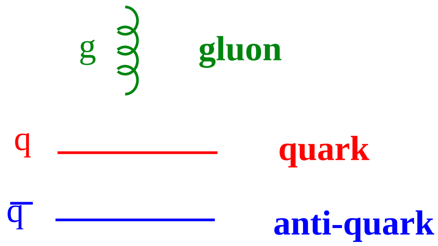
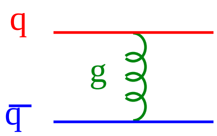
Standard Model Mesons

Building blocks:

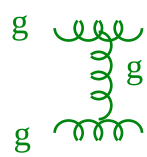




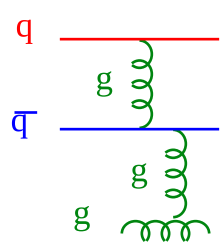
a conventional meson

Also allowed in the Standard Model are these non-conventional mesons:

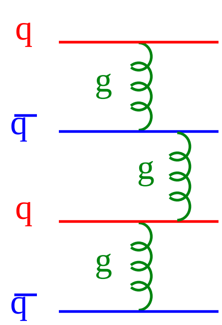
glueballs
- pure glue, no quarks



hybrids
- with valence glue



4 - quark states
- or molecules



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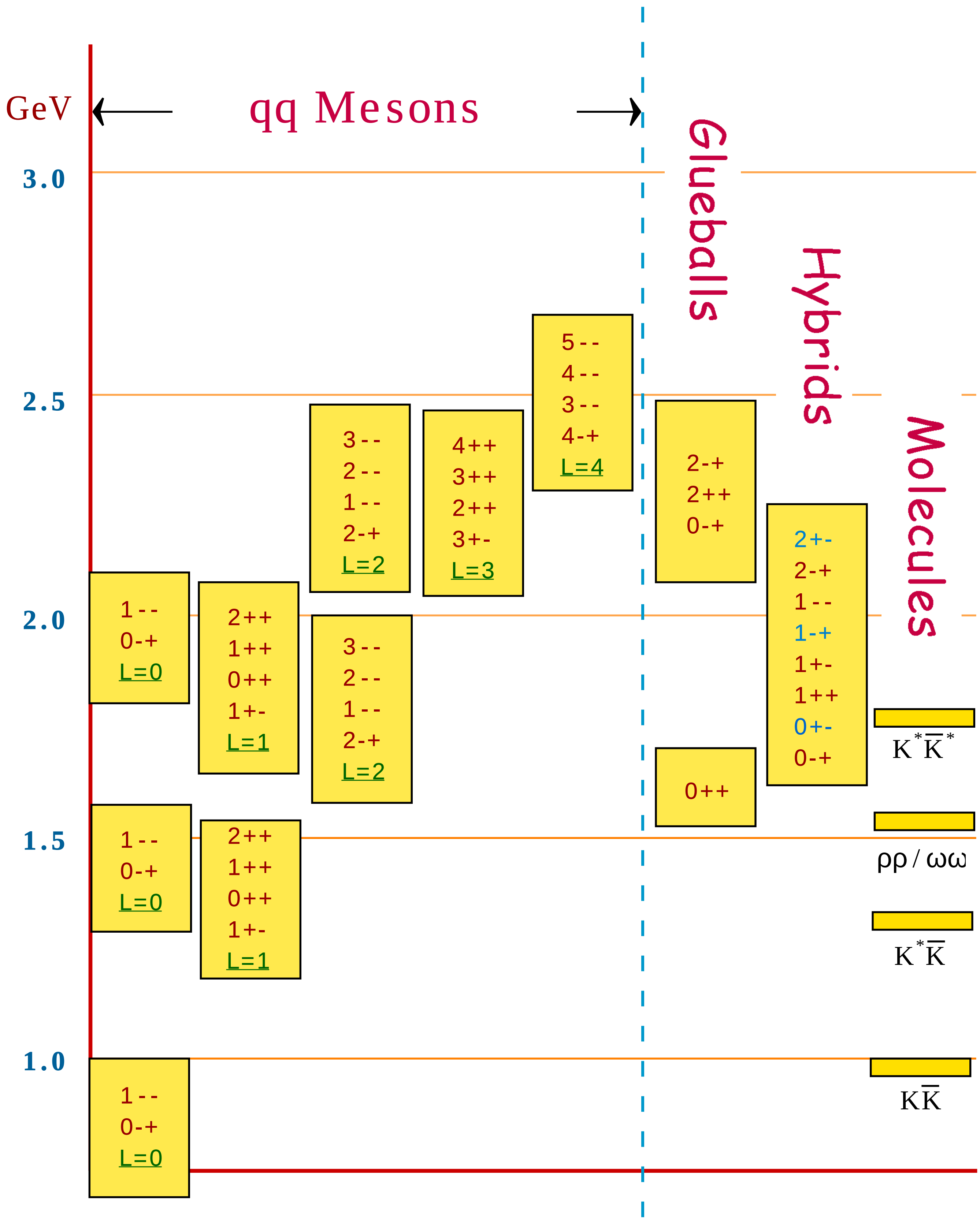
Map of the Mesons



