E160 SPECTROMETER DESIGN

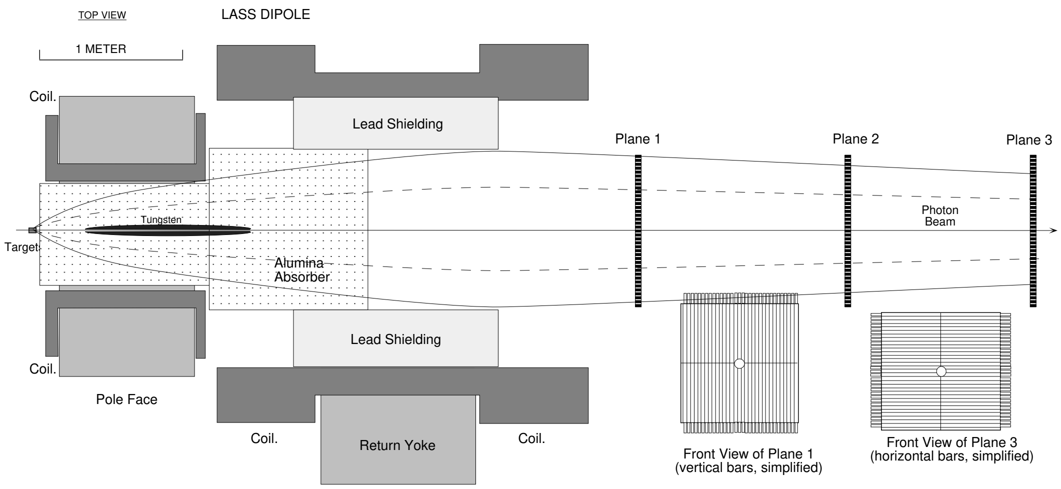
RPC Collaboration Meeting, May 18, 2001

P. Bosted

- Problems with Proposal Design
- How LASS design can be improved
- Muon Telescope
- D3 Design
- Background simulations for D3 Design

PROPOSAL DESIGN

- Uses 2 m of alumina absorber, 29D36 and LASS dipoles.
- Mass resolution about 4.5%, p_t resolution 0.14 GeV, z resolution 5%: all right at limit.
- Acceptance (35 GeV) about 0.3 with R_e cut.



PROBLEMS WITH PROPOSAL DESIGN

- Proposal assumed ψ'/jpsi cross section ratio 0.3: really 0.15 (world average from 50 to 1000 GeV, consistent no E dependence).
- Hadronic punch-through rates in alumina were under-estimated by factor of about 3. Now using detailed PYTHIA simulations to generate hadronic events, rather than simply one pion per NI.
- No f factor for BH subtraction was taken into account.
- Taking these together, and assuming detector limited to 80 charged particles/spill (already high!), find we are about factor 15 below physics goal for ψ' (and factor 3 for J/ψ).
- Punch-through rate decreases rapidly with thickness as shown on next page: would like to run near "knee" where mostly muons left (or 3.5 m of alumina).

PUNCH-THROUGH RATES IN ALUMINA

Filled diamonds are muons, circles other charged, squares all charged particles. Similar plots were made for other materials by Piotr.

