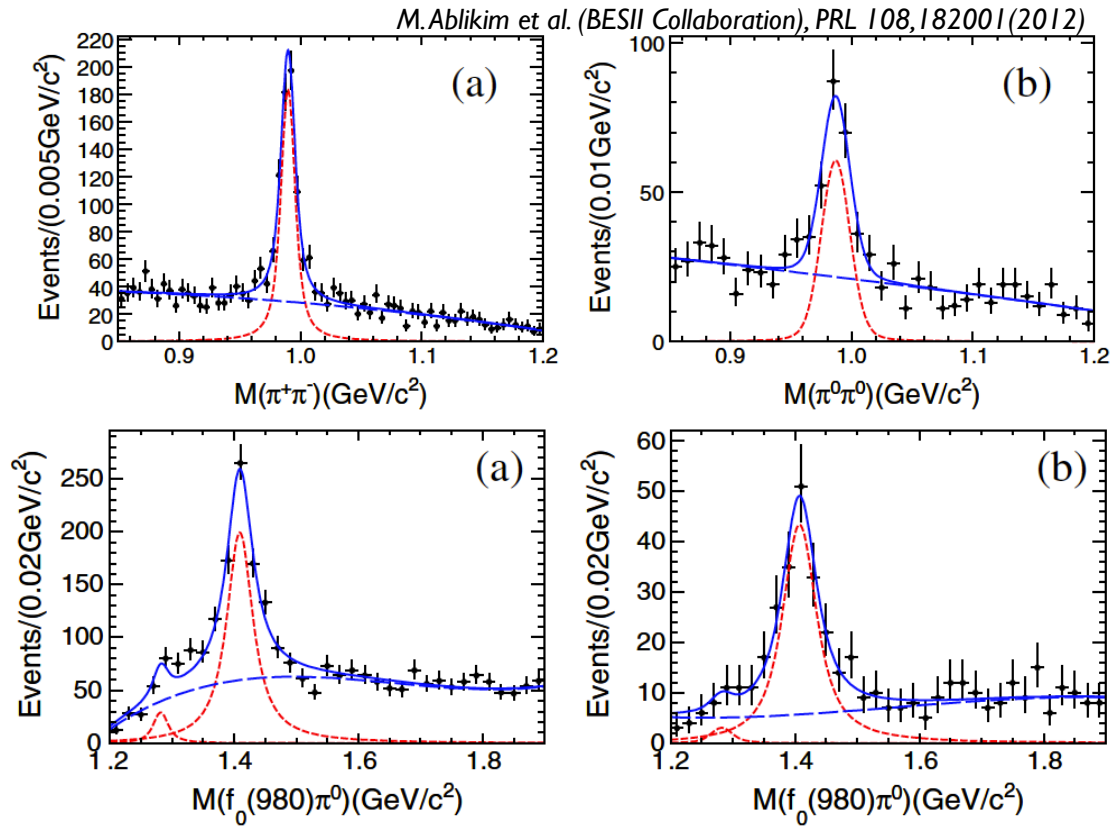


M. Battaglieri et al. (CLAS Collaboration), PRL 102, 102001

The $f_0(980)$ at BESIII

Anomalous line shape for the $f_0(980)$ observed at BESIII in $J/\Psi \to \gamma\eta(1405) \to \gamma f_0(980)\pi^0$





- observed width of the f_0 much narrower than world average (PDG2012: 40-100 MeV)

  Γ<11.8MeV @90%CL
- Explanation in terms of Triangle Singularities (TS), KK* loops by J.Wu et al.

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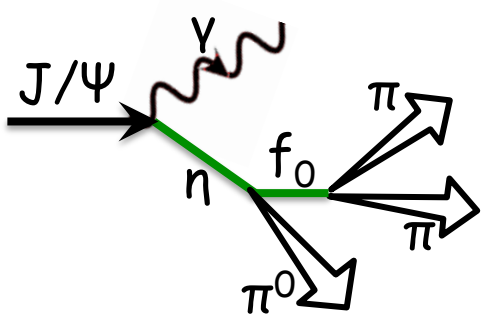
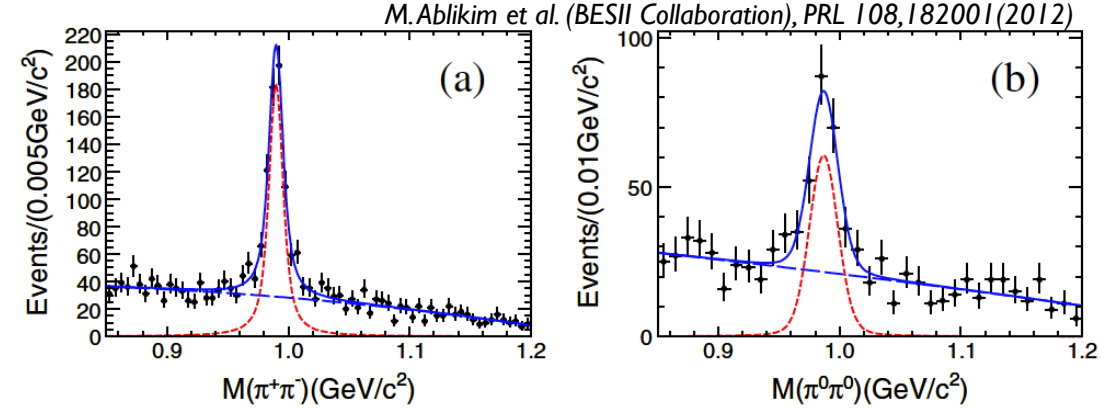


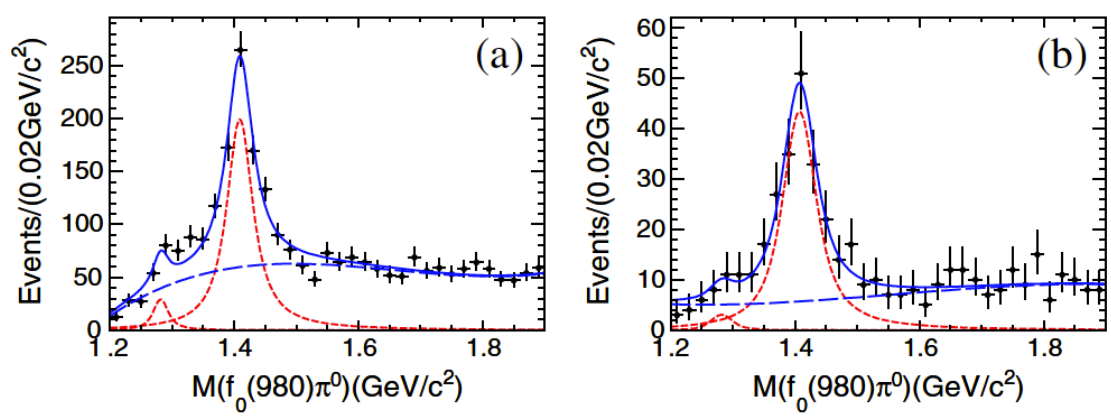
M. Ablikim et al. (BESII Collaboration), PRL 108,182001(2012)



- Large isospin violation in η decay

$$\frac{BR(\eta(1405) \to f_0(980)\pi^0 \to \pi^+\pi^-\pi^0)}{BR(\eta(1405) \to a_0(980)\pi^0 \to \pi^0\pi^0\eta)} \approx (17.9 \pm 4.2)\%$$

compared to what expected from a_0/f_0 mixing (<1%)



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  - Need better understanding of production processes and decay patterns for conventional states in the scalar sector

- Higher mass glueballs are predicted to be 2^{++} and $0^{-+}$with masses above 2 GeV
- Experimental searches are very challenging:
  - 2^{++} candidate will overlap with radial excitations of the f_2 ($f_2(1950)$, $f_2(2010)$, $f_2(2300)$, $f_2(2340)$…)
  - Pseudoscalar sector may be cleaner (eta, eta' excitations)

Hybrids and Exotics

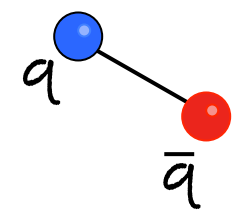
Another category of unconventional mesons are **hybrids**, i.e. states with $q\bar{q}g$ configuration

- In the flux tube model, hybrids arise from **excitations of the flux tube** that connects the quark and antiquark
- The excited flux tube carries **non-zero angular momentum** that contribute to the quantum numbers of the new system
- Excitation of the flux tube leads to a **new spectrum of hadrons** that can have both regular and **exotic quantum numbers**

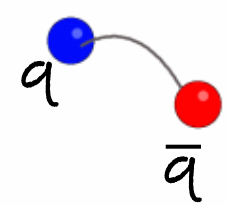
  $J^{PC} = 0^{-+}, 0^{+-}, 1^{++}, 1^{--}, 1^{-+}, 1^{+-}, 2^{-+}, 2^{+-}$

- For each J^{PC} combination a **nonet** of states is expected
- Masses of the lower states are predicted to be around 2 GeV

Normal meson:
flux tube in ground state
$m=0$, $PC=(-1)^{S+1}$



Hybrid meson:
flux tube in excited state
$m=1$, $PC=(-1)^{S}$

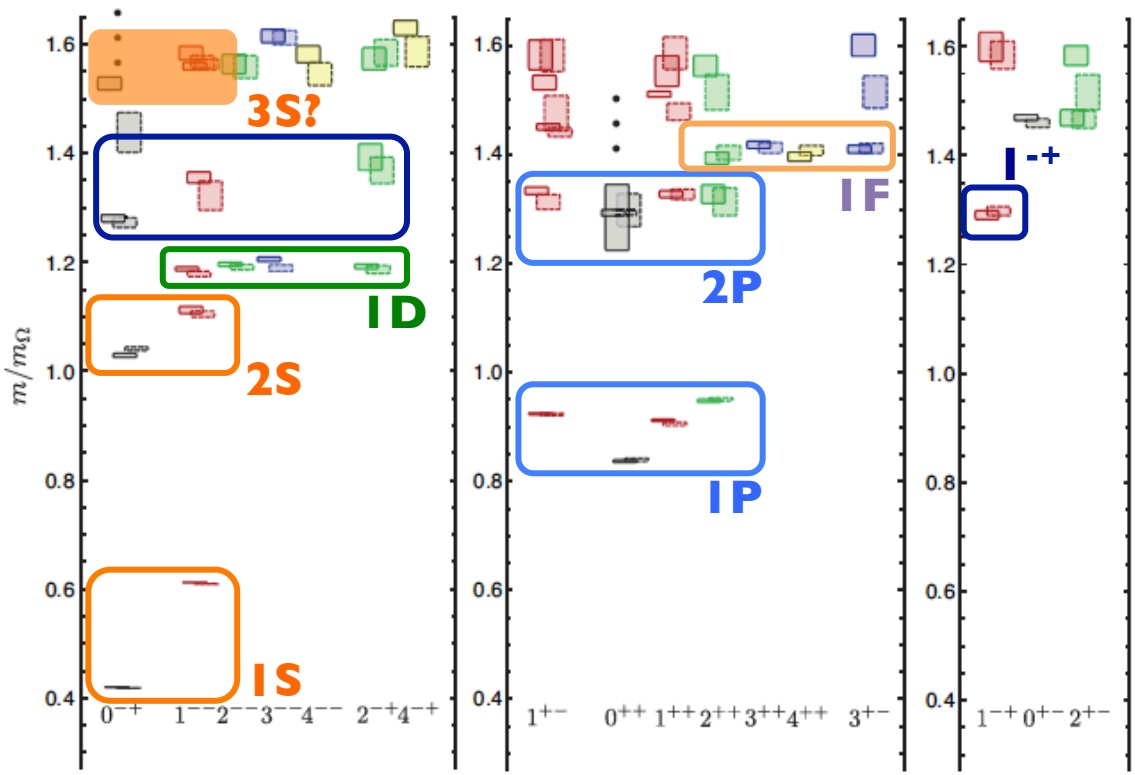


Lattice QCD

Existence of exotics is supported by LQCD

Fully dynamical calculation by the JLab Hadron Spectrum Collaboration:

- two flavors of light quarks and an heavier (strange) quark
- two lattice volumes
- large set of operators
- stable dependence on quark masses



J. Dudek et al., Phys. Rev. D82, 034508 (2010)

- Good agreement of regular meson spectrum with known states
- Exotic multiplets with quantum numbers 1^{-+},0^{+-} and 2^{-+} are predicted

Experimental Evidence

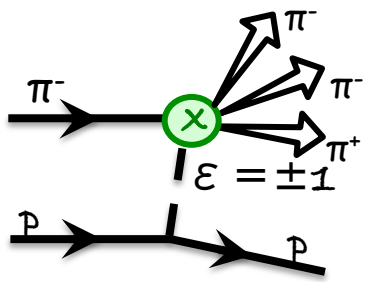
The lightest exotic hybrids are expected in the 1^{-+} wave:

* $\pi_1(1400)$: observed in $\eta\pi$ final states by several experiments(GAMS, KEK, E852, Crystal Barrel) with a width of few hundreds MeV. Mass lower than expectations and interpretation still unclear

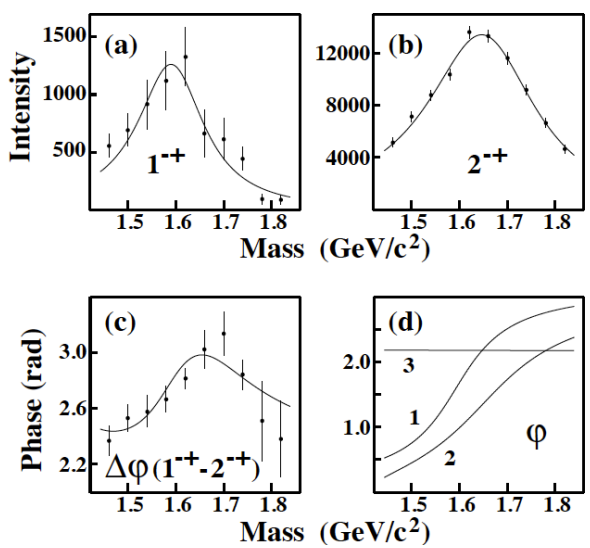
* $\pi_1(1600)$: observed in several decay modes ($\rho\pi$, $\eta'\pi$, $f_1\pi$, $b_1\pi$) including decays to L=1-L=0 meson pairs as predicted by the flux tube model. Observations confirmed by different experiments (E852,VES,COMPASS) but with different production mechanisms. Evidence in the $\rho\pi$ decay still controversial: not observed in reanalysis of E852 data and by CLAS.

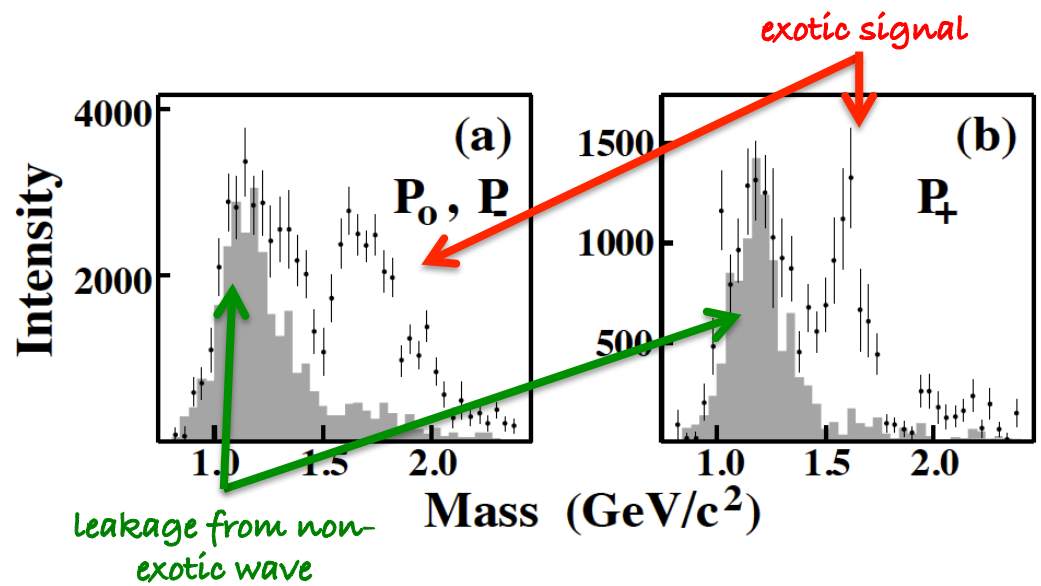
* $\pi_1(2000)$: seen by E852 in $f_1\pi$ and $b_1\pi$ final states produced in peripheral πp scattering. Further confirmation is desirable

$\pi_1(1600)$ in E852 at BNL



Partial wave analysis of ~25000 events with fit including up to 42 waves





P_+ or $M^{\varepsilon} = 1^+$ natural-parity exchange

$P_{0,-}$ or $M^{\varepsilon} = 0^-, 1^-$ unnatural-parity exchange

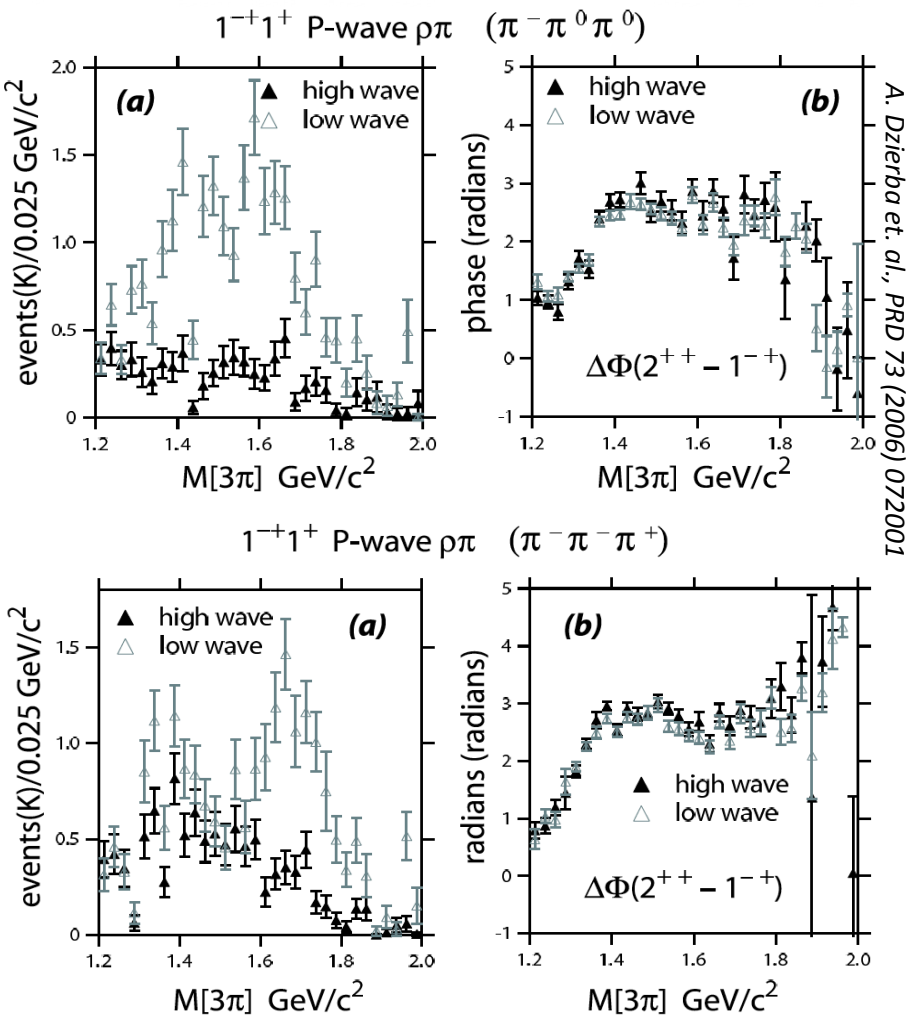
Significant intensity in the 1^{-+} wave with clear phase motion with respect to the 2^{-+}

$$M = \left(1.593 \pm 0.080^{+0.029}_{-0.047}\right) GeV$$

$$\Gamma = \left(0.168 \pm 0.020^{+0.150}_{-0.012}\right) GeV$$

$\pi_1(1600)$ in E852 at BNL

- The E852 data for 3 pion production were reanalyzed by an independent group using more statistics (x10) and higher number of waves in the PWA
  - $\pi_2(1670) \rightarrow \rho\pi$ (L=3)
  - $\pi_2(1670) \rightarrow \rho_3\pi$
  - $\pi_2(1670) \rightarrow (\pi\pi)_S\pi$
  - a_3 decays
  - $a_4(2040)$
  - ...
- New analysis results did not show evidence for the $\pi_1(1600)$
- Most of the exotic wave strength is re-absorbed in known decays of the $\pi_2(1670)$