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Photons and Meson Spectroscopy

Light Quark Mesons below Charm Threshold

★ **Essentially nothing is known from photoproduction**

✓ **Needed to complement hadroproduction**
many open questions remain

★ **Photons are expected to excite:**

✓ **Spin-1 hybrids**
✓ **States rich in $s\bar{s}$**
✓ **Excited vector states**

★ **Need to explore mass range from 0 to $c\bar{c}$ threshold**

✓ **Photon beam energy: ultimately - 12 GeV**

✓ **Photon flux - 3 x 10^8 photons/sec**
to achieve stats comparable to π beams

✓ **Beam Energy resolution - 0.25% to 0.1%**

✓ **Hermetic Detector**
identify exclusive reaction (for PWA)
measure p, E with good resolution
identify π, K, p
measure final state γ's

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Photoproduction and Meson Spectroscopy

- why is the photon so special ?

1. **Information on meson production comes from**

- ★ **peripheral & central hadroproduction with (π and K beams)**
- ★ e^+e^- **and** $p\bar{p}$ **annihilations**
- ★ $\gamma\gamma$ **collisions**
- ★ J/ψ **radiative decays**

This variety of processes necessary to study the meson spectrum: production and decays are both important.

Data on photoproduction of mesons in the 0-3 GeV mass range is essentially non-existent. The photon is a very different probe (a vector or a $q\bar{q}$).

2. **At JLab energies, the photon is a $s\bar{s}$ and is expected to produce states rich in hidden strangeness (at FNAL energies photopro- duction opened the doors to charm spectroscopy).**

3. **The photon is expected to create hybrids with exotic quantum numbers.**

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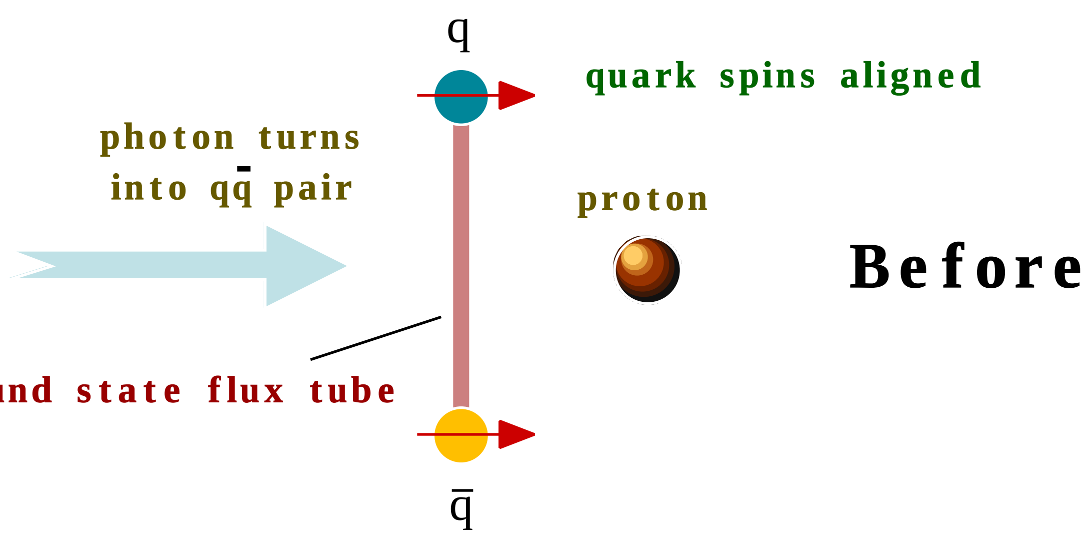
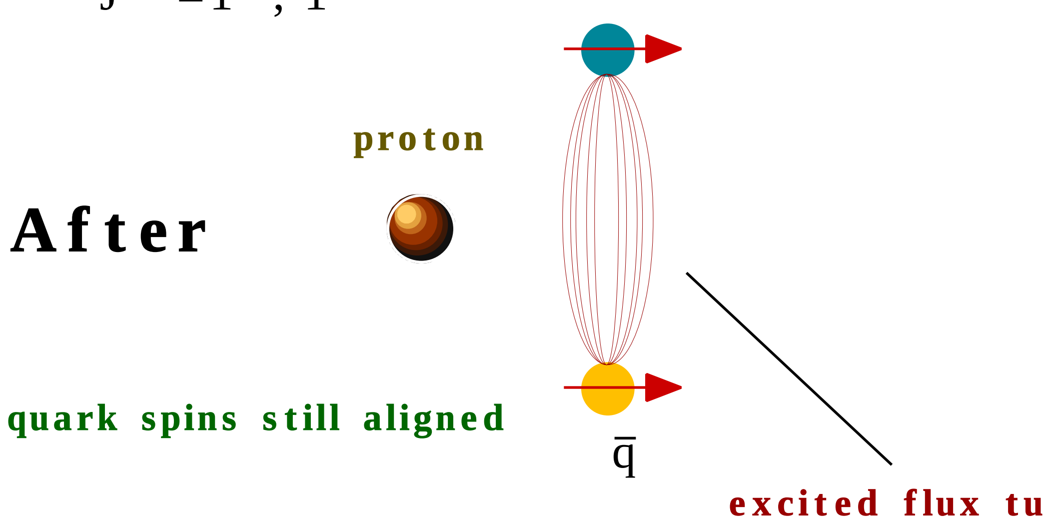
How Photon Beams Create
Exotic Hybrids



