Update on J/ψ electroproduction near threshold in Hall C at 12 GeV

Hall C Users Meeting

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Physics motivation

Ultimate goal: understand non-perturbative QCD, by observing/measuring nucleon-meson bound state.

In contrast with lighter mesons (ρ, ω), quark exchange are completely suppressed in *J/ψ-N* interactions, leaving a quasi-pure gluonic interaction;

hence, interaction between *J/ψ* and a nucleon in a *J/ψ-N* bound state may be described by the exchange of soft gluons **-> QCD Van der Walls force.**

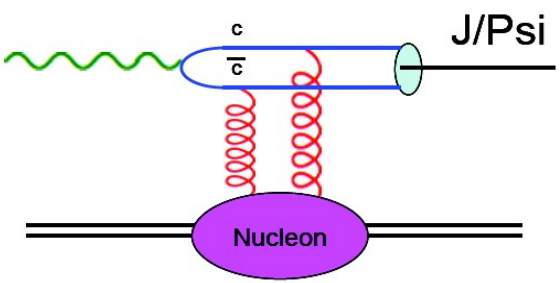
First prediction of *J/ψ-A* state by Brodsky and De Teramond in 1990: binding energy of ~100 MeV for A>3;

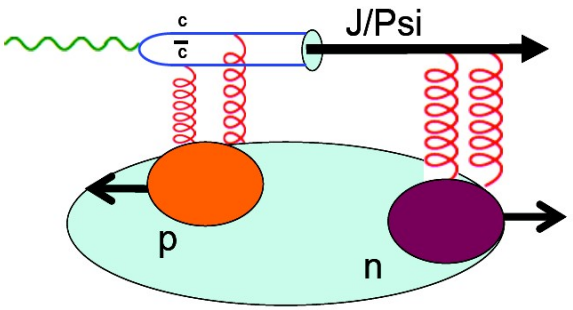
Since then, several calculations using OPE, QCD sum rules, and lattice QCD came to correct, improve and refine this result; however, *no experimental result has ever been produced to confront those calculations.* The *J/ψ* experiment in Hall C proposes to provide such a result, in several steps...

Physics motivation

Experiment idea:

- Produce exclusive *J/ψ* near threshold, at high *t*, and in a nucleus, to maximize the chances of rescattering;
- An evidence of this rescattering would be the enhancement of the cross section of *eA* -> *ep*(*A*-1)*J/ψ* (*i.e.* ep -> ep*J/ψ* on a proton bound in a nucleus) compared to eH -> ep*J/ψ* (*i.e.* on a free proton)





Deuteron

-> need to measure the cross section on hydrogen and its *t* dependence first, to have a "calibration". If possible, measure e', p, *J/ψ* (Phase 1);

-> then, the same experiment would be done in the same conditions on deuterium, to hopefully observe rescattering (Phase 2);

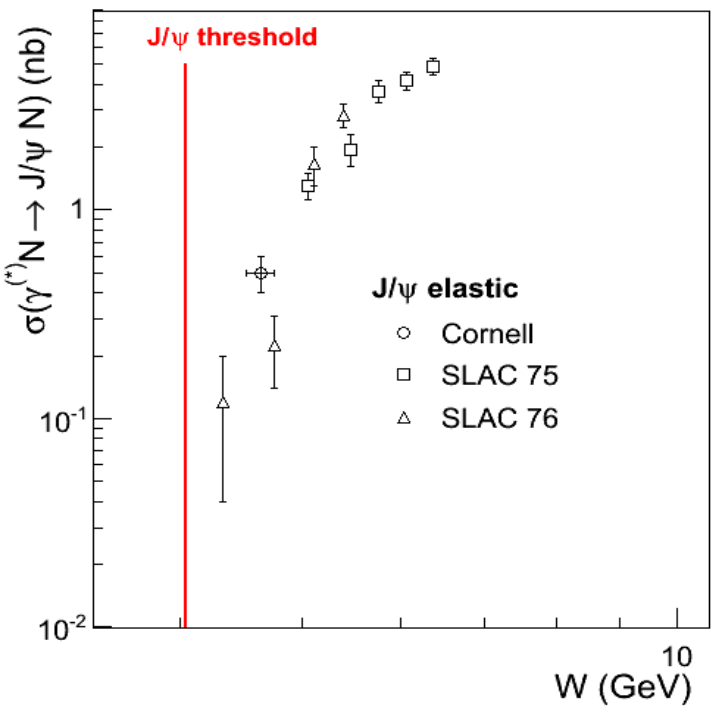
-> *if Phase 2 is successful*, then the experiment could be done on heavier nucleus such as ^{12}C (Phase 3).