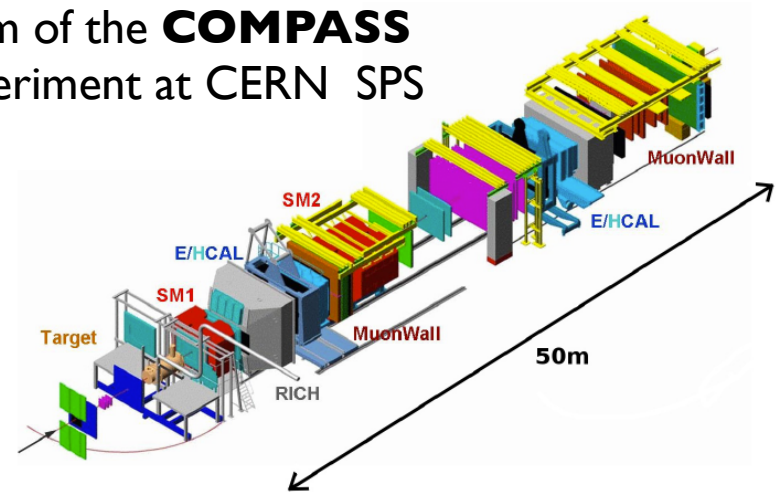


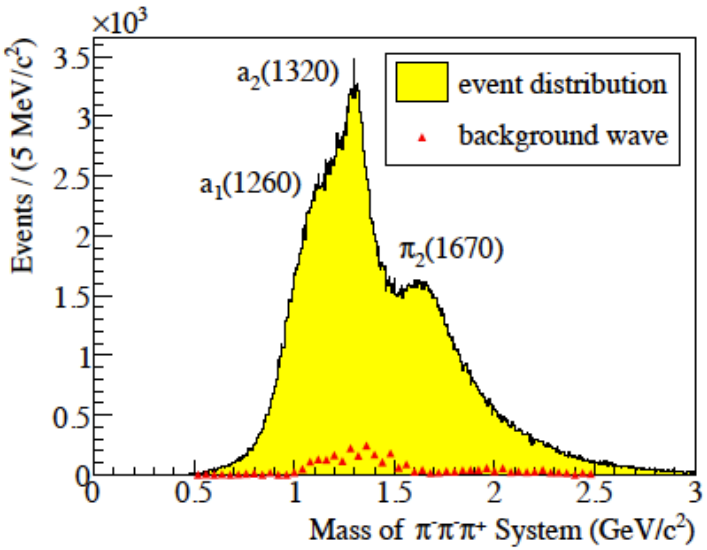
A. Dzierba et. al., PRD 73 (2006) 072001

$\pi_1(1600)$ at COMPASS

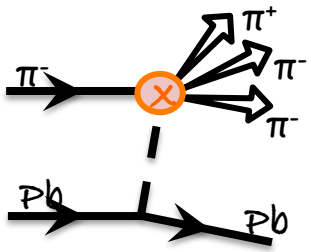
Meson spectroscopy is one of the main program of the **COMPASS** (**CO**mmon **M**uon and **P**roton **A**pparatus) experiment at CERN SPS

- M2-beamline: high intensity π/p beam up to 280GeV/c
- Two-stage magnetic spectrometer
- Large acceptance charged tracking
- Calorimetry (ECAL/HCAL)
- Data taking since 2002





Evidence for the $\pi_1(1600)$ has been searched in the 3 pion final states via diffractive dissociation on lead target at 190 GeV/c



$\pi_1(1600)$ at COMPASS

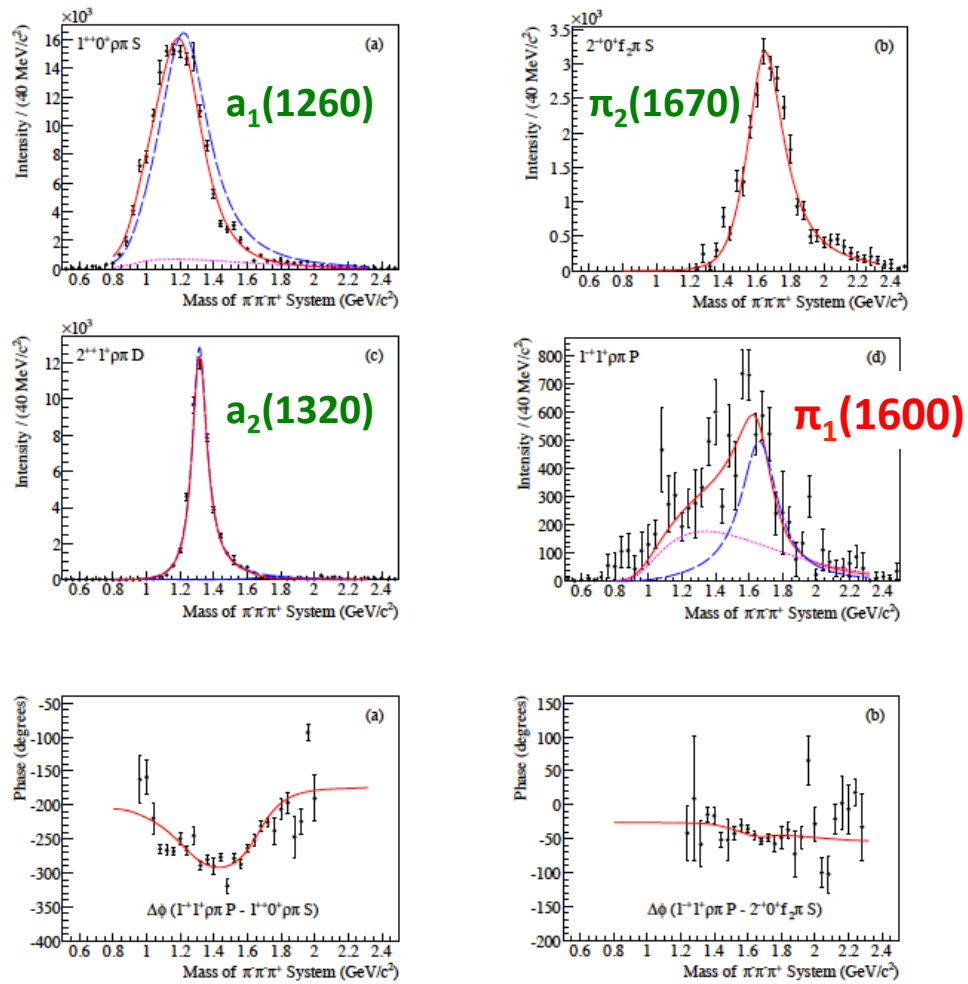
Full PWA of ~420000 events (2004 run) with 42 waves (isobar model approach)

A signal for the exotic 1^{-+} wave is found with

$$M = \left(1.660 \pm 0.010^{+0}_{-0.064}\right) GeV$$

$$\Gamma = \left(0.269 \pm 0.021^{+0.042}_{-0.064}\right) GeV$$

- Clear signal for other known mesons
- Dominant production of the exotic is $M^{\varepsilon} = 1^{+}$ and dominant decay is $\rho\pi$
- Mass of the exotic very close to the $\pi_2(1670)$ and no significant phase motion between π_1 and π_2
- Signal strength of π_1/π_2~20%

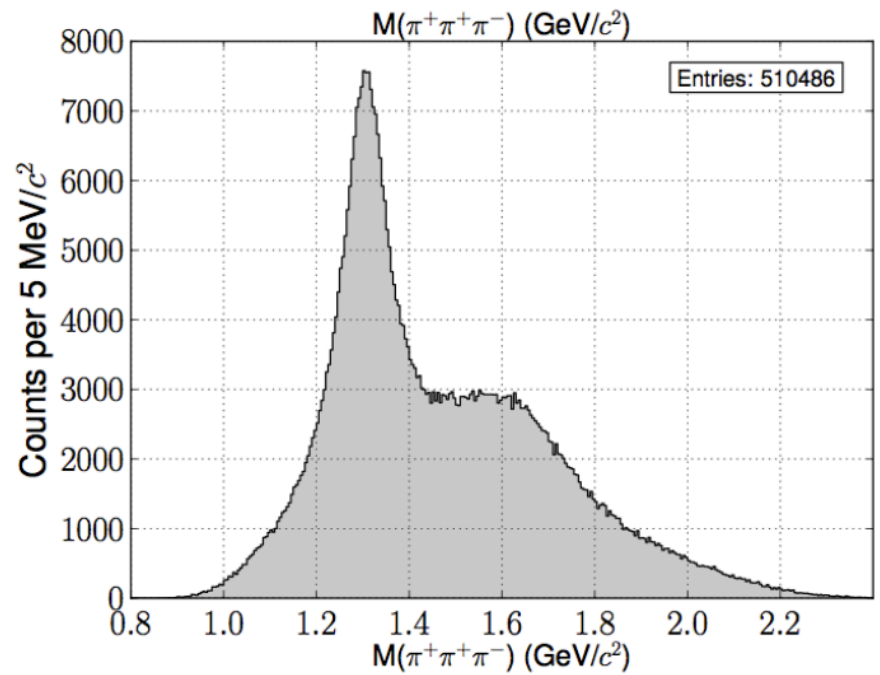


$\pi_1(1600)$ at CLAS

Search for exotics in $\gamma p \to n\pi^+\pi^+\pi^-$

* First analysis of 2001 data show no signal
* New analysis of high statistics 2008 data

- Full PWA with S,P,D waves and ρ and f_2 isobars
- unpolarized photon beam:
  - photon beam is a coherent mixture of both parity eigenstates
  - Final states of different reflectivity do not interfere
- π exchange dominance:
  - equal production of $M^{\varepsilon} = 1^+$ and 1^- (ambiguity)
  - no $M^{\varepsilon} = 0^{\varepsilon}$, no J=0 meson production (spin zero filter)

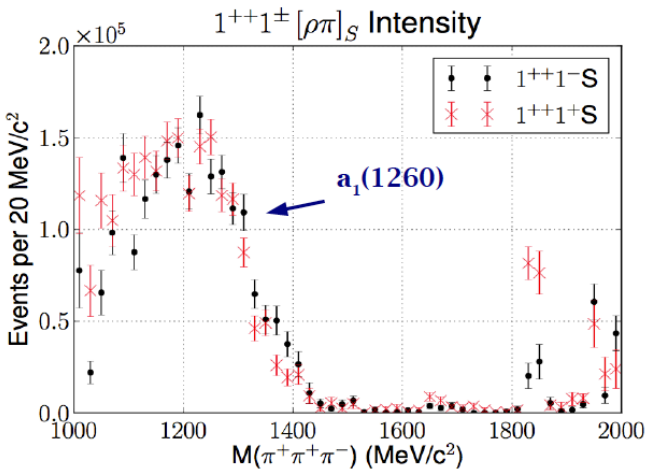


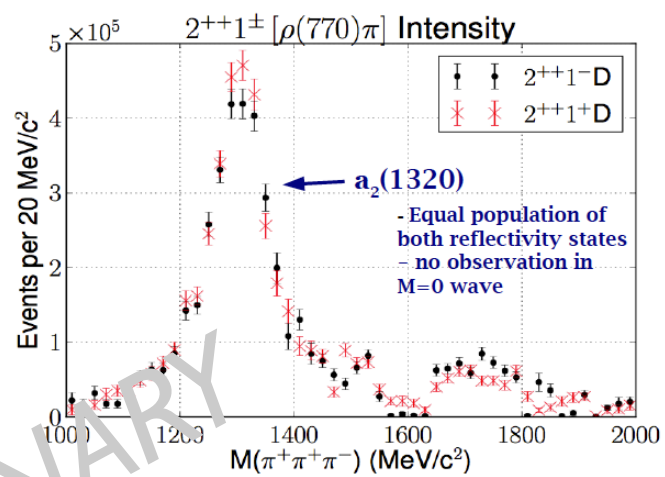
C. Bookwalter (FSU) thesis

Baryon background cuts:
$|t'| < 0.1$ & $\theta_{lab}(\pi^+) < 25°$

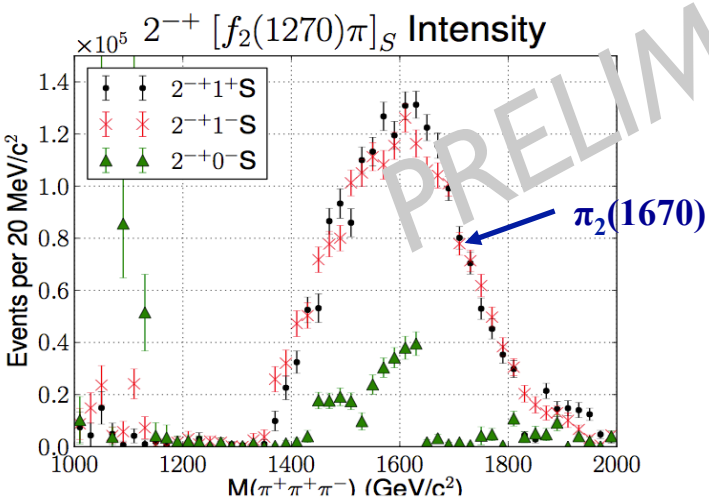
Data dominated by low-t processes, consistently with pion exchange