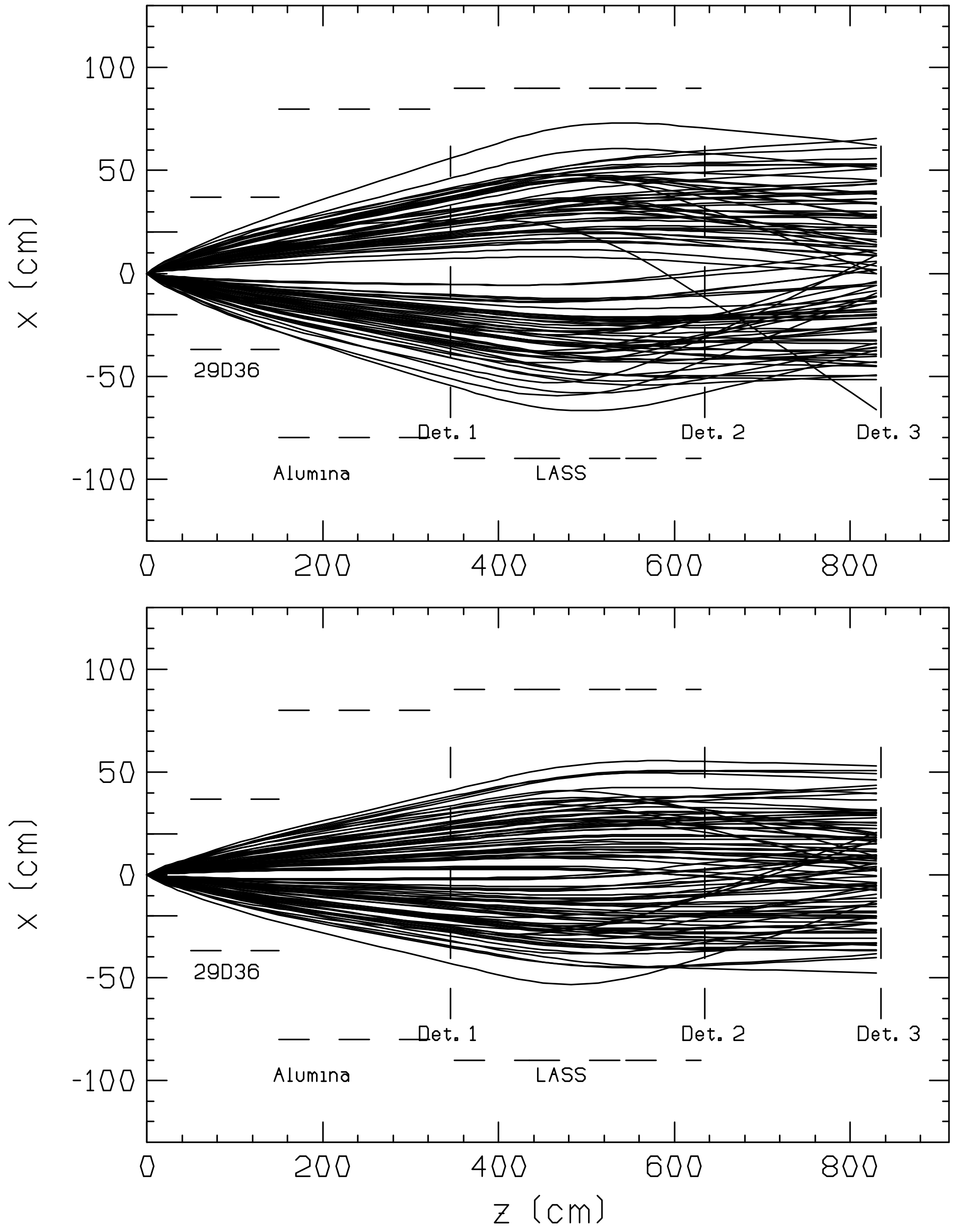
HOW TO FIX PROPOSAL DESIGN

- Different absorber (i.e. Be or C) doesn't help.
- Can gain factor 50 in luminosity if make alumina thicker (i.e. 3.5 m).
- But, proposal tracking scheme (target point plus two planes after LASS dipole) gives mass resolution $> 6\%$: no good for ψ'.
- Need about factor 1.6 more integrated B field to get back to 4% mass resolution: cannot see how to get this with LASS coil geometry.
- Can recover 4% mass resolution by moving LASS dipole back, and putting extra tracking layer in front of magnetic field.
- Now system 6 m long, so acceptance about 0.12 (down factor of 4). Overall, gain factor 10 in luminosity: experiment feasible again.

- **Main difficulty: detector granularity in all three planes must be < 2.5 mm in x (or $\sigma_x < 0.7$ mm). Now tracking without using target point. Need approximately 6000 to 8000 detector channels each with good timing: probably scint. fiber. Would need to share channels to common PMT/electronics to make affordable. Detectors would be in several kG field.**
- **May be good option if has common requirements with E161.**

REVISED LASS DESIGN: RAY TRACE

Plot shows 25 GeV (top) and 35 GeV (bottom) ray traces from top view. In y, maximum angle is about 0.09 rad.