$S_{\pi\pi} = 1 \qquad \Lambda = 0 \qquad J^{PC} = 1^{--},\ 1^{++}$



$S_{\pi\pi} = 1 \qquad \Lambda = 1$

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

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

Exotic

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Photoproduction of Mesons

Data on meson in the 0 - 3 GeV range:
almost non-existent

Example of state which has been studied in photoproduction at SLAC - the a_2:

$$\gamma p \rightarrow a_2(1320)\Delta^{++}$$

BC-72 at SLAC using 19 GeV photons.

The signal in resonance region contains about 200 events in a 350 MeV window with S/N = 1/1. The cross-section is about 0.5 μb.

In Hall-D, we expect 380 events/μb/sec with a beam flux of 3×10^8 photons/sec.

Compared to BC-72, in one day we will see:

16 million events - compared to - 200 events

Physics Goals

- ***search for gluonic excitations - notably the spin 1 exotic hybrids.***
  The search for these manifestations of glue. The soft gluonic degrees of freedom remain completely unexplored. This sector is crucial to understanding the non-Abelian structure of QCD.

- ***search for multi-quark states and meson molecules.***
  The reactions $\gamma p \rightarrow PPN$ and $\gamma p \rightarrow VVN$ will be fertile territory for such searches.

- ***produce excited states of vector mesons and other conventional mesons.***
  There is a dearth of information of these conventional states, e.g. excited states of the ρ, ω and φ, in the 1 to 3 GeV mass regime. Since the low-lying hybrids and glueballs are expected to populate this regime - and can mix with conventional states - it will be essential to understand conventional mesons as well. At these incident energies, diffractive and meson exchange processes can be separated - this will shed light on the nature of the pomeron.

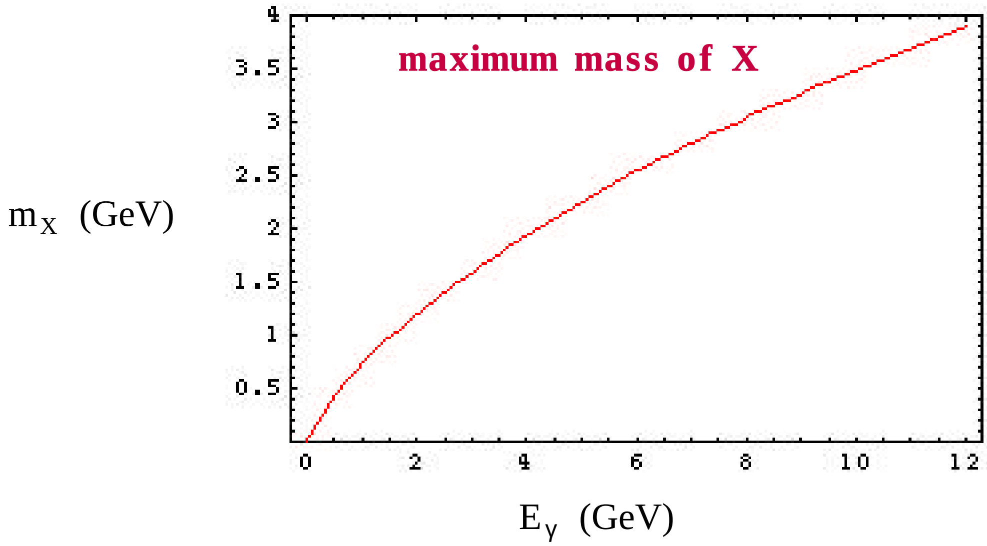
- ***mass produce states rich in hidden strangeness.***
  This will allow the search for decays of the η, η', φ., ...

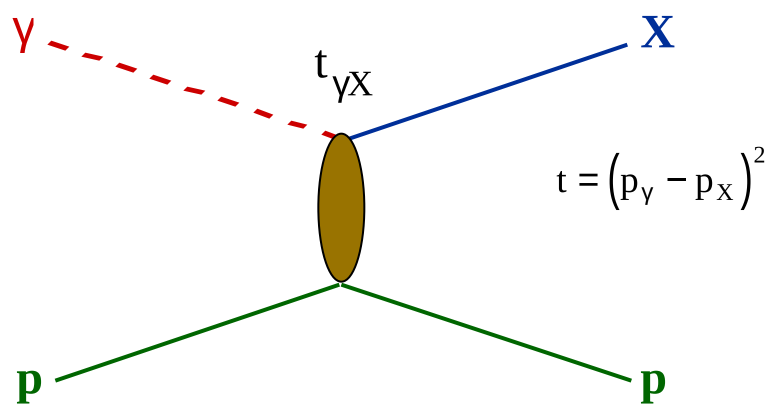
- ***study the threshold production of charm.***
  The proposed energy regime straddles the light quark and heavy quark regimes.