Physics motivation

Existing exclusive *J/ψ* data near threshold: only photoproduction, and on nuclei:

Cornell [PRL **35** (1975) 1616] : photoproduction on beryllium;
SLAC [PRL **35** (1975) 483, SLACPUB-1741 (1976)] : photoproduction on hydrogen and deuterium (squares: double-arm, tringles: single-arm) ;

Need a high precision measurement, closer to threshold;

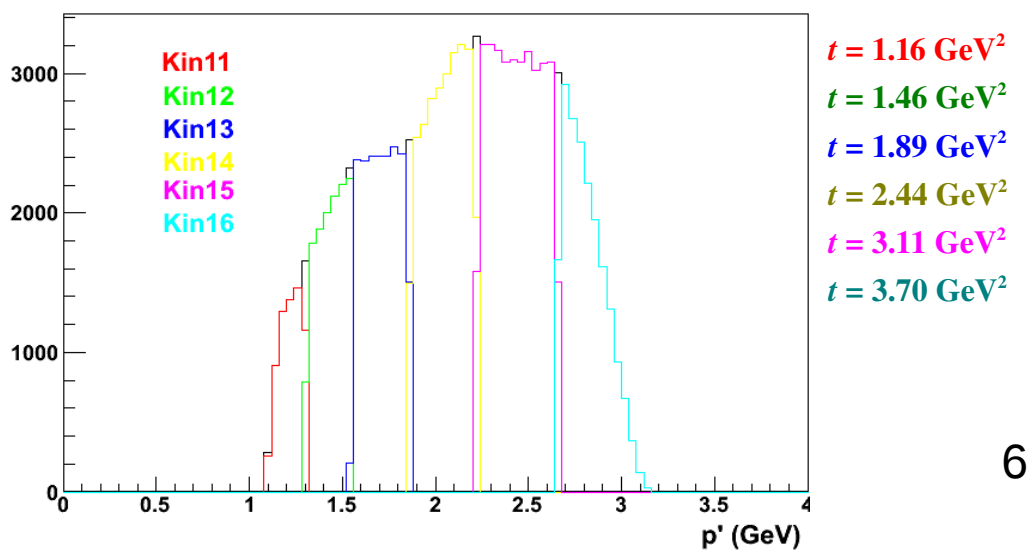


Experimental setup

We want to measure H(e, e' p [J/ψ–>]e^+ e^-) in Hall C at 12 GeV, with the help of SHMS-HMS pair;
e' measured in SHMS, p' measured in HMS, e^+ e^- pair in custom calorimeters;

Currently considering two options for SHMS-HMS setting:
-> θ_{SHMS} = 5.5 deg, p_{SHMS} = 2.0 GeV, θ_{HMS} = 12 deg;
-> θ_{SHMS} = 2.5 deg (6.5 deg+septum), p_{SHMS} = 2.0 GeV, θ_{HMS} = 11 deg;
=> advantage: about twice more rates;
=> disadvantage: more complicated, expensive design;