MUON RANGE TELESCOPE

- Put absorber near “knee”, then measure opening angle of muons with position.
- Followed by about 40 layers of iron interspersed with detectors. See where particle lost to get range. Rokni calculations and actual experience say 5% momentum resolution possible up to 10 GeV (may be worse at 30 GeV).
- Mass resolution of 4.4% (C absorber) to 4.9% (alumina) (a little above our limit).
- Acceptance ≈ 50% for $E_J > 25$ GeV.
- Size needed is huge: rectangle about 5 m by 5 m by 30 m, or 3 million pounds of iron, > 400 m^2 of detector surface. Rough cost estimate is $> \$3,000,000$
- Not good for E161 unless iron magnetized, detectors have fine granularity for measuring sign of muon. (Volume for E161 would be about 1/4).
- Does not take advantage of point target: better suited to neutrino detection.
- Can any existing detector be borrowed?

ABSORBER CHOICE, RESOLUTIONS

For various materials, the length in meters and r.l. of the material that matches the "knee" condition; number particles emerging is for 25,000 nuclear interactions; invariant mass resolutions that would be obtained from:

- **a) θ resolution from absorber alone (no magnetic field);**
- **b) same as a) but P resolution from an iron range telescope;**
- **c) same as a) but P resolution from tracking in LASS dipole;**