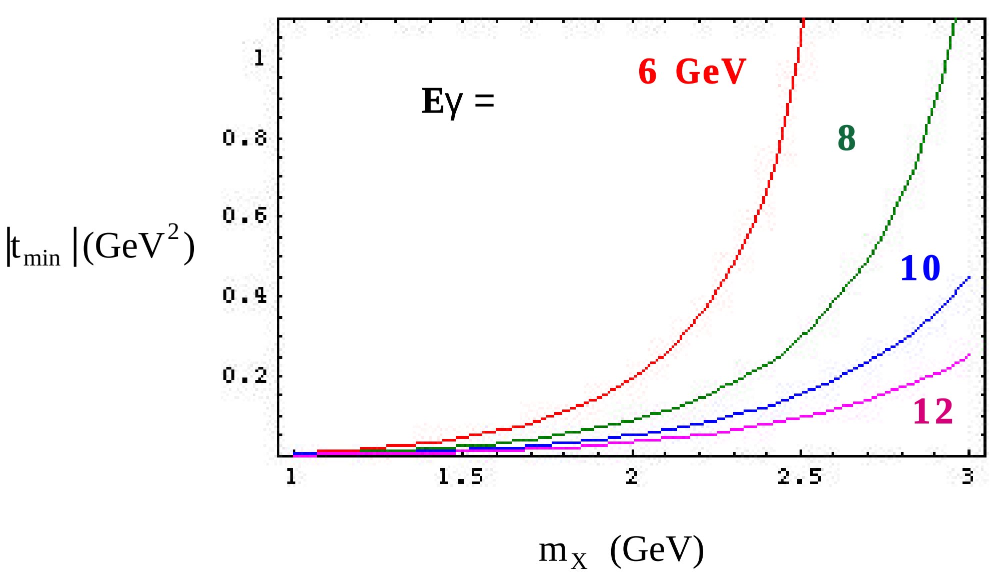
- ***test chiral symmetry.***
  The decays of the η and η' provide a laboratory for such tests.

- ***test CPT invariance.***
  This will exploit the copious source of φ mesons.

Kinematics of $\gamma p \rightarrow Xp$







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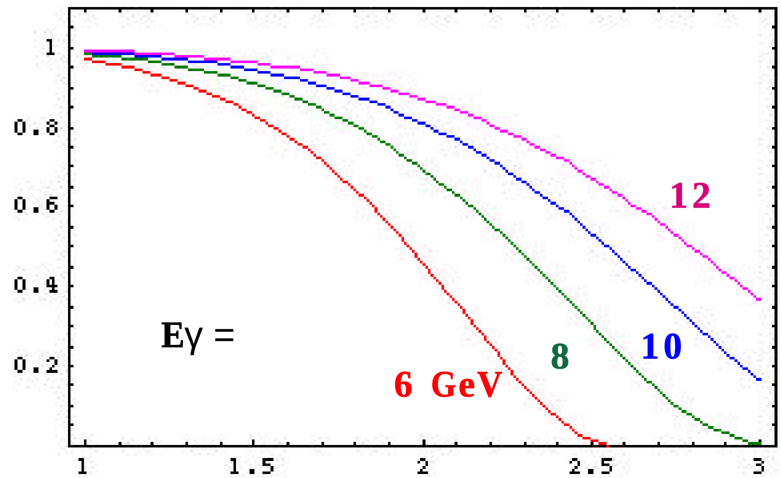
Effect of t_{min} on Yields

$a = 4\ GeV^{-2}$

$$f = \int_{t(min)}^{t(max)} \frac{d\sigma}{dt} dt$$

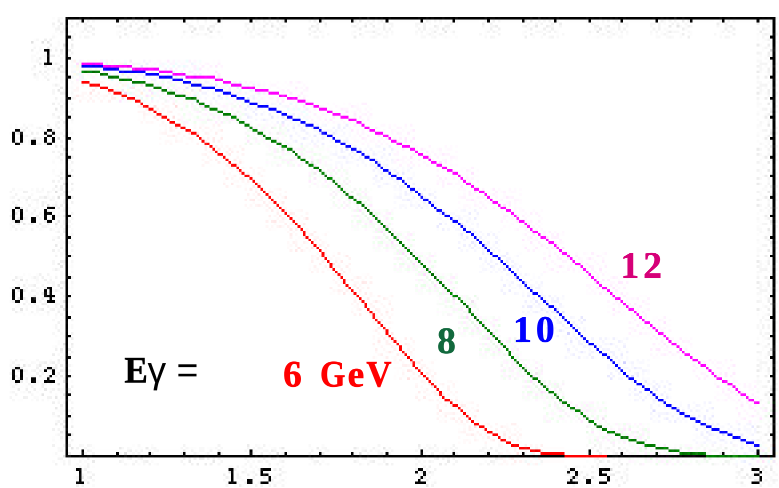


m_X (GeV)

$$\frac{d\sigma}{d|t|} = a\ e^{-a|t|}$$

$a = 8\ GeV^{-2}$

$$f = \int_{t(min)}^{t(max)} \frac{d\sigma}{dt} dt$$



m_X (GeV)