$\pi_1(1600)$ at CLAS





C. Bookwalter (FSU) thesis



PRELIMINARY

- Observation of known resonances with expected feature
- Non zero M=0 signal in 2^{-+} wave
- Mass dependent fits:

  1^{++}: M~1198 MeV Γ=289 MeV
  2^{++}: M~1309 MeV Γ=109 MeV
  2^{-+}: M~1650 MeV Γ=235 MeV

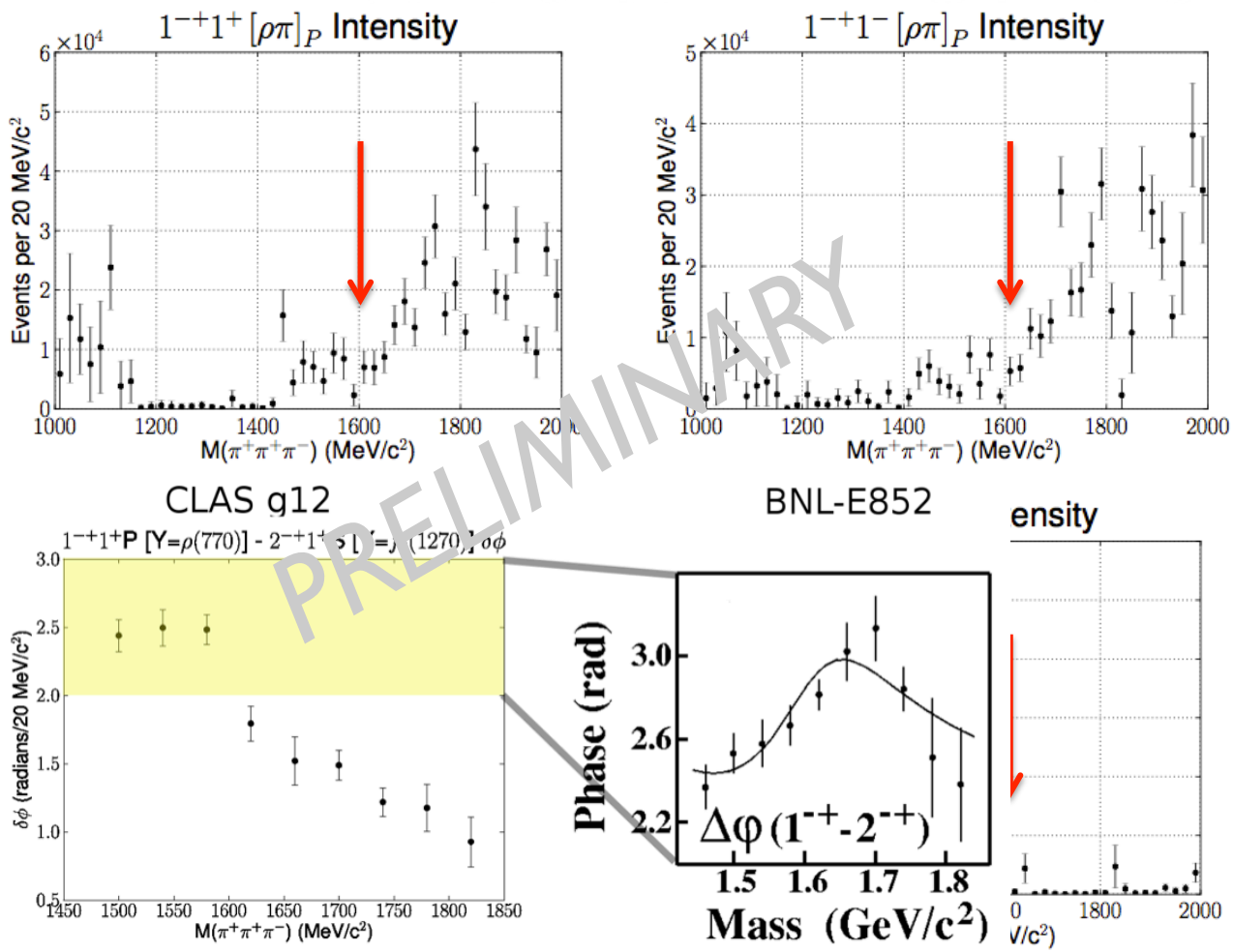
  in good agreement with PDG values

$\pi_1(1600)$ at CLAS

- No signal is observed in M=1,0 waves
- Fluctuations at high mass
- Wave intensities accounts for ~2% of total strength

- No evidence of exotic 1^{-+} phase motion
- Phase motion consistent with resonant 2^{-+} wave

Seems inconsistent with COMPASS results but could be explained if exotics is produced via pomeron exchange



π_1 Summary

- $\pi_1(1600)$ is probably the most studied exotic candidate…
- Most recent investigations focused on 3 pion channel with controversial results:
  - discrepancies may be explained with different production mechanism
  - new (preliminary) analysis of COMPASS data seems to confirm this hypothesis
  - old results in other decay modes ($\eta'\pi$, $f_1\pi$, $b_1\pi$) still needs confirmation from high statistics data analyses

May look discouraging but many progresses have been made in understanding production and decays showing we are on the right path…

Still a lot to do:

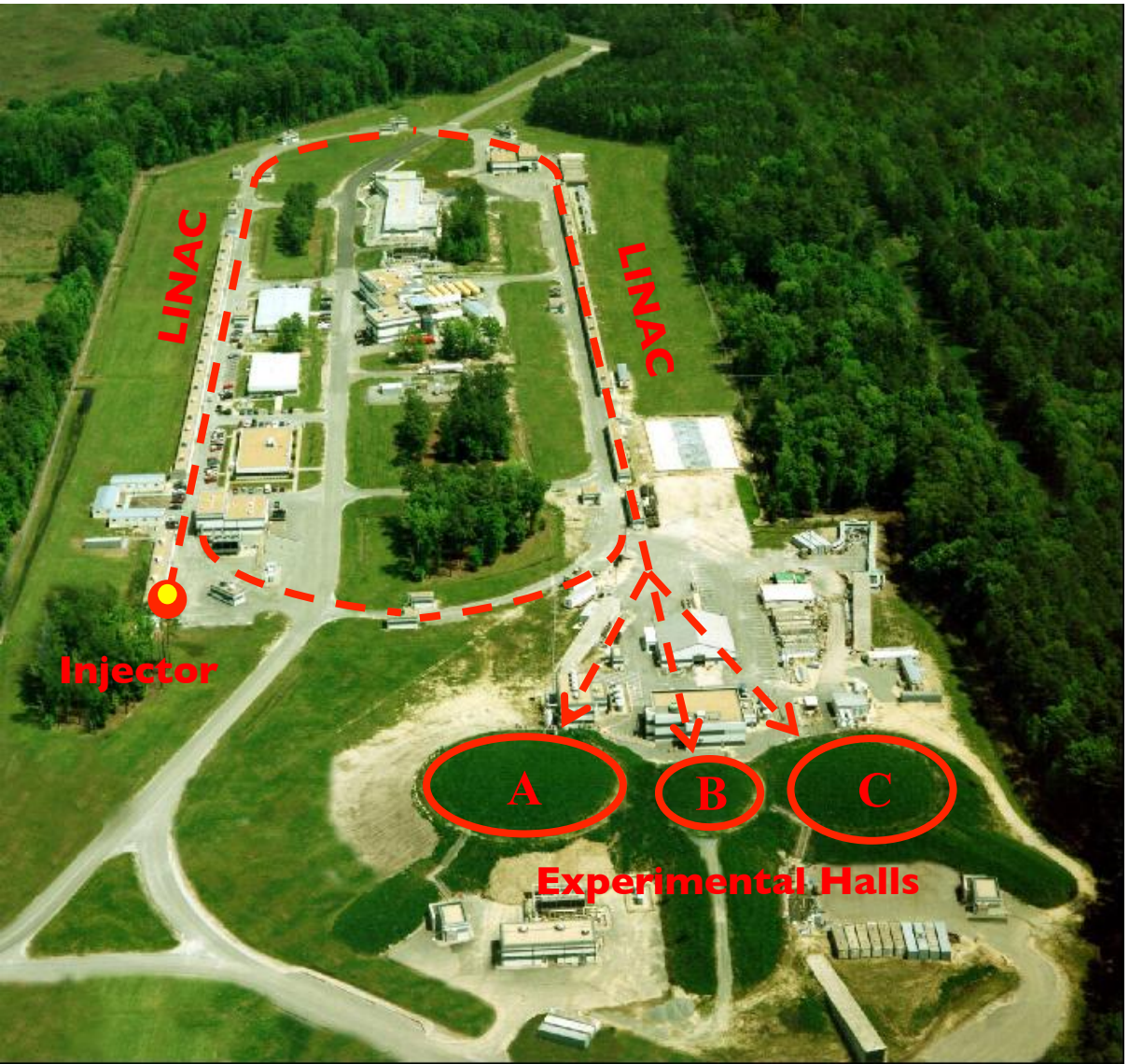
- no signal reported yet for the other members of the 1^{-+} multiplet, η_1 or η_1'.
- no signal reported yet for other exotics (2^{+-} or 0^{+-})

Future Perspectives

- Many experiments in the world have searched and are searching for exotic signals in the light-quark sector
- Many experiments are planned to start in the near future…

- proton-antiproton annihilation:
  Crystal Barrel at CERN, LHC, Panda at GSI, ...
- $e^+ e^-$ annihilation:
  LEP, Babar at SLAC, DAΦNE at Frascati, CLEO at Cornell, BES at Beijing, …
- proton-proton scattering:
  WA experiments at CERN, GAMS at Protvino, …
- pion beams on fixed target:
  E852 at BNL, COMPASS at Cern, VES …
- photoproduction experiments:
  CLAS at Jefferson Lab, GlueX and CLAS12 at Jefferson Lab