- **d) absorber immersed in constant 23 kG.**

Material	density	Knee	Knee	Part.	Res (a)	Res (b)	Res (c)	Res (d)
Be	1.87	10 m	28 rl	100	2.6%	4.3%	4.0%	2.3%
C	2.20	6 m	32 rl	60	2.6%	4.4%	4.0%	2.2%
Al_2O_3	3.60	3.5 m	48 rl	50	3.1%	4.9%	4.0%	3.2%
Al	2.70	5 m	56rl	80	3.6%	5.0%	4.4%	2.9%
Cu	8.96	2.0 m	140 rl	10	5.7%	6.5%	6.0%	11%

D3 DESIGN

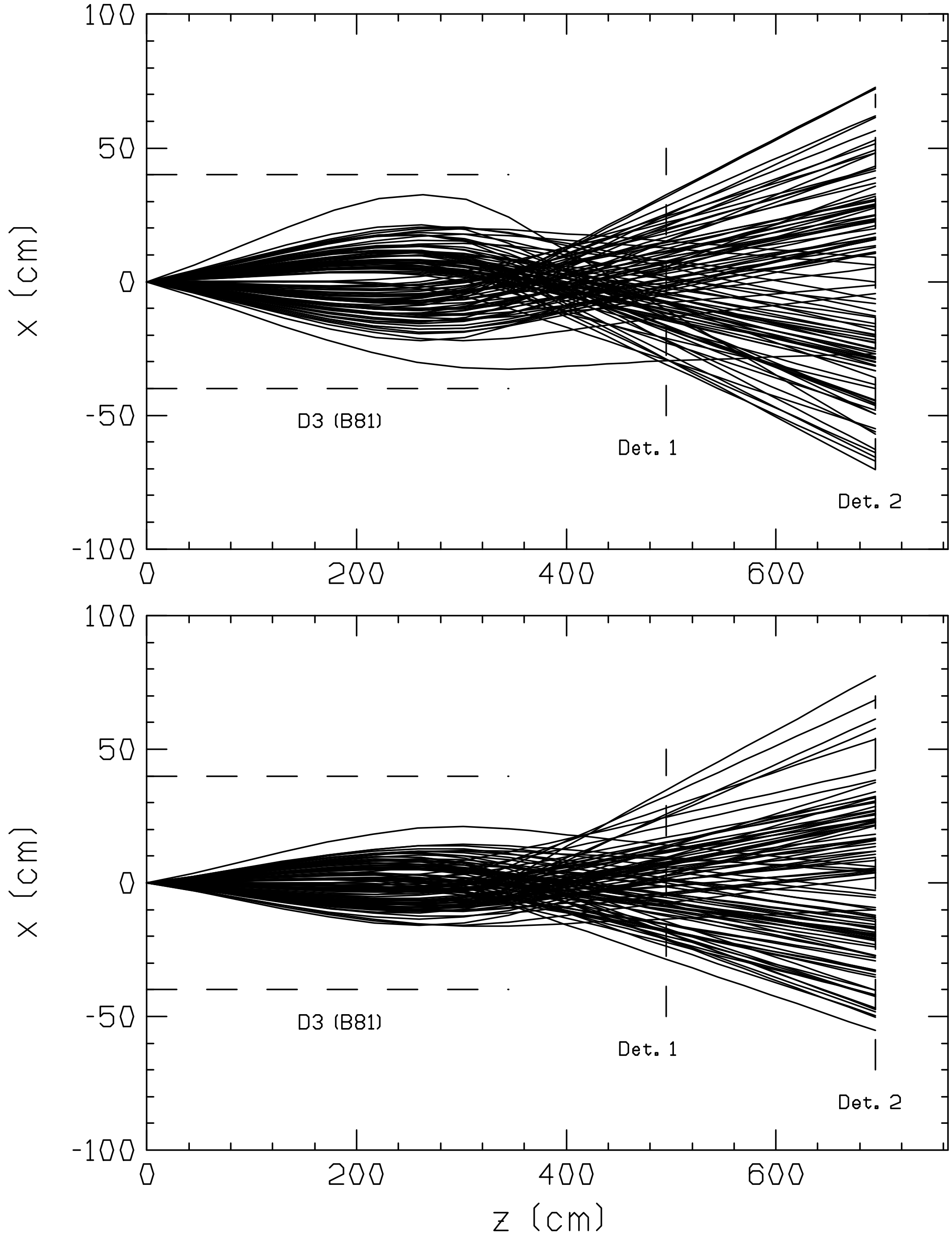
- Studies show immersing absorber in constant 23 kG magnetic field gives better mass resolution than any other method, because both angle, momentum resolution improved (see case d) previous page).
- Need large, long, high field magnet. Best choice at SLAC (by far) is E158 D2 or D3 (B81, B82 in 8 GeV spectrometer). Opening 55 cm wide, 35 cm tall (flared at end), 345 cm long.
- Backgrounds also reduced (high field sweeps away low energy charged particles).
- Design has target position just at beginning of D3 (to maximize acceptance).
- D3 filled with absorber (pure aluminum in present design, alumina/carbon combination under study).
- 1.5 drift to first detector plane: drift also filled with absorber. 2 m drift in air to second detector plane.
- At 15 GeV, resolution requirements looser, allow muons to pass through 30 cm wide copper coils (field drops linearly with distance into coil).