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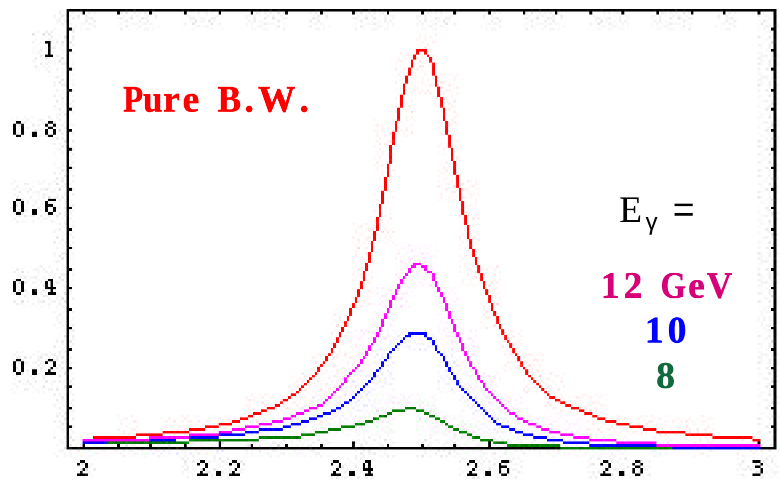
Effect of t_{min} on Line Shape

$$\int_{t(min)}^{t(max)} \frac{d\sigma}{dt}\, dt \times \frac{(\Gamma/2)^2}{(m - m_o)^2 + (\Gamma/2)^2}$$

$m_o = 2.5$ GeV

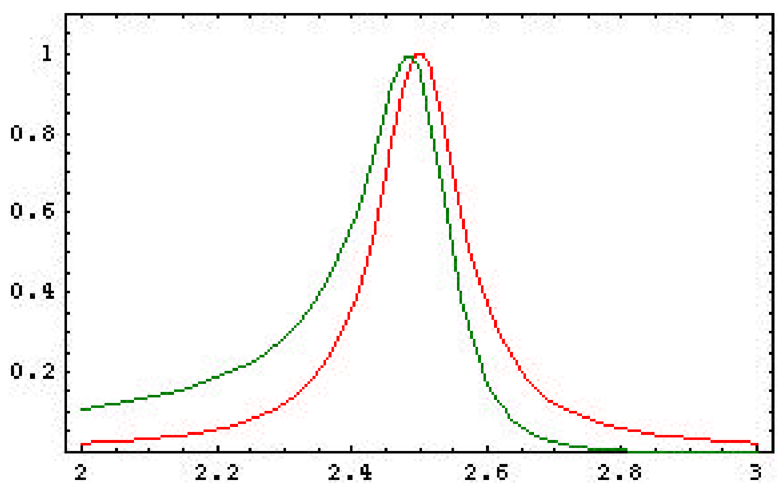
$\Gamma = 0.15$ GeV



m_X (GeV)

$a = 8\ GeV^{-2}$

Green curve (8 GeV) scaled to same peak as the pure Breit-Wigner:



m_X (GeV)

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Beams

Techniques are under consideration to produce photon beams:

tagged bremsstrahlung beams

✓ Can get desired flux near endpoint with 1μA electron beam.

✓ Energy resolution (0.25 to 0.1%) - OK.

✓ No linear polarization - just circular - need linear for PWA.

tagged coherent bremsstrahlung beams

✓ An attractive possibility.

✓ Refers to the enhancement which occurs inside a crystal radiator when the momentum transfer from the electron to atom matches the reciprocal lattice vector.

✓ Collimation can be used to suppress the incoherent component and narrow the energy spread of the coherent photon spectrum.

