E160 PHYSICS REQUIREMENTS

RPC Collaboration Meeting, May 18, 2001

P. Bosted

- What we want to measure
- Statistical and systematic error goals.
- Resolutions needed.
- Luminosity, considering background subtractions.
- Kinematic coverage needed.

PPHYSICS GOALS

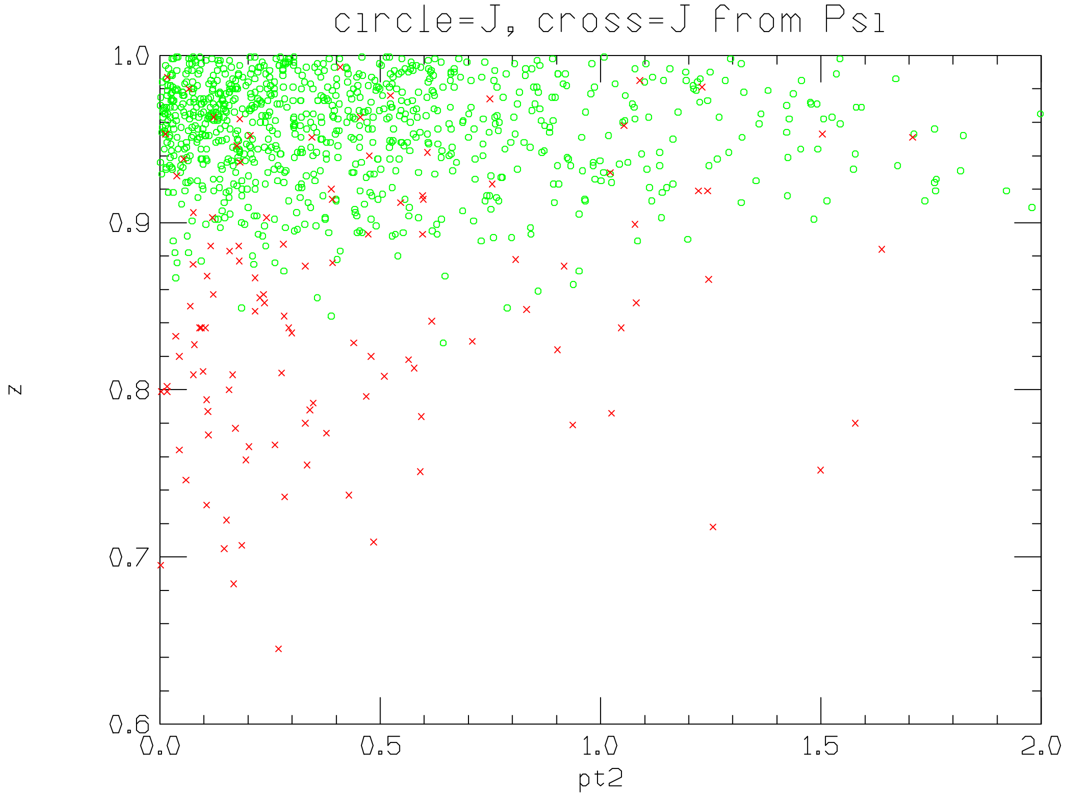
- **A-dependence of quasi-elastic J/ψ photoproduction at k near 15, 25, and 35 GeV.**
- **About 1.5% statistical and systematic errors.**
- **Four targets ranging from Be to Pb (only 2 at 15 GeV, and 2error).**
- **Also ψ' A-dependence with 200 clean counts per target at 25 and 35 GeV. This is harder than J/ψ due to large backgrounds and drives resolution and luminosity requirements.**
- New, **measure linear polarization asymmetry (see Keith's talk).**

DETECTION OF J/ψ AND ψ'

- Duty factor SLAC means di-leptons only practical way for J/ψ at SLAC (6% B.R.)
- Muons prefered over electrons *if* can put absorber near target (else swamped pi/K decays).
- For ψ', not so obvious: only 0.9% B.R.
- ψ' cross section about 15% of J/ψ, independent of photon energy.
- About 54% of ψ' decay to J/ψ (plus two pions, or η, or even two muons 1% B.R.
- These have typical $z = E/K$ of 0.7. Perhaps can distinguish from inelastic J/ψ by higher average p_t^2.