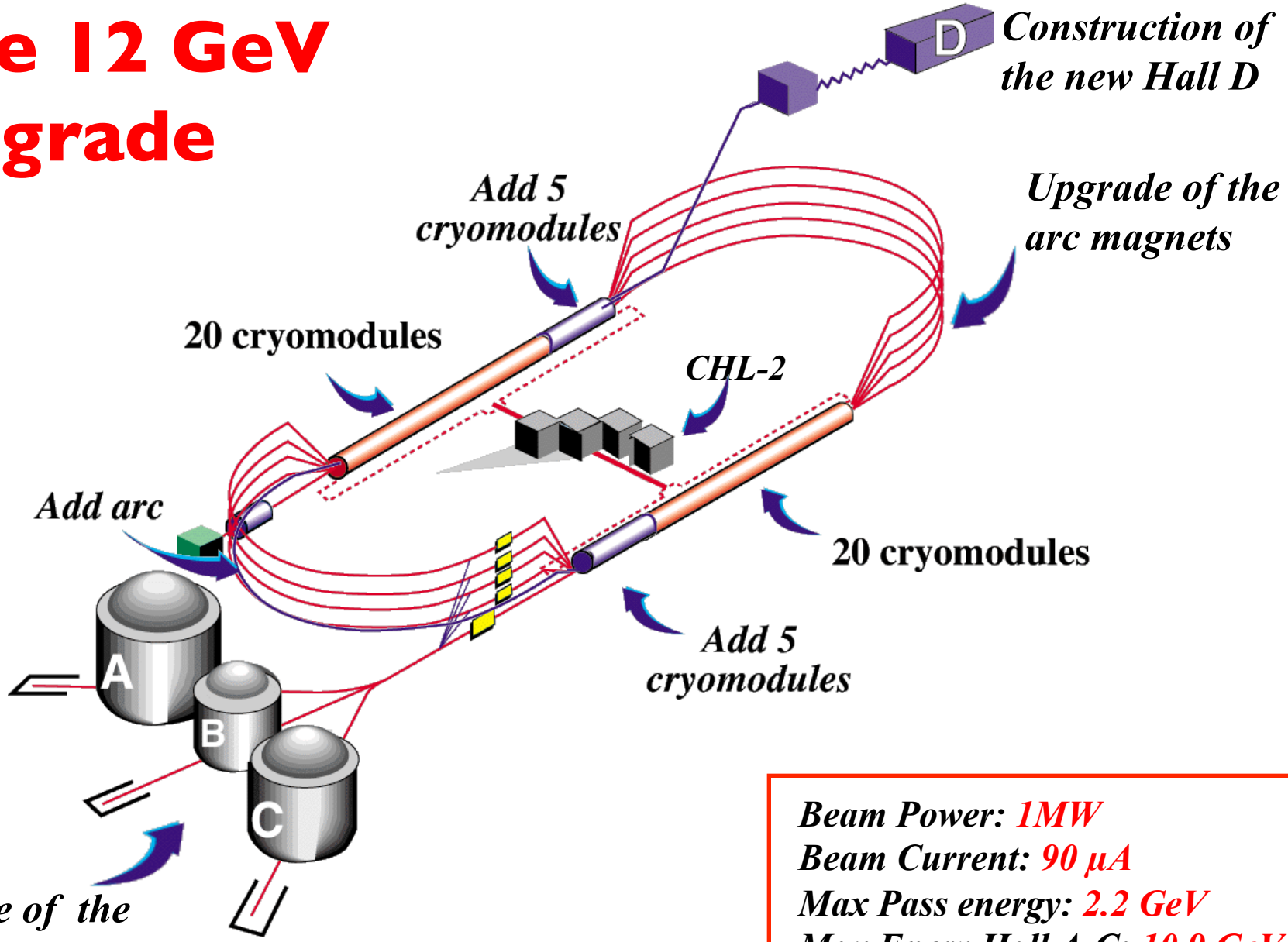
Jefferson Laboratory



Continuous Electron Beam Accelerator Facility

- → E: 0.75 –6 GeV
- → I_{max}: 200mA
- → RF: 1499 MHz
- → Duty Cycle: ~ 100%
- → s(E)/E: 2.5×10^{-5}
- → Polarization: 80%
- → Simultaneous distribution to 3 experimental Halls

The 12 GeV Upgrade



Upgrade of the instrumentation of the existing Halls

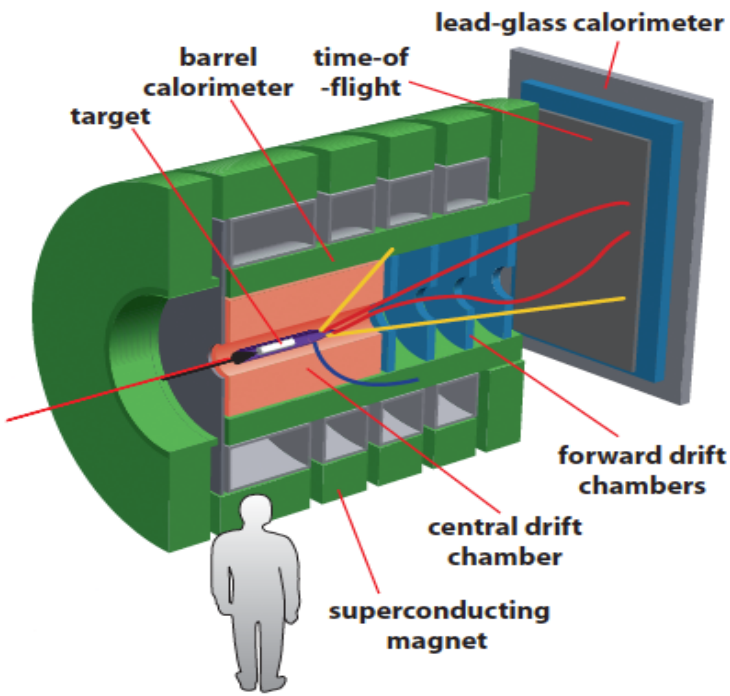
Beam Power: 1MW
Beam Current: 90 μA
Max Pass energy: 2.2 GeV
Max Enery Hall A-C: 10.9 GeV
Max Energy Hall D: 12 GeV

CLAS12 and GLUEX

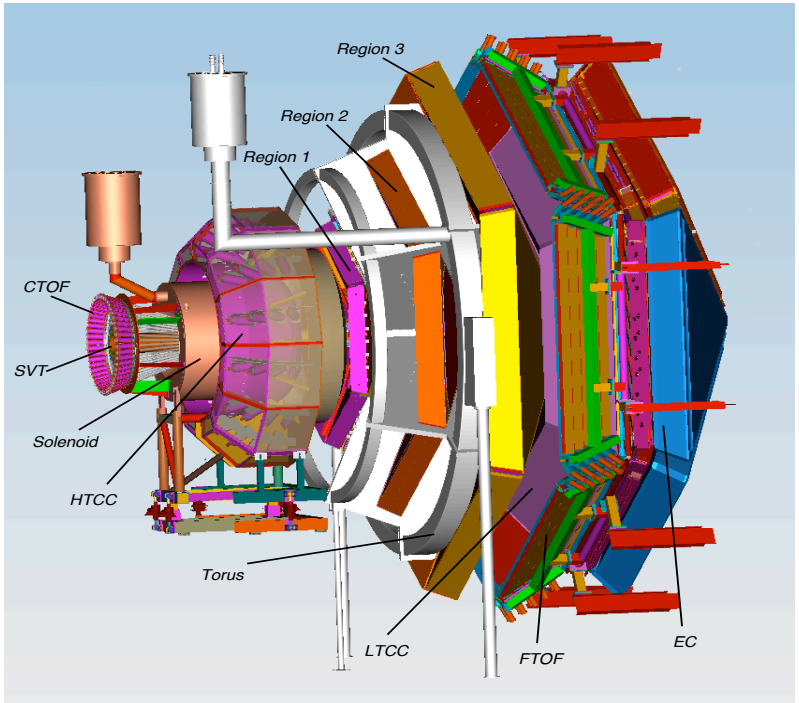
Meson spectroscopy is one of the main topics that will be studied with the Jlab 12 GeV upgrade. Key elements are:

- High intensity tagged photon beams
- Detectors with large acceptance and good particle identification capabilities

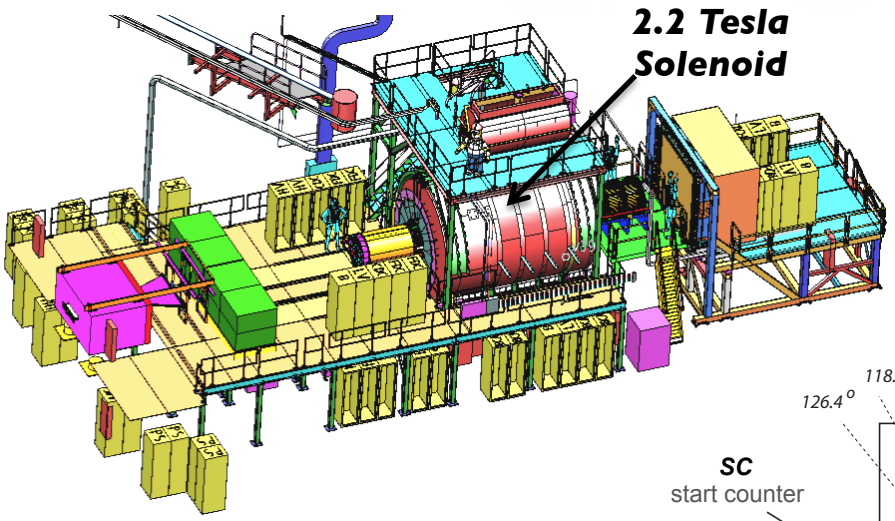
GlueX in Hall D



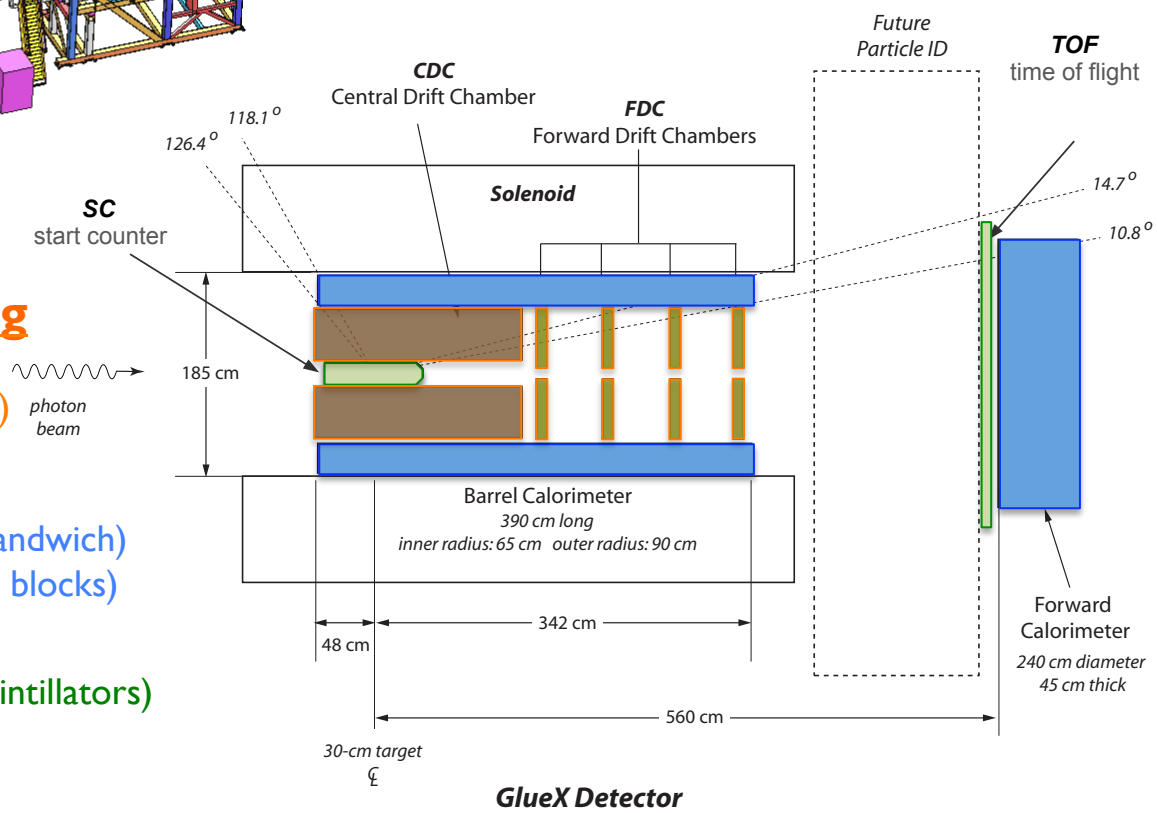
CLAS12 in Hall B



The GlueX Detector



- 2.2T superconducting solenoidal magnet
- Fixed target (LH_2)
- 10^8 tagged γ/s (8.4-9.0GeV)
- hermetic