p_{HMS} setting determines *t*:
currently 6 kinematics



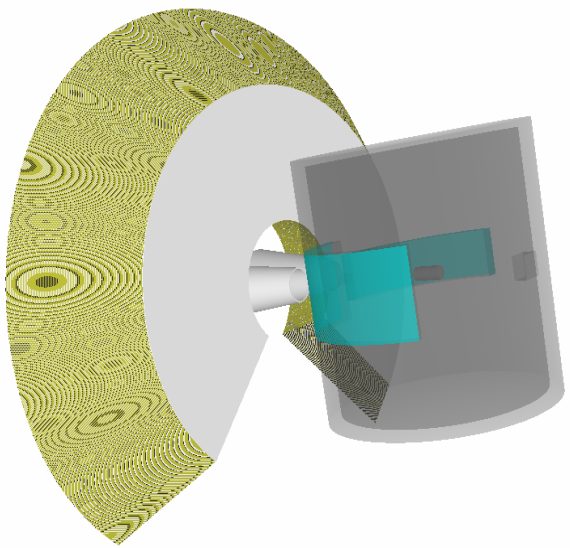
Experimental setup

Two options are also considered for the calorimeters:

Ring Shashlyk Calorimeter:

Angular coverage: $18 < \theta < 46$ deg

ϕ coverage: 2π, or $3/2\pi$ ring (shown)

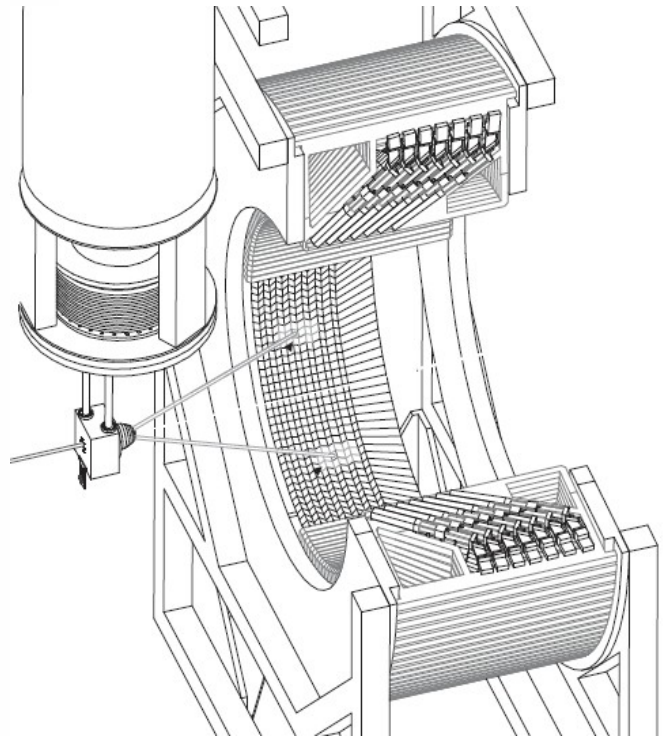


Simple design, would insure decent rates, but needs to be built from scratch;

PbF_2 Calorimeters:

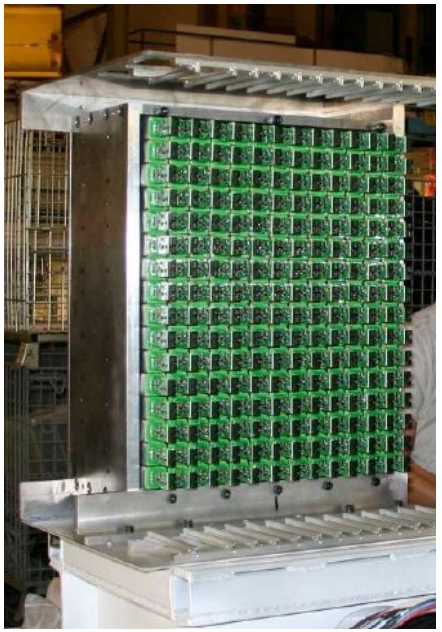
PVA4 + DVCS

1022 (7x146) PbF_2 blocks



208 (13x16) PbF_2 blocks

3x3x18.5 cm3



Already exist, but need to be reassembled (design not fixed); rates may be lower.