- Small beam pipe inside: careful design to minimize backgrounds (see Piotr's talk).
- Acceptance about factor two lower than revised LASS design, but backgrounds lower by factor of two also: figure of merit same within error of estimate.
- Much easier setup (uses D3 in current location). Detector requirements much more manageable (similar to original proposal).
- Bottom line: Photon spectra shown in my talk this morning give enough luminosity with D3 acceptance to meet physics goals in alloted time, with tolerable backgrounds (details below).

Energy (GeV)	15	25	35
Mass Resolution J/ψ (%)	3.2	3.4	3.8
Mass Resolution ψ' (%)	5.0	3.9	3.5
psi Energy Resolution (%)	6.2	6.0	6.7
p_t Resolution (GeV)	0.11	0.11	0.12
J/psi Acceptance	0.008	0.033	0.060

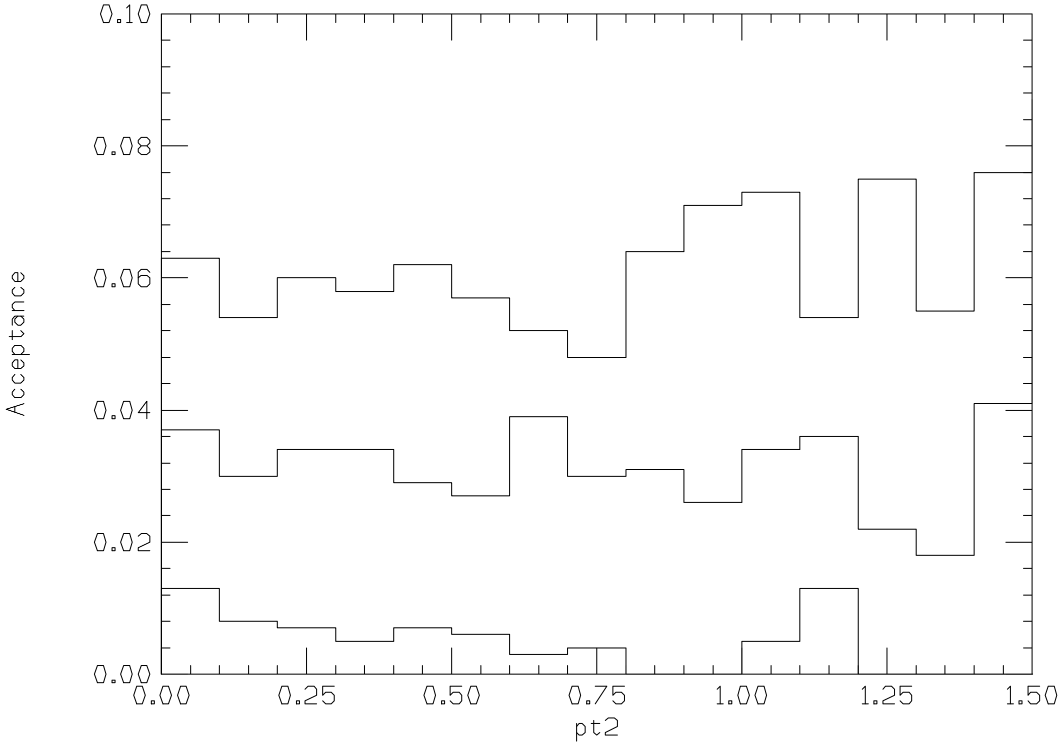
D3 DESIGN: RAY TRACE

Plot shows 25 GeV (top) and 35 GeV (bottom) ray traces from top view. In y, maximum angle is about 0.05 rad.



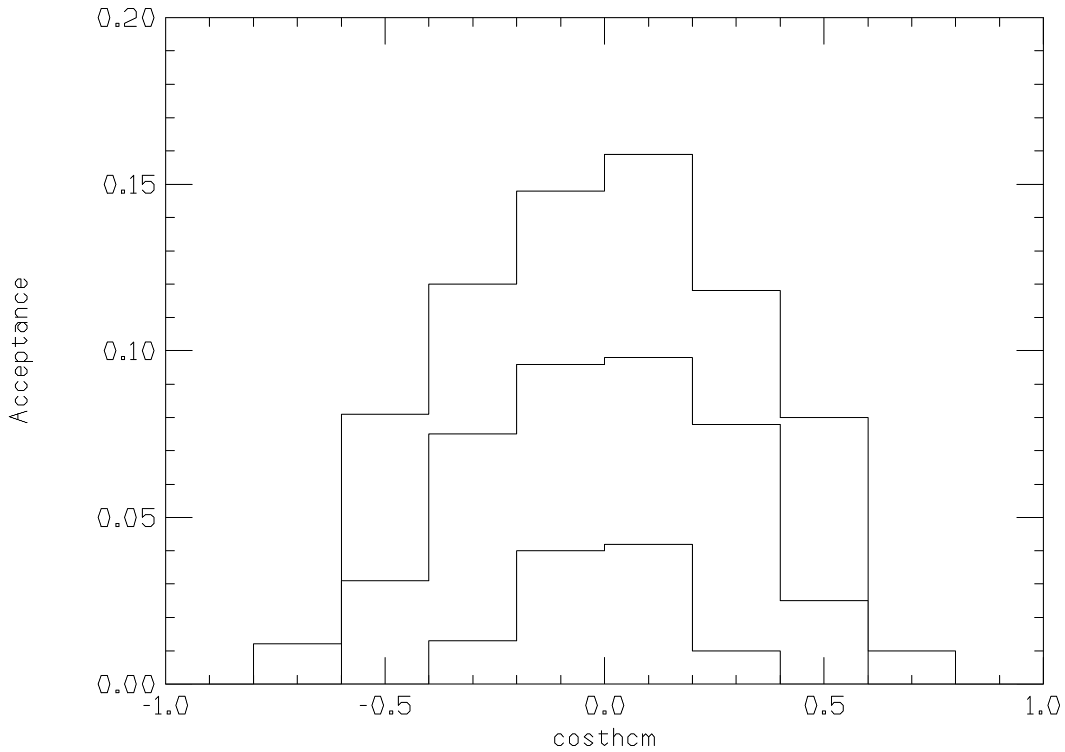
D3 DESIGN: p_t^2 ACCEPTANCE

Curves are at 15 (bottom), 25, and 35 GeV (top).