Charged particle tracking

- Central drift chamber (straw tube)
- Forward drift chamber (cathode strip)

Calorimetry

- Barrel Calorimeter (lead, fiber sandwich)
- Forward Calorimeter (lead-glass blocks)

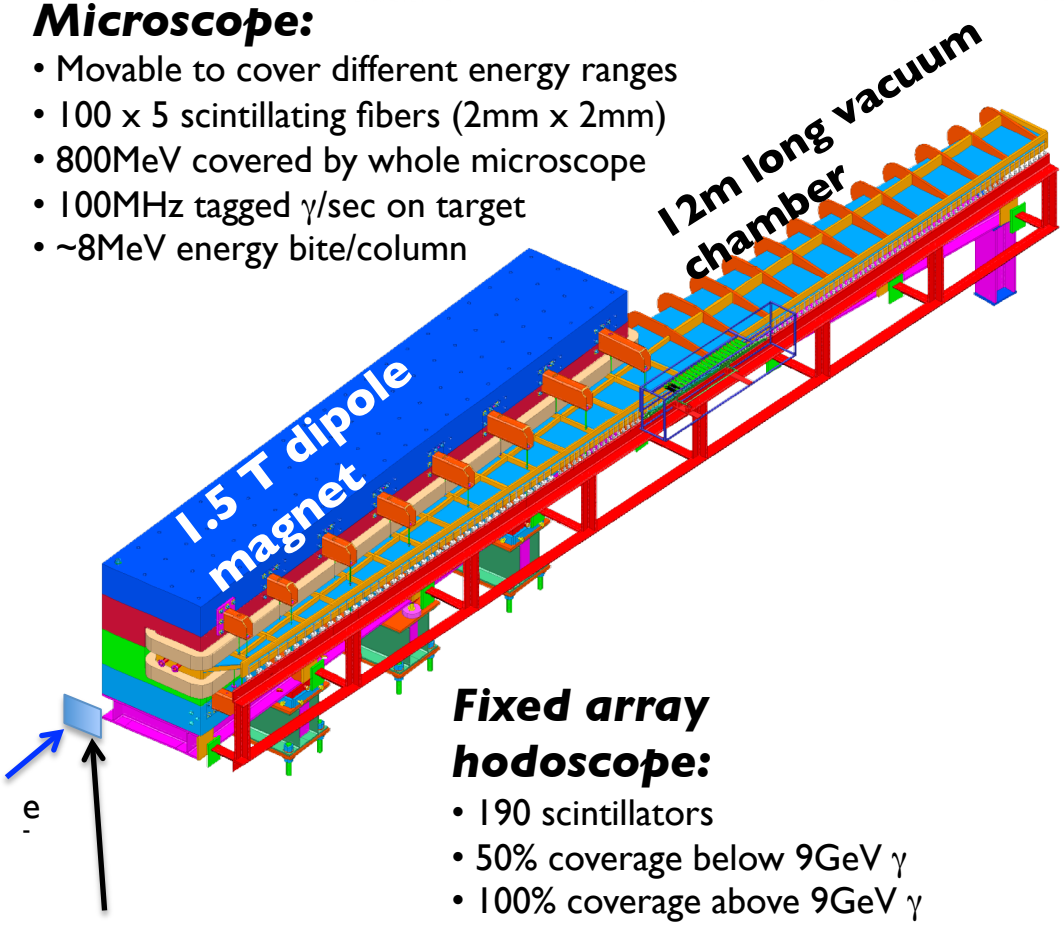
PID

- Time of Flight wall (scintillators)
- Start counter
- Barrel Calorimeter

The Hall D Photo Beam

Microscope:

- Movable to cover different energy ranges
- 100 x 5 scintillating fibers (2mm x 2mm)
- 800MeV covered by whole microscope
- 100MHz tagged γ/sec on target
- ~8MeV energy bite/column

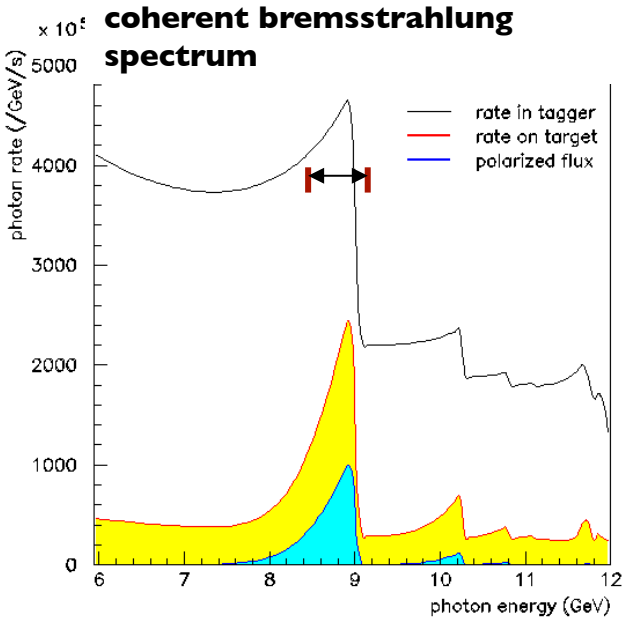


Fixed array hodoscope:

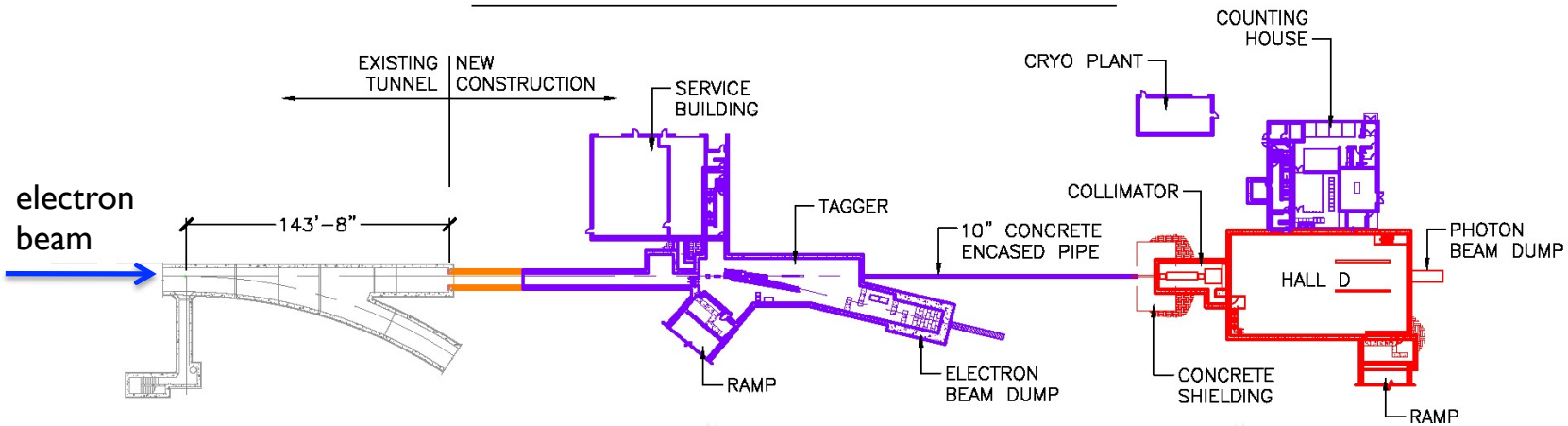
- 190 scintillators
- 50% coverage below 9GeV γ
- 100% coverage above 9GeV γ
- Tags 3.0-11.7 GeV γ
- ~30MeV energy bite/counter
- 3.5 – 17 MHz/counter

Photon Polarization:

- 20 μm diamond radiator
- Coherent peak is linearly polarized
- ~40% polarization with peak @ 9GeV
- Peak location tunable with diamond angle
- **Crucial to simplify PWA!!**



The Hall D Complex

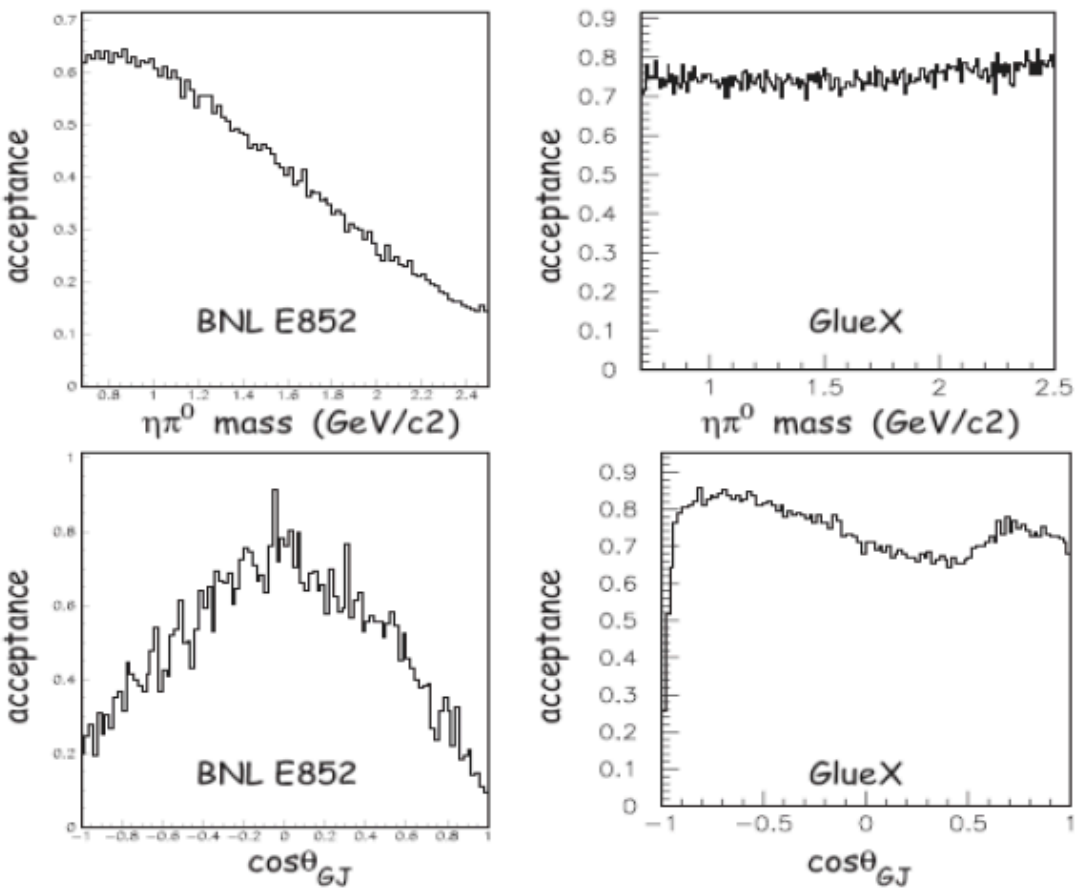



Groundbreaking, April 2009


In the Hall, February 2011

Expected performance

Design Goal: high and uniform acceptance



Comparison of acceptance plots between BNL E852 and GlueX in a sample channel:

high and uniform acceptance in invariant mass and Gottfried-Jackson angles.