Expected counts, results

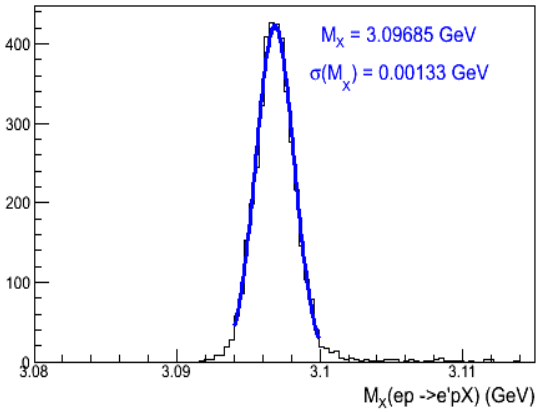
J/ψs, 10 days/Kin, 55 uA beam on 15 cm LH_2; θ_{SHMS} = 5.5 deg, p_{SHMS} = 2.0 GeV; θ_{HMS} = 12 deg; 3/2 π ring shashlyk.		
Kin	3-coincidence ($e'\ p\ e^{\pm}$)	4-coincidence ($e'\ p\ e^{+}\ e^{-}$)
11	58	4
12	106	13
13	98	17
14	84	19
15	57	15
16	10	3

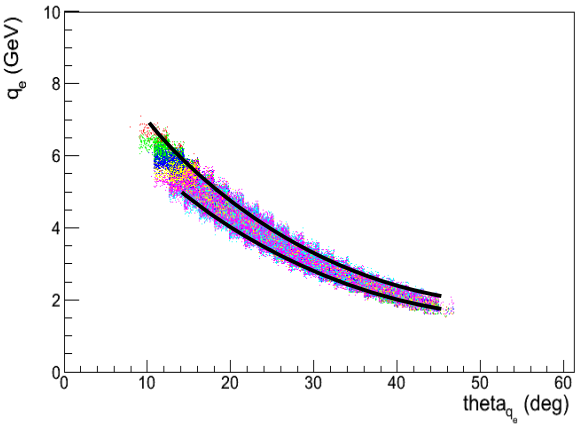
Very poor 4-coincidence statistics (~70 events over 2 months beam-on-target).

However, we may rely on two things:

- the very sharp intrinsic resolution of the spectrometers for the *J/ψ* mass reconstruction;
- the strong q_e/θ_{qe} correlation of a $e^{\pm}$ from a *J/ψ* decay to disambiguate a *J/ψ* with a single electron

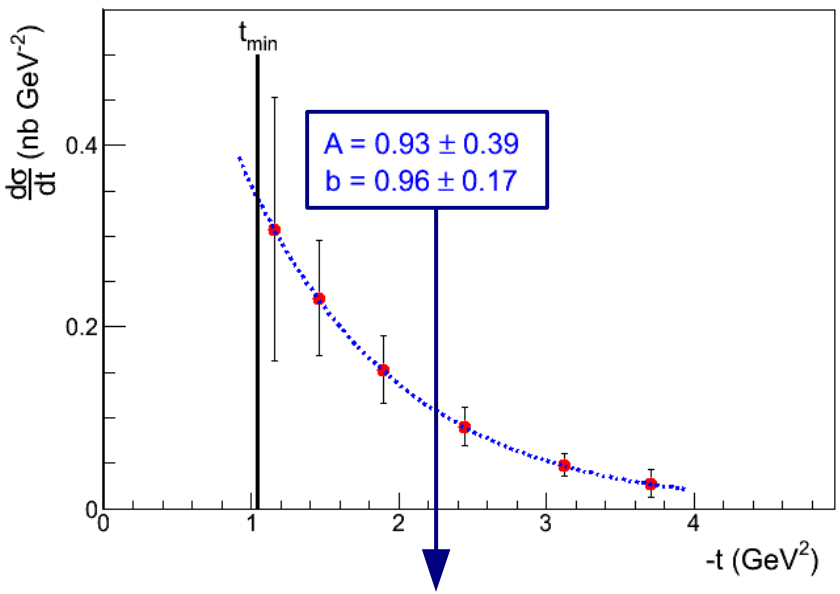
Hence, we think we might be able to use 3-coincidence events (~400 events over 2 months).