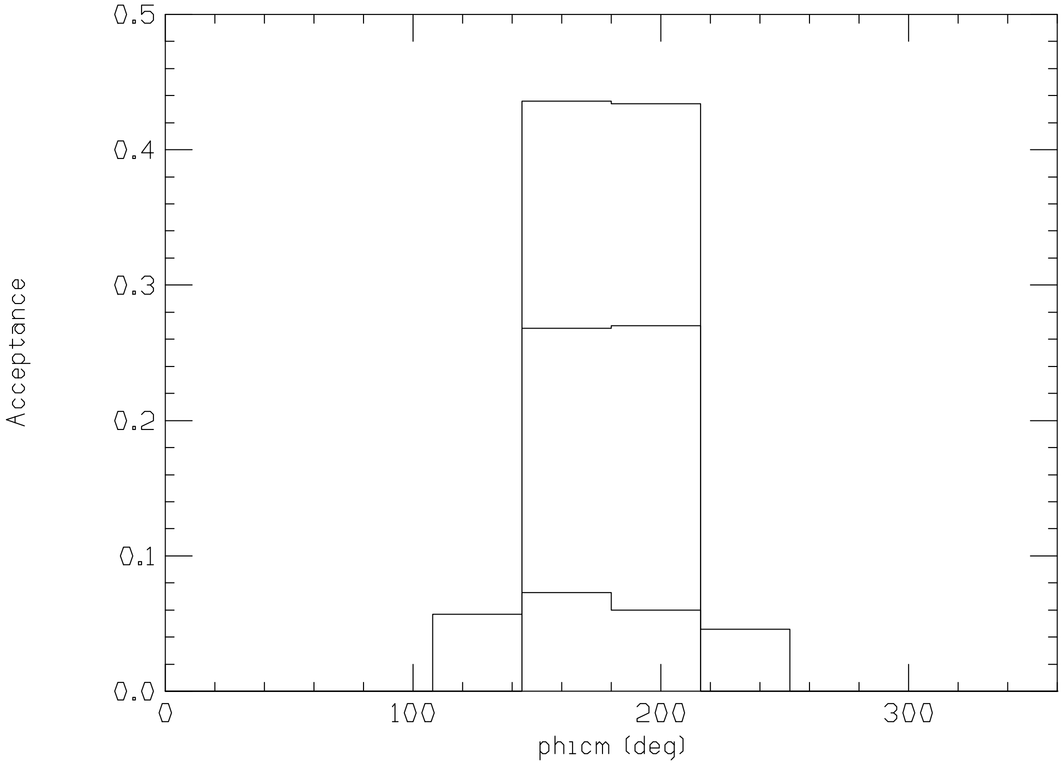
D3 DESIGN: cos(θ_{cm} Acceptance

Curves are at 15 (bottom), 25, and 35 GeV (top). Very similar to plot vrs $R_e = E_1/E_{tot}$.