CLAS12

Forward Detector:

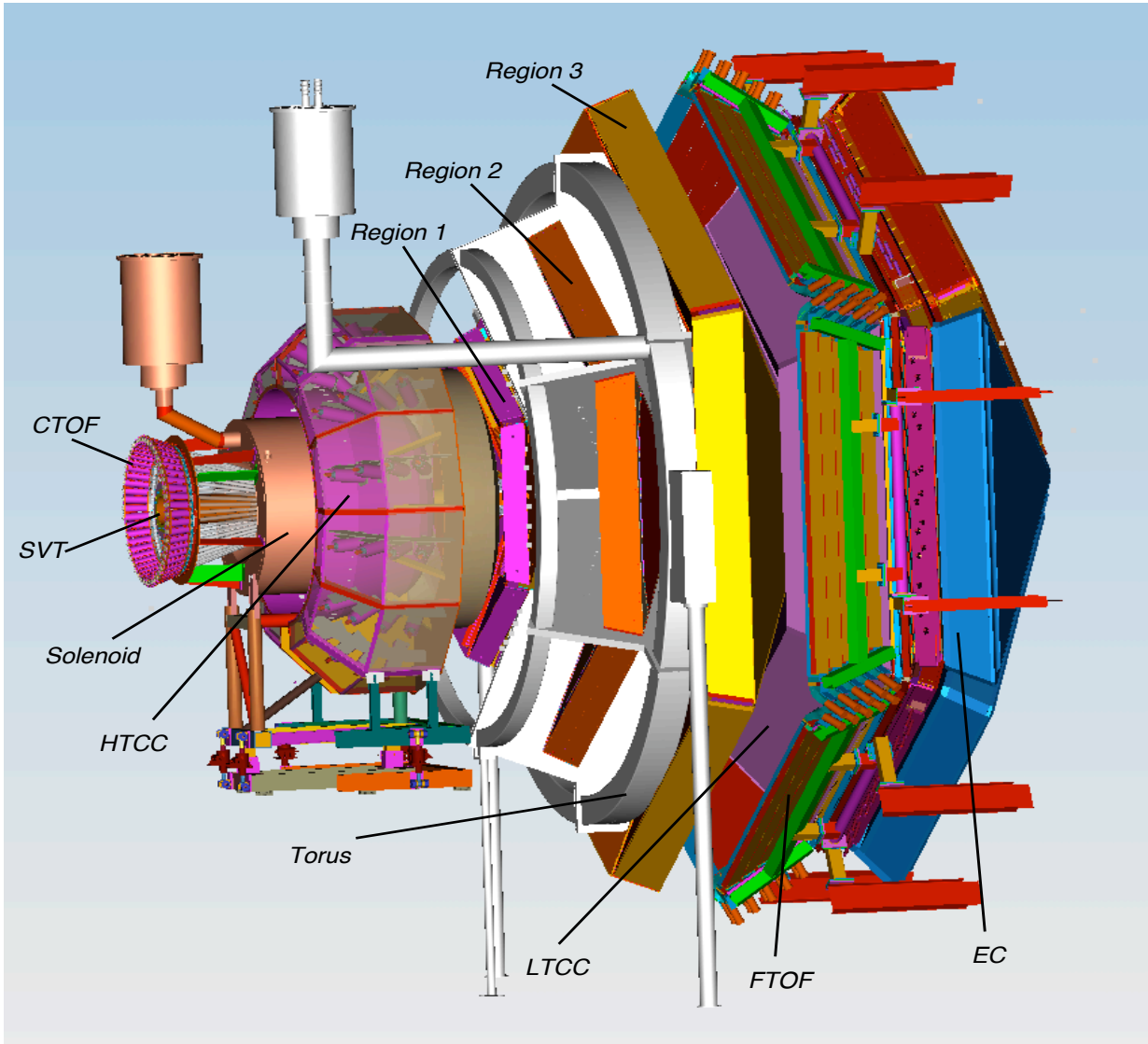
- *TORUS magnet*
- *Forward SVT tracker*
- *HT Cherenkov Counter*
- *Drift chamber system*
- *LT Cherenkov Counter*
- *Forward ToF System*
- *Preshower calorimeter*
- *E.M. calorimeter (EC)*

Central Detector:

- *SOLENOID magnet*
- *Barrel Silicon Tracker*
- *Central Time-of-Flight*

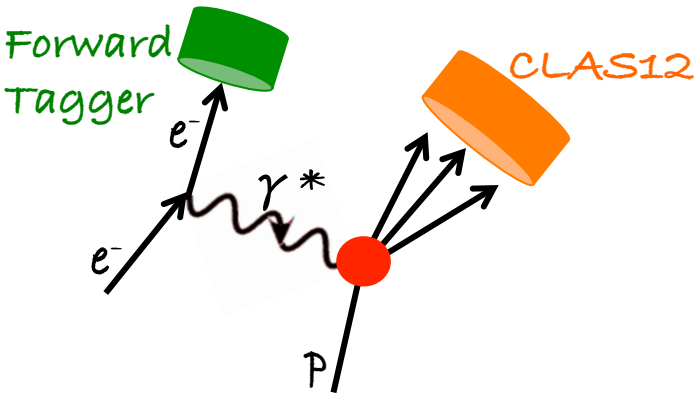
Proposed upgrades:

- *Micromegas (CD)*
- *Neutron detector (CD)*
- *RICH detector (FD)*
- *Forward Tagger (FD)*



The CLAS12 Forward Tagger

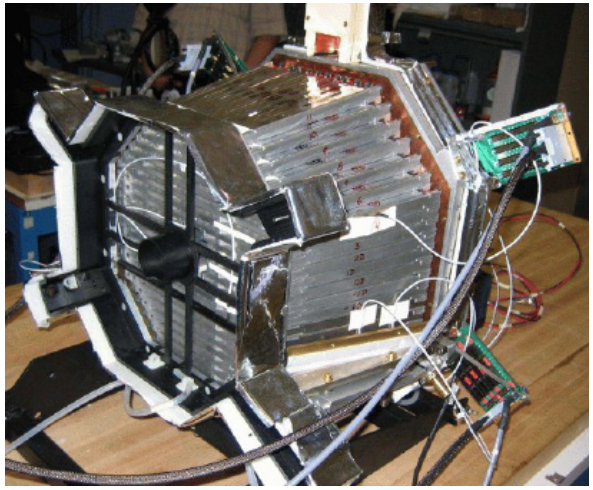
Electron detection via **Calorimeter+Tracker+Veto**



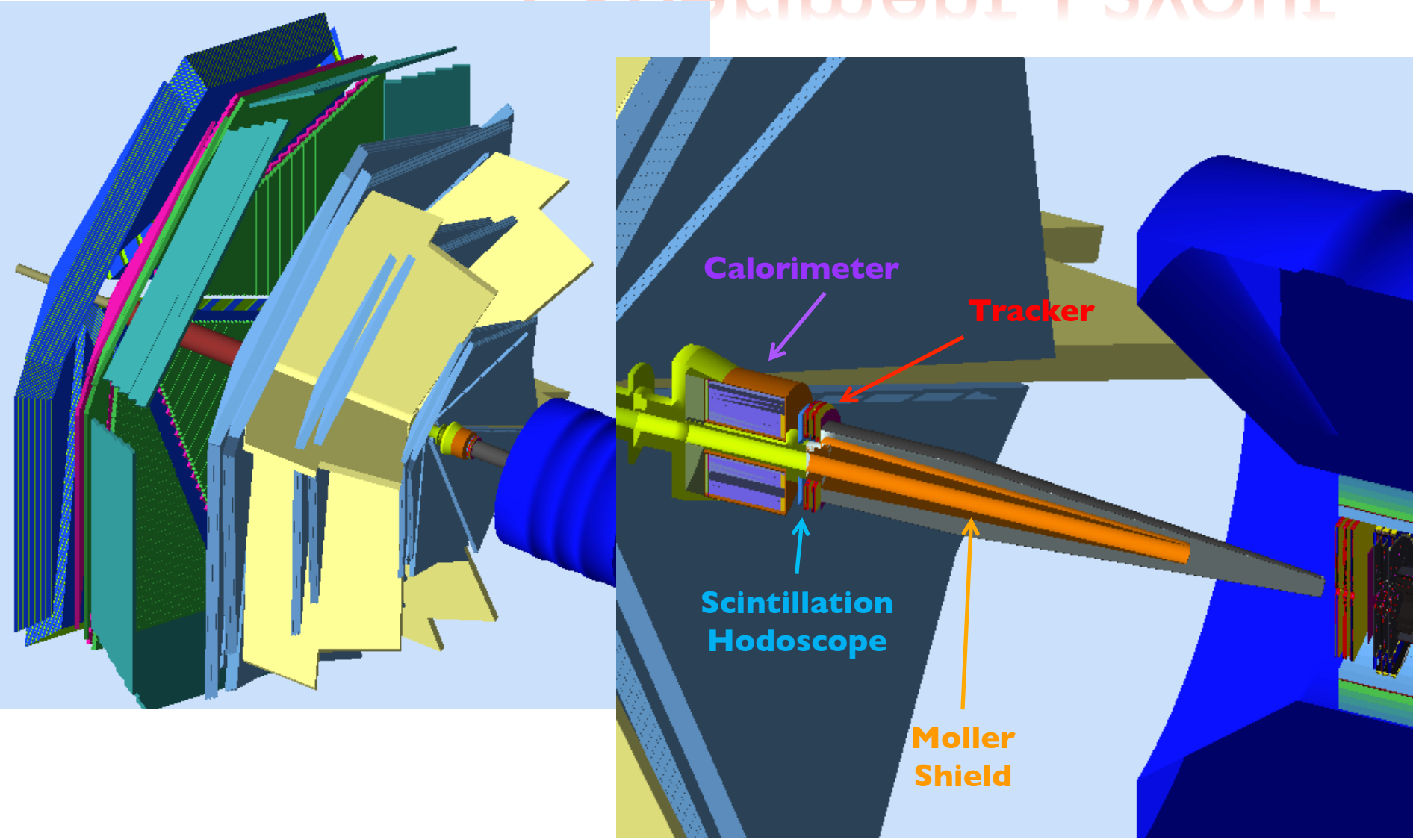
- *calorimeter* to determine the electron energy with few % accuracy → homogenous $PbWO_4$ crystals
- *tracker* to determine precisely the electron scattering plane and the photon polarization → micromegas
- *veto* to distinguish photons from electrons → scintillator tiles with WLS fiber readout