Expected counts, Results

Projected $d\sigma/dt$ as a function of t (with error bars)



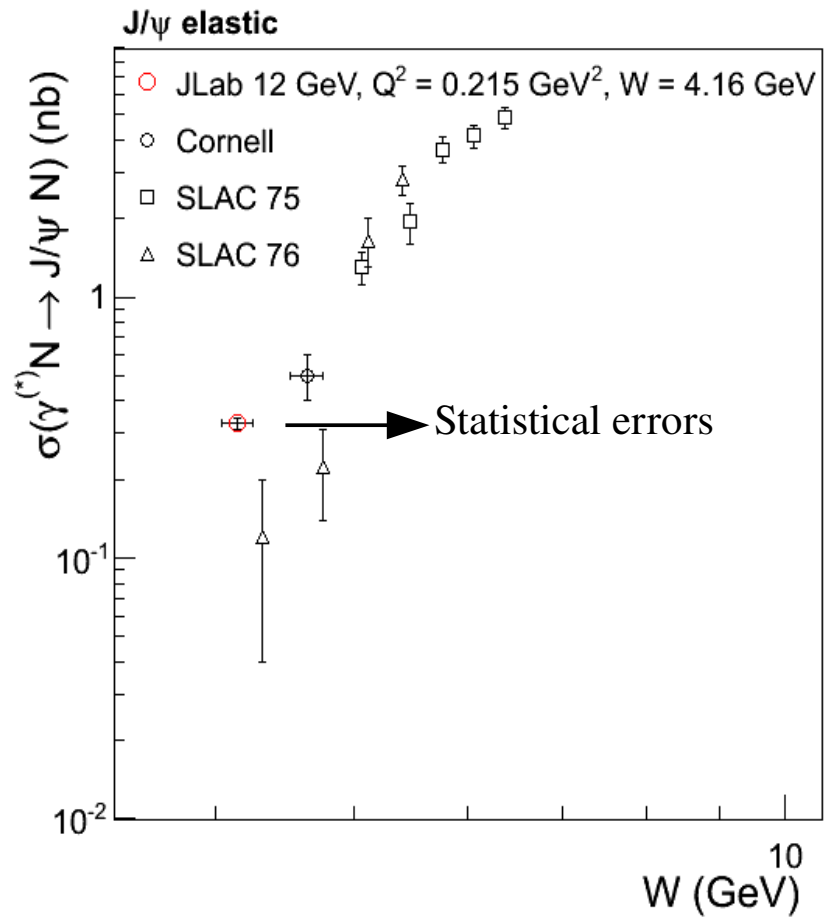
Model injected:

$$d\sigma/dt = Ae^{bt}$$

with $A = 0.94$ nb GeV^{-2};

$b = 0.97$ GeV^{-2}.

(Cornell cross section on Be)



Background: Singles

55 uA beam on 15 cm LH_2;	
e^- rates w/ QFS (kHz)	π^- rates w/ EPCV (kHz)
θ_{SHMS} = 2.5 deg, p_{SHMS} = 2.0 GeV;	
10771*	118
θ_{SHMS} = 5.5 deg, p_{SHMS} = 2.0 GeV;	
760	117