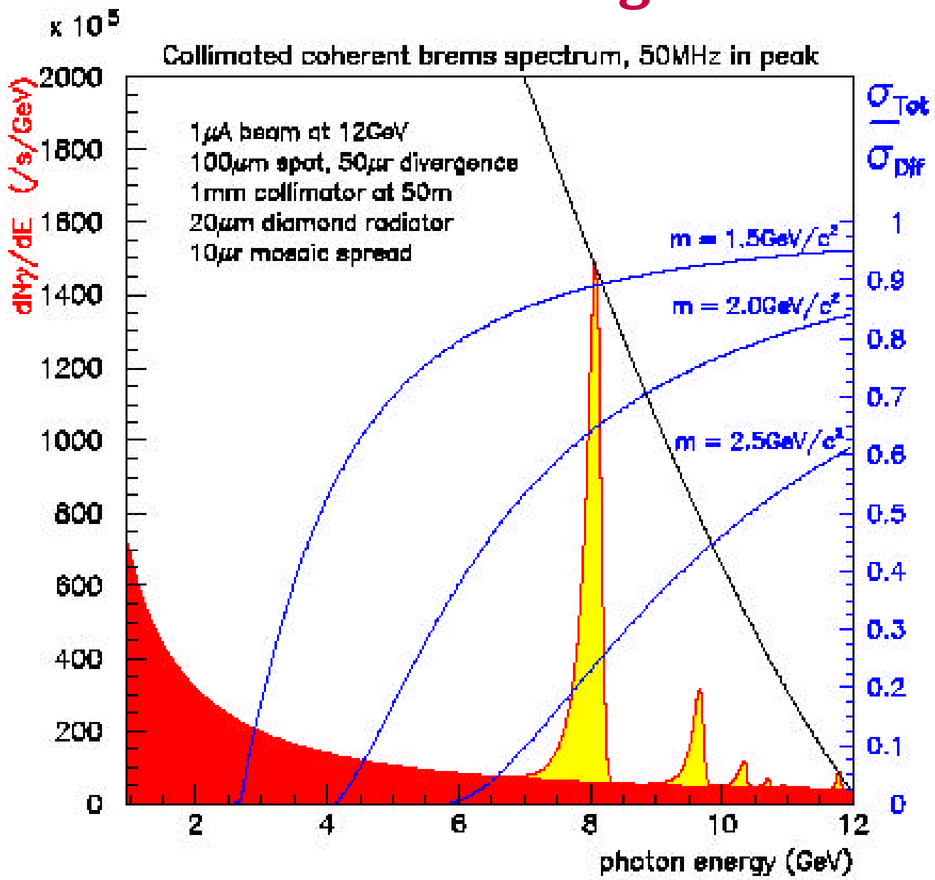
✓ Possible to achieve an average linear polarization of 15% in the desired energy range. Falls to zero at endpoint.

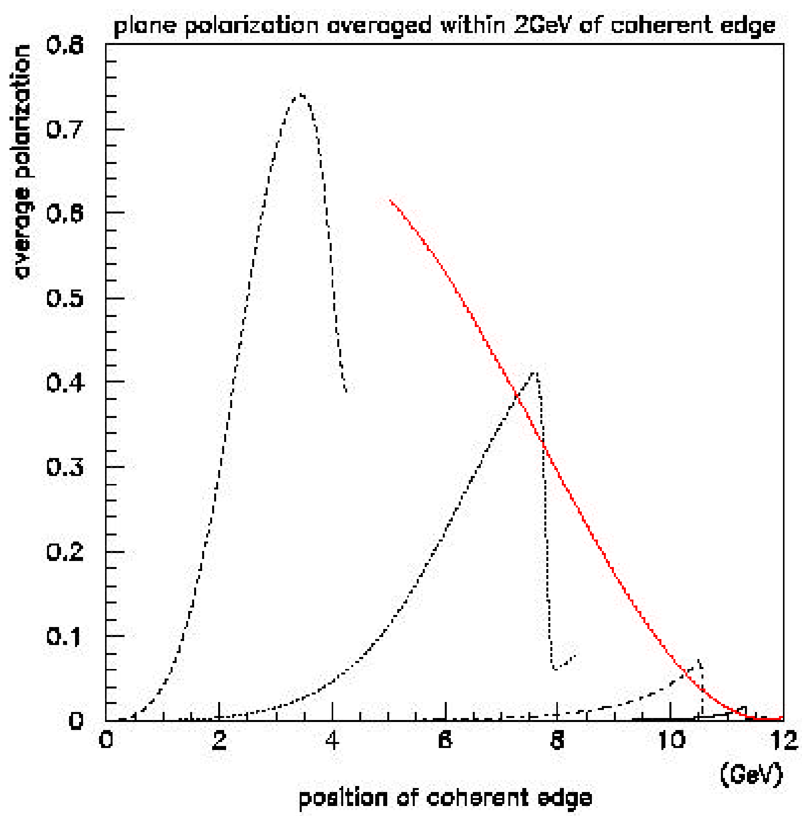
Compton backscattered laser beams

✓ Energy/flux too low even with 100 μA 12 GeV electron beam and not quite state of the art lasers