KINEMATICS OF ψ' DECAYS

Circles are quasi-elastic J/ψ with 5% z resolution. Crosses are J/ψ from ψ' decay.

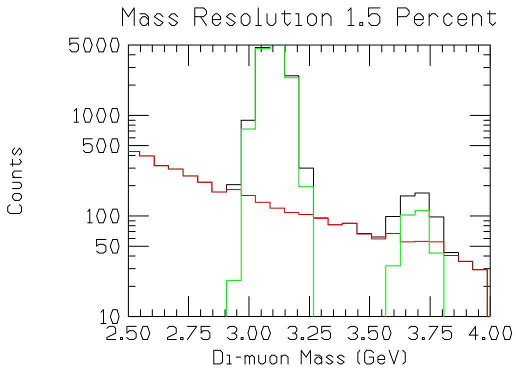


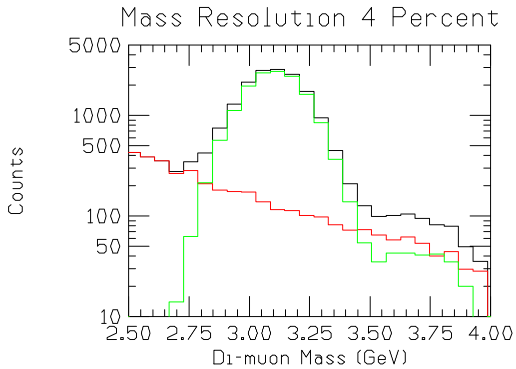
INVARIANT MASS RESOLUTION

- Main requirement separate J/ψ peak mass 3.097 GeV from ψ'peak mass 3.686 GeV, which is also 2% of height (factor 15 in cross section, 7 in B.R.). Proposal assumed 3% by error.
- If Mass resolution $> 5\%$, ψ' peak quickly becomes overwhelmed by J/ψ tail
- B.H. background (muon pairs) much larger fraction of ψ'signal than J/ψ. Dilutes statistics. Systematic error from imperfect knowledge of acceptance, if cannot measure on either side of ψ' peak.
- B.H. background can be reduced by about a factor of two (relative to ψ') with cuts: $0.2 < R_e = E_1/E_{tot} < 0.8$ (follows naturally for most spectrometer designs) and $p_t^2 > 0.1$ GeV^2 (region we will cut anyway for coherent/quasi-elastic separation).
- Resolution should be better than 4% to maintain systematic error about same as statistical error on ψ'.
- Worse resolution means more running time to compensate for background.

SIMULATED MASS SPECTRA

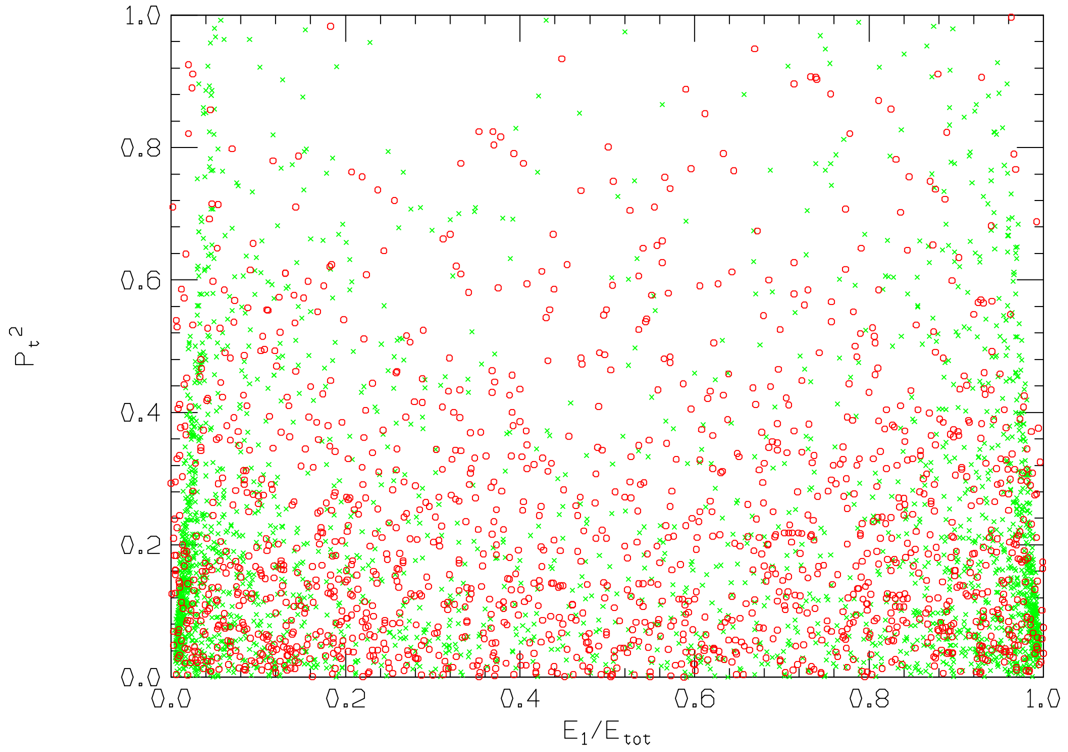
Simulated mass spectra for 35 GeV photon beam and mass resolution of 1.5% (left) and 4% (right), with a cut in R_e applied. The BH background is shown in red, the J/ψ and ψ' signals in green, and the sum in black.