Forward Tagger	
E'	0.5-4.5 GeV
ν	7-10.5 GeV
θ	2.5-4.5 deg
Q^2	0.007 – 0.3 GeV^2
W	3.6-4.5 GeV
Photon Flux	5 x 10^7 g/s @ $L_e=10^{35}$

PbWO4 calorimeter
424 crystals



Experiment Layout



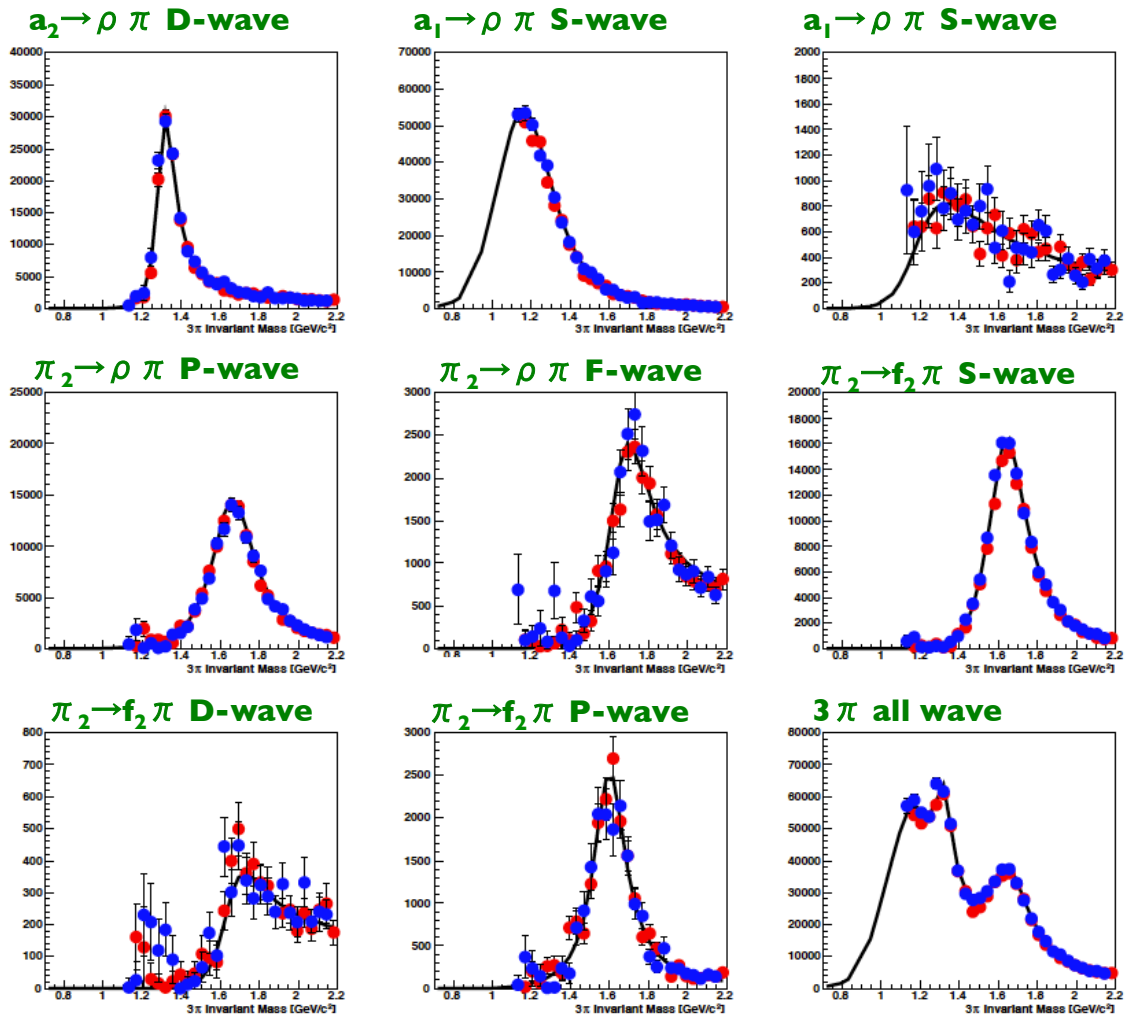
PWA in CLAS12

In preparation for the experiment, **PWA tools** are being developed and tested on pseudo data (Monte Carlo) for different reactions as $\gamma p \rightarrow n\pi^+\pi^+\pi^-$

Test for 2 t bins:

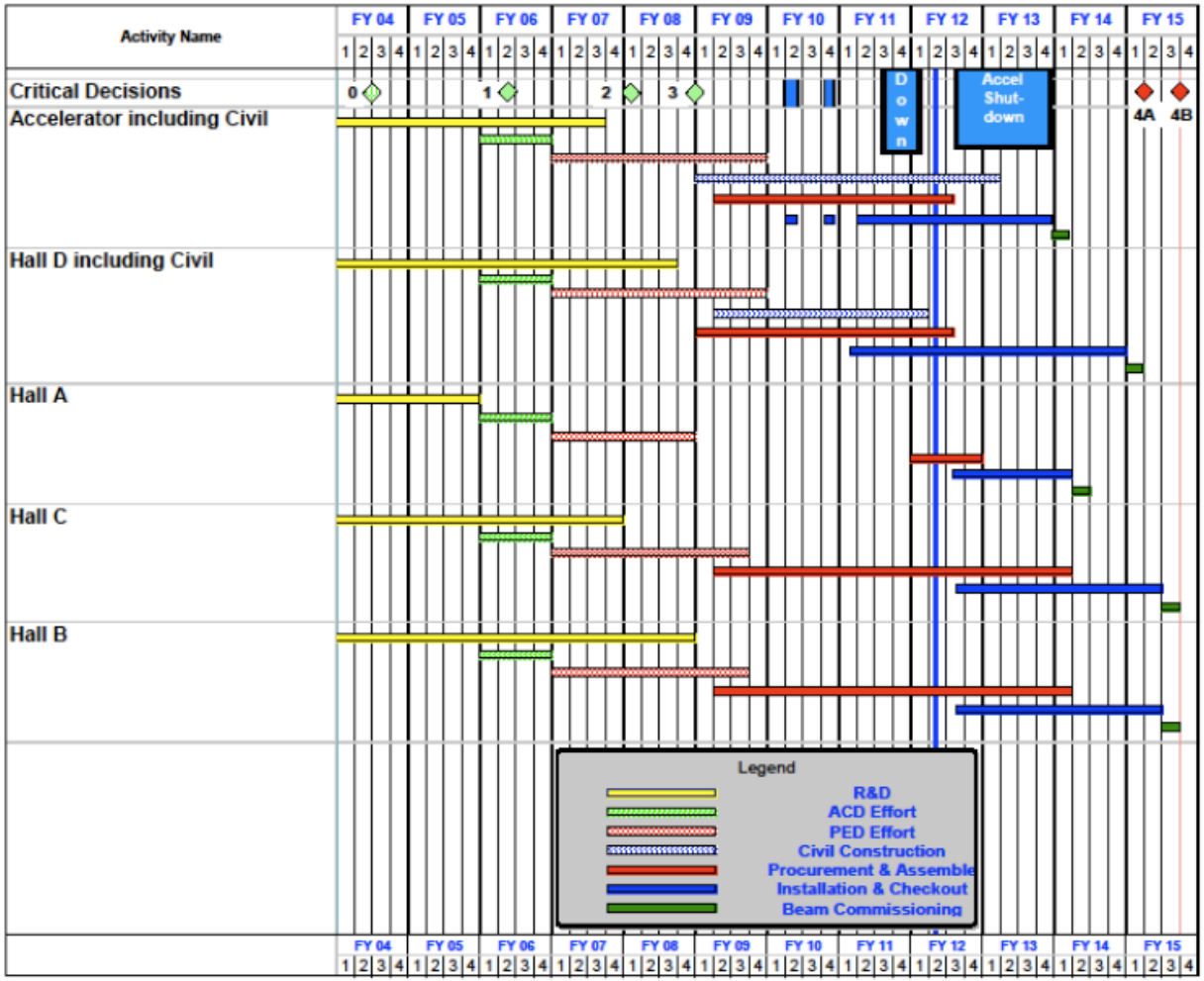
- line: generated wave
- $|t|=0.2$ GeV^2
- $|t|=0.5$ GeV^2

As a function of $M_{3\pi}$



The CLAS12 detector system is intrinsically capable of meson spectroscopy measurements

12 GeV Program Schedule



- Hall D/Gluex commissioning starts October 2014
- Hall B/CLAS12 commissioning starts April 2015

Future Challenges

* High statistics, high quality data sets are expected to be collected in the near future to continue the study of meson spectroscopy
* These will give access to low cross-section channels and multi-particle decay modes that could not be studied before

New challenges will have to be faced:

Analysis and Computing:

- full partial wave analysis of the new data sets demand for large computing power both for data analysis and Monte Carlo simulation
- new, optimized PWA codes with built-in support for GPUs are been developed by the experimental collaborations

Amplitudes Parameterization and Theoretical Input:

- Most of existing PWA codes are based on the isobar model
- Extraction of small waves (<10%) requires higher level of sophistication
- Strict collaboration between theorists and experimentalist is needed:
  - *INT Workshop on Hadron Spectroscopy, Seattle, November 9-13 2009*
  - *ECT* Workshop on Amplitude Analysis in Hadron Spectroscopy, Trento, January 10-14 2011*
  - …
  - *Jefferson Lab Advanced Study Institute, Williamsburg, May 31- June 13 2012*
  - *ATHOS12 Workshop on New Partial Wave Analysis Tools for Next Generation Hadron Spectroscopy Experiments, Camogli, June 19-22 2012*

Summary

* Meson spectroscopy is a key field for the understanding of fundamental questions in hadronic physics as what is the origin of the nucleon mass and what is the role of gluons

* Primary focus of the experimental activity in this field aims at establishing the quark-antiquark bound state spectrum and searching for exotic configurations such as glueballs and hybrids

* Experiments all over the world are collecting high statistics high precision data, providing new insight in the meson spectrum

* The coherent effort of experimentalist and theorists will allow us to improve our understanding of QCD in the strong regime