✓ 100% linear polarization at endpoint

Coherent Bremsstrahlung





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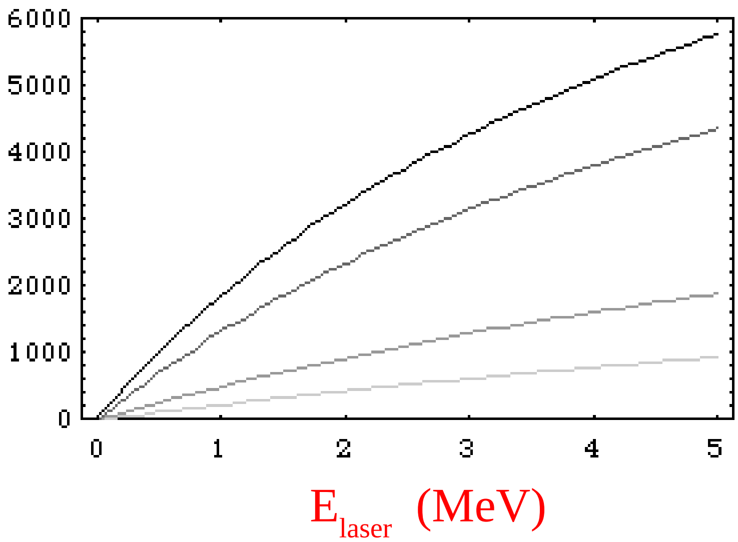
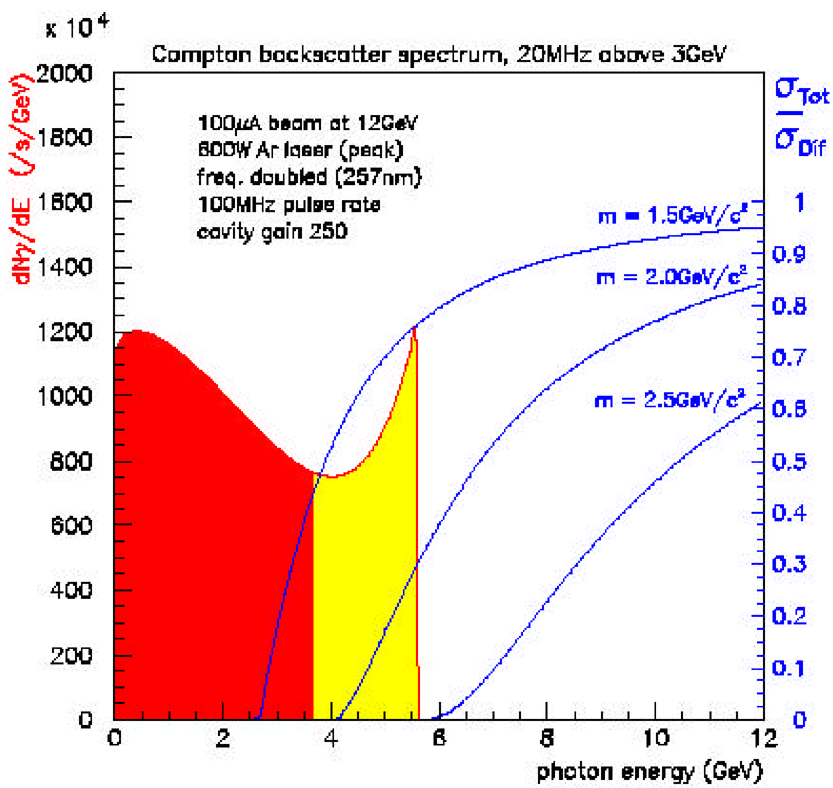
from Richard Jones

Backscattered Laser

Pros: **Clean beam without the low-energy component and the beam is linearly polarized (100% at the endpoint).**

Cons: **High electron flux is necessary (100 μA)**
Energies too low - even with lasers avaiable in a few years





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Detector Issues

For each subsystem ask

- what is needed?
- availability?
- R & D?
- cost?
- staging?
- who will design & build?

- **beam** - tagged coherent brem or Compton backscatter
- **target** - LH2 and nuclear targets
- **magnets** - LASS/MEGA (solenoid) - TPLB (dipole)
- **sheet of flame** - flux exclusion? deaden chambers?
- **particle I. D.** - RICH? DIRC? Threshold C? TOF?
- **calorimetry** - CsI? PbO? target and forward regions
- **target tracking** - straw tubes? vertexing? TPC?
- **forward tracking** - straw tubes? drifts? PWCs?
- **trigger** - rates? FADCs? pipelining? location?