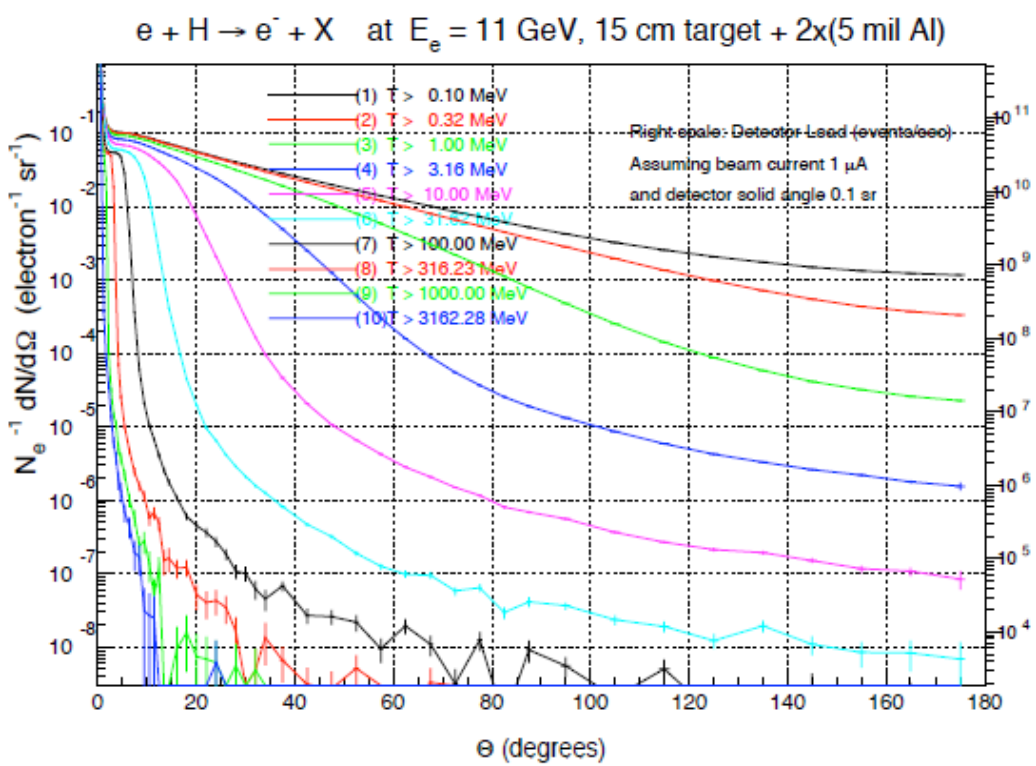
*handleable ?

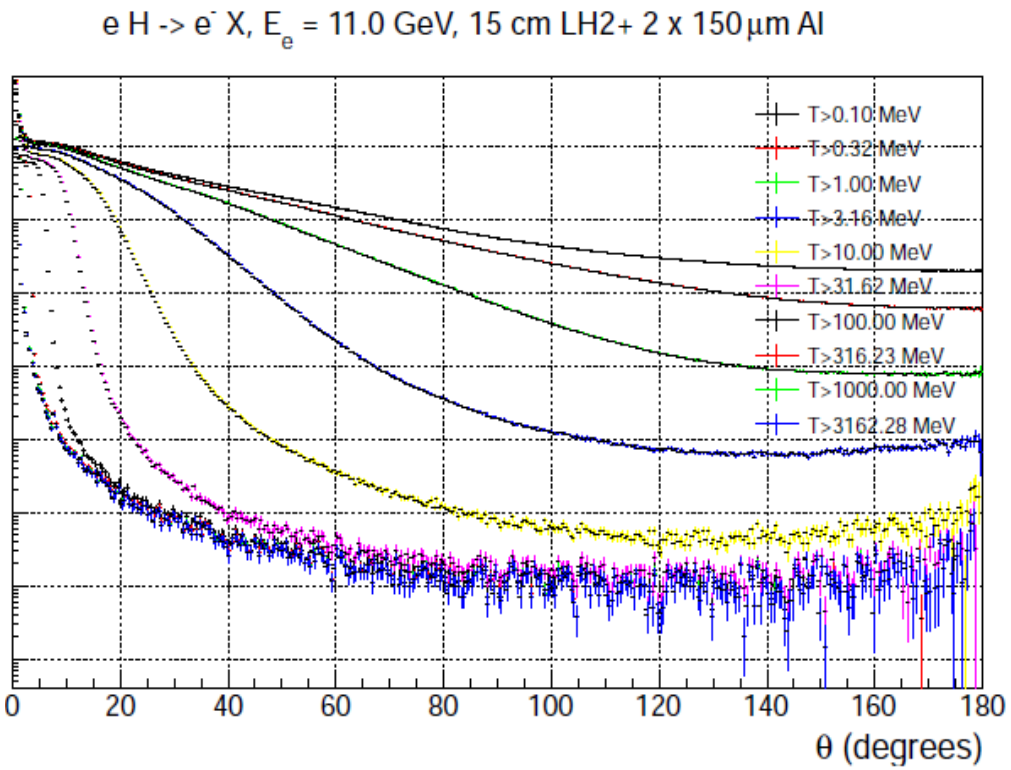
55 uA beam on 15 cm LH_2; θ_{HMS} = 11 deg;		
Kin	p rates w/ EPCV (kHz)	π^+ rates w/ EPCV (kHz)
11	508	69
12	499	73
13	501	77
14	507	82
15	512	88
16	518	94