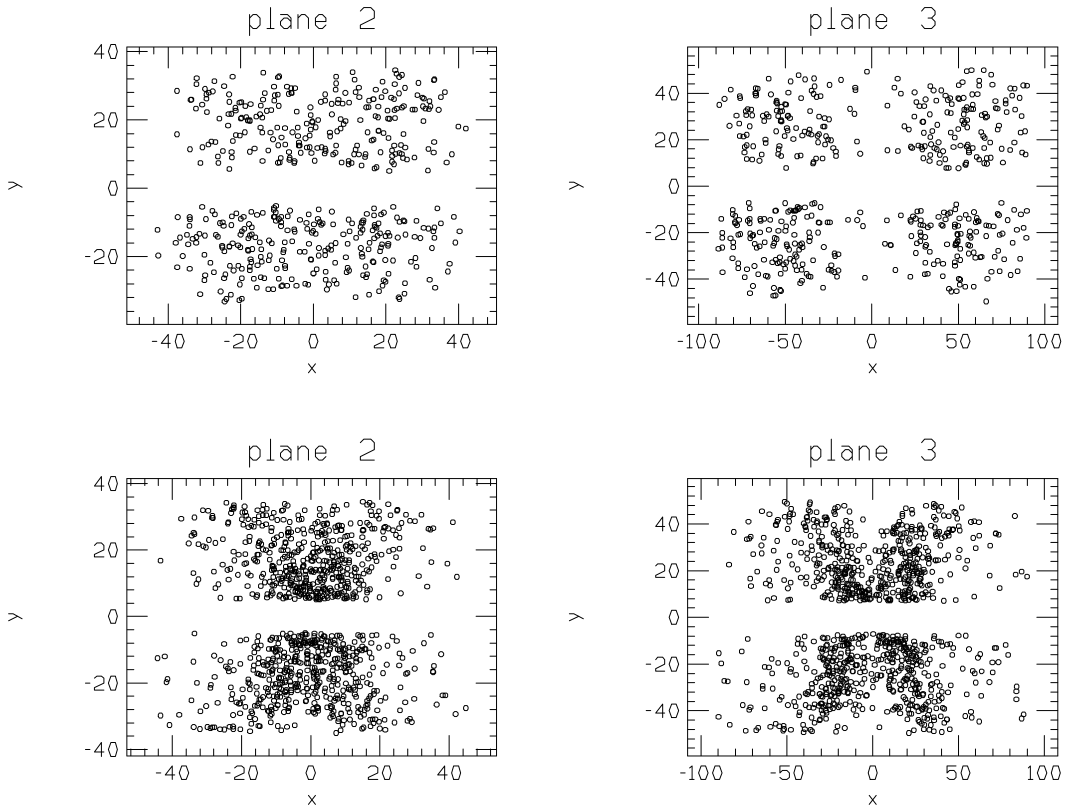
D3 DESIGN: ϕ_{cm} ACCEPTANCE

Curves are at 15 (bottom), 25, and 35 GeV (top).



COUNTS vrs x/y AT DETECTORS

Top plot for 15 GeV, bottom plots for 35 GeV.



BACKGROUND RATES IN DETECTORS

- Define sprinkle hit as low energy charged particle (doesn't fire many planes). Mostly from photons converting. Assume 1 gm/cm^2 per sub-plane.
- Tracks defined as particle hitting both planes.
- Background from photons that Compton scatter in target: about 4 sprinkle hits/spill in back detectors; negligible in front. No tracks.
- Background from e^+/e^- pairs produced in target: Based on statistics of 1/1000 spill. Get about 70 sprinkle hits/spill in front or back planes. No tracks observed: could be some from muons.

- **Background from nuclear interactions in target: about 200 (30) sprinkle hits in front (rear) detector, based on statistics on 1/10 spill. No tracks seen, but expect a few/spill from decays.**
- **Background from Bethe-Heitler muons pairs. About 5,000 produced/spill (lead target), but most swept away (momentum too low). Most of rest pass in $\pm$5 cm ($\pm$7 cm) gap in detectors. Detailed simulation not yet done. Expect no sprinkle hits, but potentially dozens of tracks per spill (depending on gap size).**
- **Bottom line: About 1 sprinkle hit per detector element per spill and order of 10 tracks/spill. Similar to E155: should work o.k.**

DETECTOR GRANULARITY

- Front planes (top and bottom) each about ± 50 by ± 30 cm.
- Back planes (top and bottom) each about ± 90 by ± 43 cm.
- Resolution (σ) needed is about 0.2 mm in x and 2 cm in y. Can be worse on x edges because only low energy J/ψ here.
- Assuming each plane has 3 sub-planes with overlap for redundancy and resolution, need about 1000 detectors (as in proposal).
- Optimization of sizes still to be done.
- Not shown: third plane of large UVA 10 cm by 10 cm by 160 cm scintillators, behind another absorber, for positive muon i.d. Good for defining muon times: starting tracking.

SUMMARY

- Proposal design has problems
- Could be modified to work with very fine granularity tracking using LASS field.
- Muon range telescope could work.
- Solution using D3 proposed. Less expensive, best mass resolution of any three designs.
- Suggest we concentrate on D3 design, but keep other designs in mind if highly overlapping with E161.
- will continue background studies: finalize by early June review.