BETHE-HEITLER COMPARED TO ψ'

For a 35 GeV photon beam, distribution in R_e and p_t^2 of ψ' muons pairs (circles) and BH events (crosses) in the mass region $3.5 < M < 3.9$ GeV.



BACKGROUNDS UNDER ψ' MASS PEAK

Ratios of ψ' di-muon signal to J/ψ tail only (R) and to J/ψ tail plus Bethe-Heitler background with no cuts (R_{nc}) and with the cut $0.3 < R_e < 0.7$ (R_c) for 25 and 35 GeV photons as a function of invariant mass resolution in percent. A $\psi'/J/\psi$ cross section ratio of 0.02 is assumed, and the Bethe-Heilter production from lead (although it is almost indistinguishable from lighter nuclei). The signal/noise is averaged from -1 sigma on the low mass side, to 1.5 sigma on the high mass side.

		20 GeV		40 GeV	
Resolution (%)	R	R_{nc}	R_c	R_{nc}	R_c
1.0	$> \mathbf{1000}$	1.29	3.02	1.19	2.71
2.0	$> \mathbf{1000}$	0.65	1.53	0.61	1.38
3.0	1000	0.45	1.08	0.42	0.96
4.0	90	0.35	0.79	0.32	0.77
5.0	3.3	0.27	0.53	0.25	0.56
6.0	0.65	0.18	0.30	0.17	0.30
7.0	0.24	0.12	0.16	0.11	0.17

RUNNING TIME INCREASE FROM BACKGROUNDS

Increase in luminosity/acceptance f needed to compensate for the BH and J/ψ tail backgrounds shown in previous table.

	20 GeV		35 GeV	
Resolution (%)	R_{nc}	R_c	R_{nc}	R_c
1.0	2.56	1.66	2.68	1.74
2.0	4.06	2.31	4.26	2.45
3.0	5.42	2.85	5.82	3.09
4.0	6.71	3.52	7.17	3.60
5.0	8.52	4.75	9.00	4.60
6.0	12.07	7.77	12.71	7.68
7.0	18.03	13.71	18.83	13.02

MOMENTUM AND ANGLE RESOLUTIONS

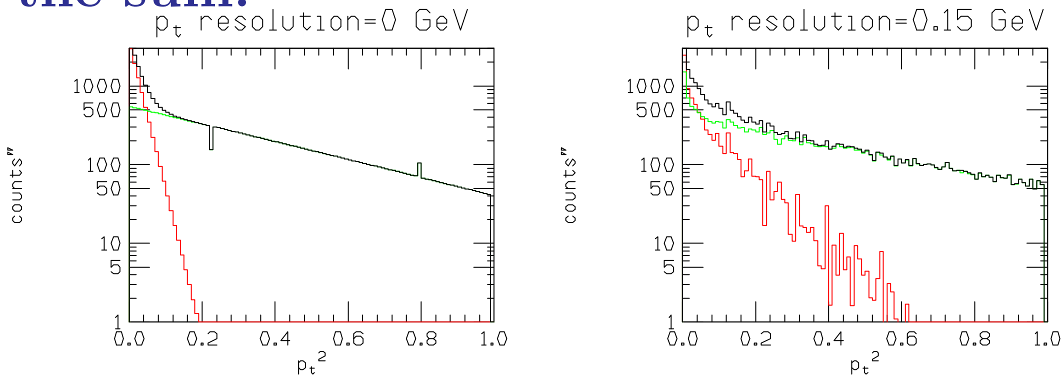
- For Mass resolution 4%, need muon momentum resolution about 5% (independent of momentum). Note: this has been achieved in muon range telescopes.
- Relative uncertainty in opening angle between two muons proportional to relative mass uncertainty.
- For 4% mass resolution, need 4% angle resolution (if dominant error), or $d\Theta = 3\sqrt{P_1 P_2}$. Notice decrease as $1/P$, as does multiple scattering, so mass resolution independent of E roughly for fixed absorber thickness.