Still need to compute the single rates on the calorimeter and the accidental e'p spectrum + the accidental e'p $e^{\pm}$ spectrum.

Background: GEANT 4 simulations

Want to use G4 to access noise information in the calorimeters.
We first try to compare our G4 simulations to P. Degtiarenko's G3 simulations.





looks somehow similar but things remain to be understood.
G4 has been run with a model of a DVCS calo to evaulate the dose, but data cannot be shown right now...

Conclusions

Some progress made on the design:

- more realistic (the shashlyk calorimeter is designed in such a way that it does not interfere with the spectrometer snouts);
- provides decent rates;
- we also have on hand a more expensive design, but which roughly doubles the counting rates.

The singles have been computed in SHMS and HMS, and they seem to be manageable (for 5.5 deg at least).

Conclusions

We will try to be ready for next PAC.

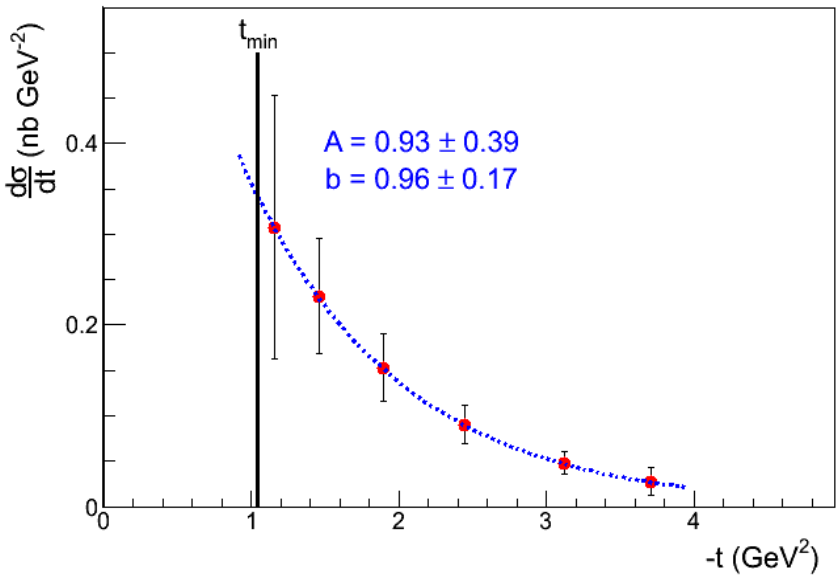
=> TO-DO: (*a minima*)