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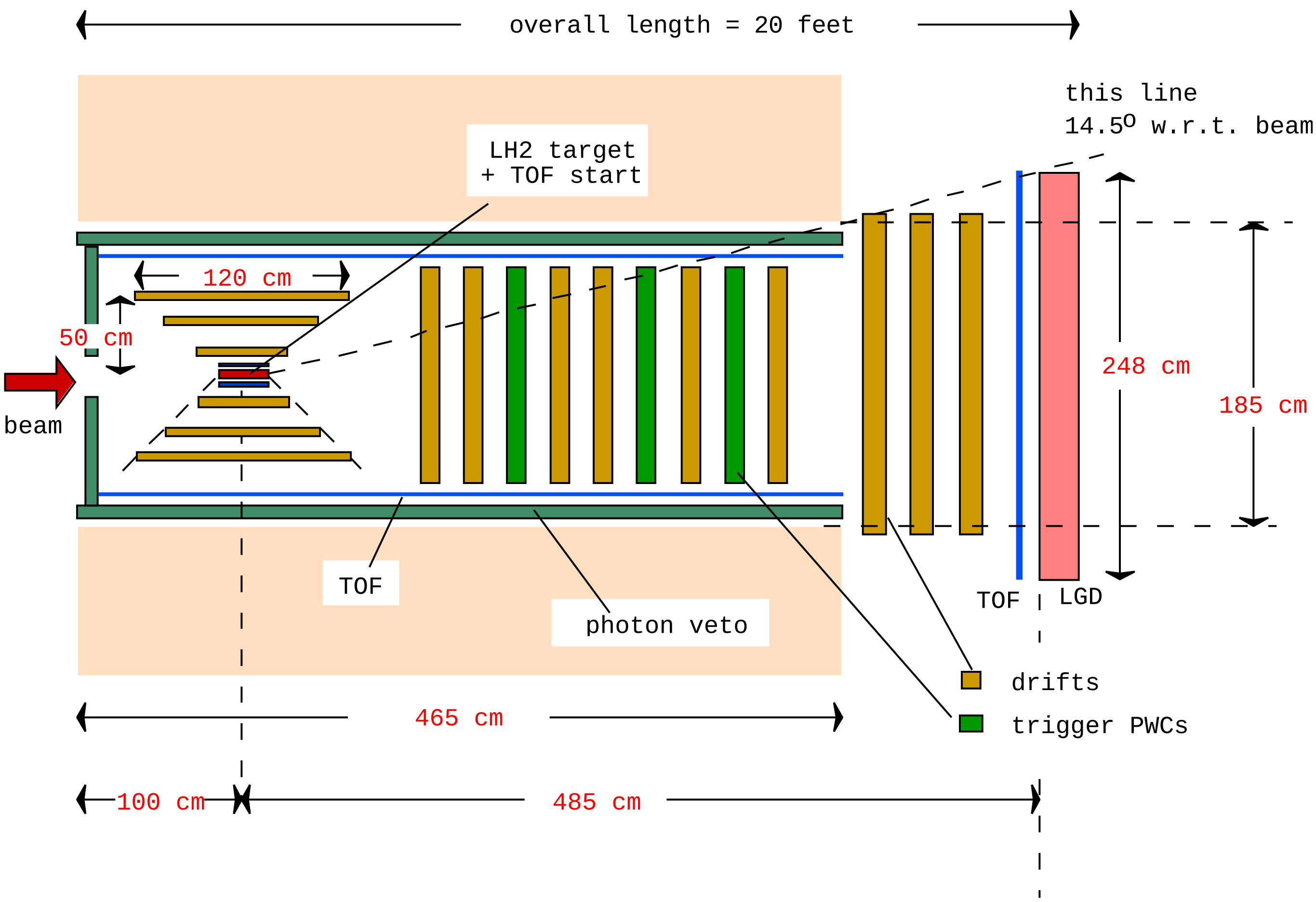
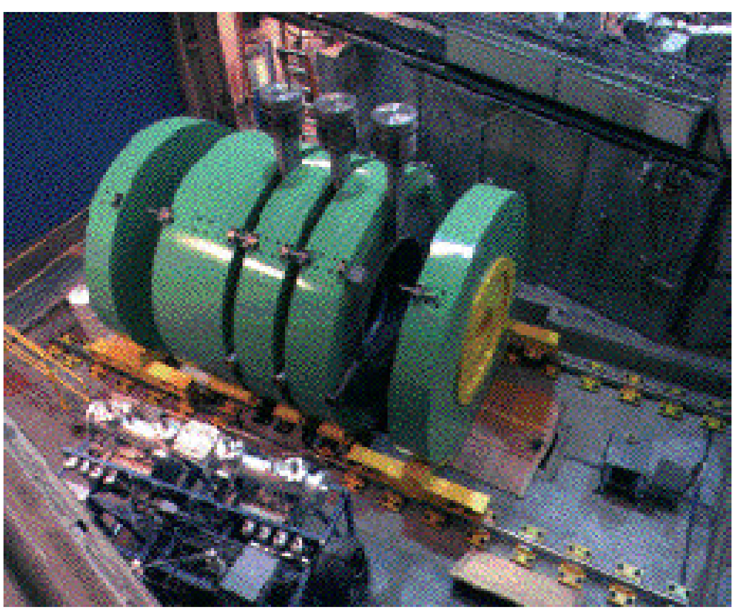
Eightplus Stage-1 Detector

for 6-8 GeV





MEGA/LASS Magnet
at
LANL

3 of 4 coils shown

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Conclusions

1. Data on photoproduction of mesons below charm threshold is essentially non-existent.

2. These data are needed to answer many open questions and are guaranteed to provide answers.

3. Photon beams of 10-12 GeV are needed to probe the required mass range. Fluxes, duty factor and resolution are no problem.

4. A world-class hermetic detector using state-of-the-art technology can be built within 2 yrs of start.

5. Other physics can also be studied with this detector - e.g. some rare decays.

6. We have the core of a collaboration in place - including experimentalists and theorists.

7. A staged approach - starting with 6-8 GeV photons can start answering important technical and physics questions.

8. We plan to submit such a proposal to the PAC by Jan 1999 - for an effort the DoE/NSF will be proud to fund.

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