p_T RESOLUTION

- Needed to separate nuclear coherent $0.14A^{1.4}33e^{33t}$ from quasi-elastic (our signal) $A^{0.94}2e^{2t}$.
- We measure $p_t^2 = P_j^2(1 - \cos^2(\theta)$, uniquely related to $t = (k-E_j)^2 - k^2 - P_j^2 + 2kP_j\cos(\theta)$
- Bad resolution pushes crossing of two curves to higher p_t^2, resulting in loss of statistics (f equivalent increase in running time needed).
- Bad resolution distorts shape of quasi-elastic.
- Resolution in p_t should not be worse than 0.15 GeV.
- Need good acceptance out to $p_t^2 = 1$ GeV^2 to separate coherent and q.e. To separate inelastic, need bigger range, out to 3 GeV^2, unless can use z cut.

RESOLUTION IN p_t

Simulated p_t^2 distributions for coherent (steep slope, in red) and quasi-elastic (shallow slope, green) contributions at 25 GeV, for perfect resolution (left), and p_t resolution for each muon of 0.15 GeV (right). The black curve shows the sum.



RESOLUTION IN p_t

Increase in luminosity/acceptance f needed to compensate for the p_t resolution (of each muon) shown. Also given is the value of p_t^2 at which the coherent/quasi-elastic ratio is about 0.2 (labeled Cross).

p_t Resolution (GeV)	Cross	f
0	0.05	1.2
0.05	0.06	1.2
0.10	0.1	1.5
0.15	0.2	1.8

z RESOLUTION

- Good z resolution allows separation elastic ($z \approx 1$) from inelastic (flat in z).
- Can help find J/ψ from ψ' decays too.
- Can get about 5peaks (neither is really Gasus-sian though).
- To match this, J/ψ energy resolution should be 5% or better.

LUMINOSITY/ACCEPTANCE

- Need good acceptance out to $p_t^2 = 1\ \mathrm{GeV}^2$ to separate coherant and q.e. To separate inelastic, need bigger range, out to 3 GeV^2, unless can use z cut.
- For linear pol. asymmetry, would like good ϕ acceptance to complement rotation of pol. using crystal, but not an absolute requirement.
- Photon flux defined by acceptance, dilution factors depending on resolution, and need to fit into 1 month running at 120 Hz, 100% efficiency.
- Detectors must be able to handle corresponding particle and background rates.

LUMINOSITY/ACCEPTANCE

Combinations of Acceptance (*Acc*), Backfround factor *f*, and quasi-monochromatic photons/spill (γ/spill) required to meet the physics goals for 35 GeV photons on a Lead target.

Acc	*f*	γ/spill
0.4	1.5	0.2×10^7
0.2	2	0.5×10^7
0.1	2	1×10^7
0.1	5	2.5×10^7
0.05	5	5×10^7
0.01	2	1×10^8

SUMMARY

- Photon Beam, quasi-monochromatic at 15, 27, 40 GeV, linearly polairzed, $> 10^7$ photons/spill in peak (depending on resolutions, acceptance). Measurement of photon flux, intensity, and spectrum.
- Spectrometer with Mass resolution $< 4\%$, p_t resolution < 0.15 GeV, z resolution $< 5\%$, p_t^2 coverage to at least 1 GeV^2, dilepton acceptance > 0.01 to match maximum possible photon flux.
- Detectors with granularity matched to spectrometer to give desired resolutions. Good timing (¡1 nsec) and high rate capability needed due to $< 10-4$ duty cycle (would like to handle of order 50 to 100 charged particles/spill, 2 sprinkle hits/detector/spill).
- Particle i.d. needed for muons or electrons.