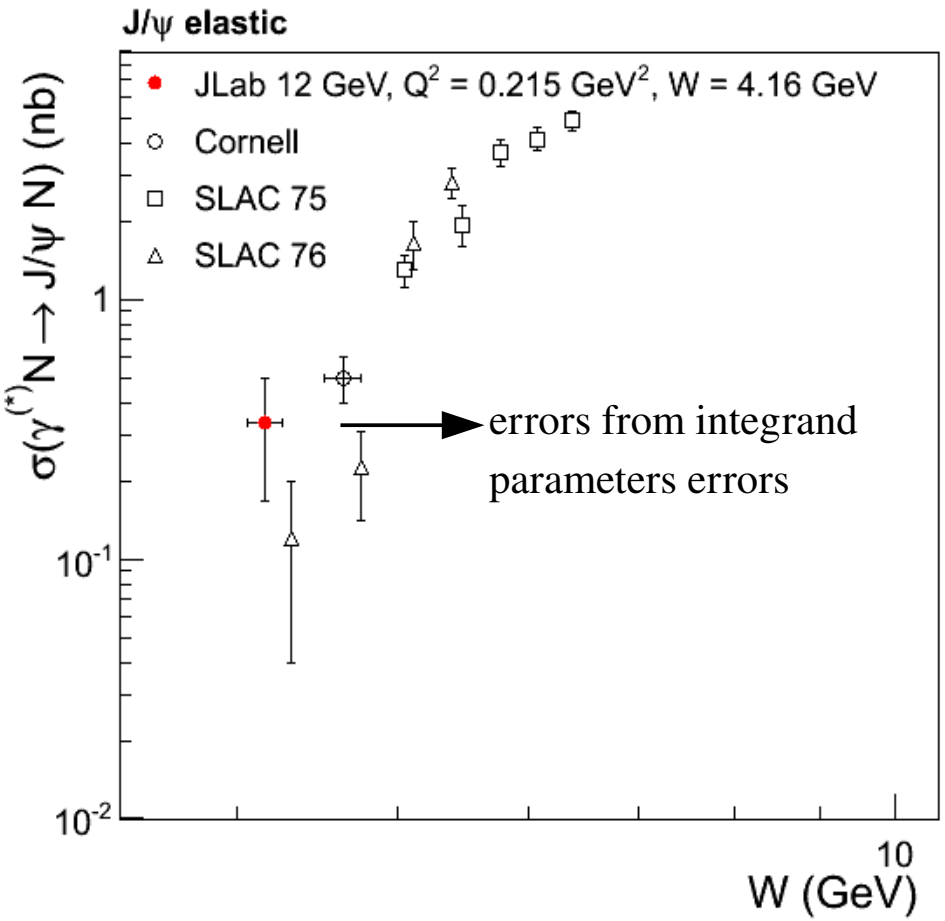
- determine the accidental e'p spectrum with SIMC + accidental e'p $e^{\pm}$ spectrum (with calo singles), compare it to the expected signal;

- some work on G4:
  -> extract noise information from calorimeters (dose primarily, signal from low energy particles);

Back-up

Expected counts, Results





Cross section Model

Reference: J/ψ photoproduction cross section from Cornell on beryllium, for 9.3 GeV < E_γ <10.4 GeV:

$$\frac{d\sigma}{dt} = A\, e^{bt} \quad (\mathrm{A} = 0.94\ \mathrm{nb\ GeV^{-2}},\ \mathrm{b} = 0.97\ \mathrm{GeV^{-2}})$$

multiplied by the usual virtual photon flux:

$$\Gamma = \frac{\alpha_{QED}}{2\pi^2}\frac{k'}{k}\frac{k_\gamma}{Q^2}\frac{1}{1-\epsilon}$$

and weighted with the leading term of the vector meson angular distribution (Schilling and Wolf):

$$W(\cos\theta) = \frac{3}{8\pi}\left(1 - r^{04}_{00} + (3r^{04}_{00} - 1)\cos\theta\right)$$

with $r^{04}_{00} = \dfrac{\epsilon R}{1+\epsilon R}$ and $R = \dfrac{d\sigma_L}{d\sigma_T} = \left(\dfrac{a\, m^2_{J/\psi} - Q^2}{a\, m^2_{J/\psi}}\right)^n - 1$ parameterized by Fiore *et al.* ($a = 2.164$, $n = 2.131$)

GEANT 4 simulations

G4 includes:

- a 15 cm liquid H2 target;
- a scoring sphere for the G3/G4 comparison;
- two “spectrometers” (detection plans), which acceptance are similar to SHMS and HMS, respectively;
- a rather advanced model of the DVCS calorimeter;
- a basic model of the shashlyk calorimeter;
- a very basic model of the PVA4 calorimeter.