TOF Report, 8 Feb 2003
Overview

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University of South Carolina
High Energy Physics

I. What are we going to build?

-- 2 +1 options.

II. A question of *t* resolution

III. The Dark Side

-- A question of *p* resolution

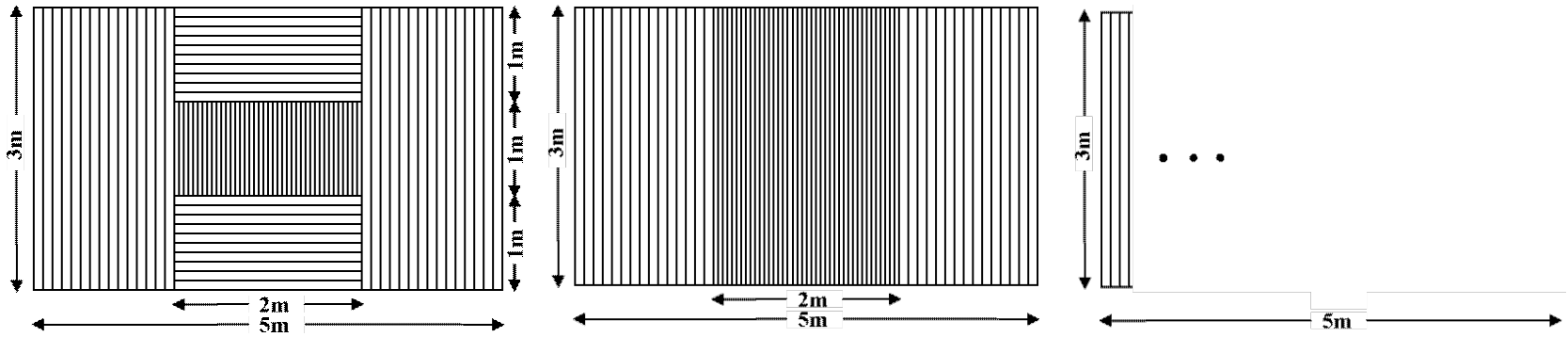
IV. TOF project status

2+1 Options

A. "Thin" design.

B. "Thick" design.

C. "Wide" design (C.R. invented this one just for this report).



A. Thin B. Thick C. Wide

2+1 Options

	Number of modules	PMT + scintillator cost	Fratricide rate in NUMI beam
A. Thin	90	$234K	~15%
B. Thick	70	204K	~17%
C. Wide	50	173K	~25%

- We must decide very soon which design to build.

A Question of *t* Resolution

- Financial exigency has driven us to extract the best possible time resolution from the Hamamatsu R5900U PMT.

Photocathode area	18 x 18 mm (small)
Transit time spread	260 ps (excellent)
Gain	$2x10^6$ (low)
B field tolerance	To ~10mT (good)
Cost	~$825 w base & connectors (cheap)

A Question of *t* Resolution

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- Compensate for small photocathode area by making large amount of light, i.e. thick scintillator, and using a good light collector, i.e. a Winston cone.
- Just upstream of the ROSIE yoke thick scintillator clearly does no harm, and cost favors bigger (square) scintillator up to 130x130 mm.

A Question of *t* Resolution

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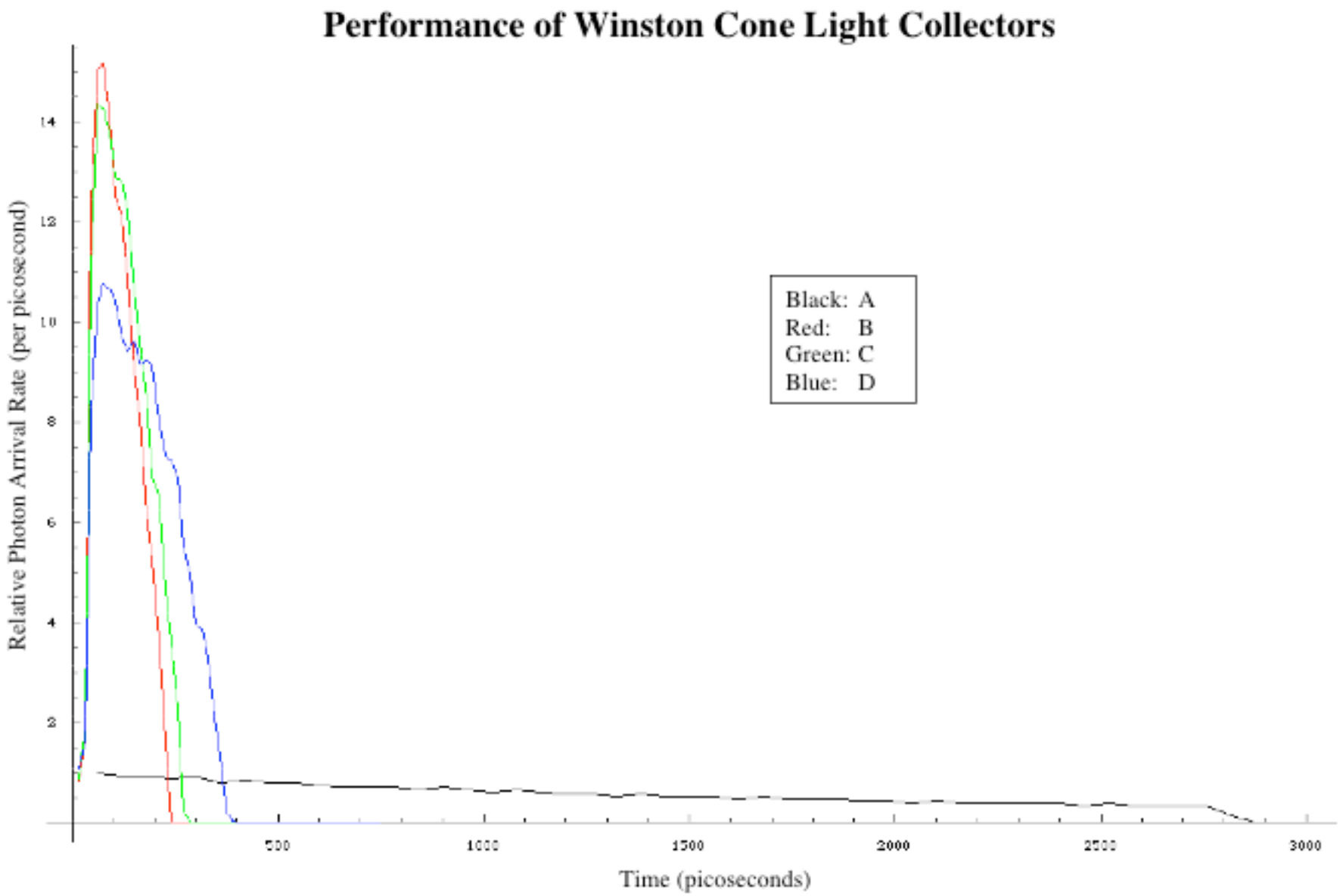
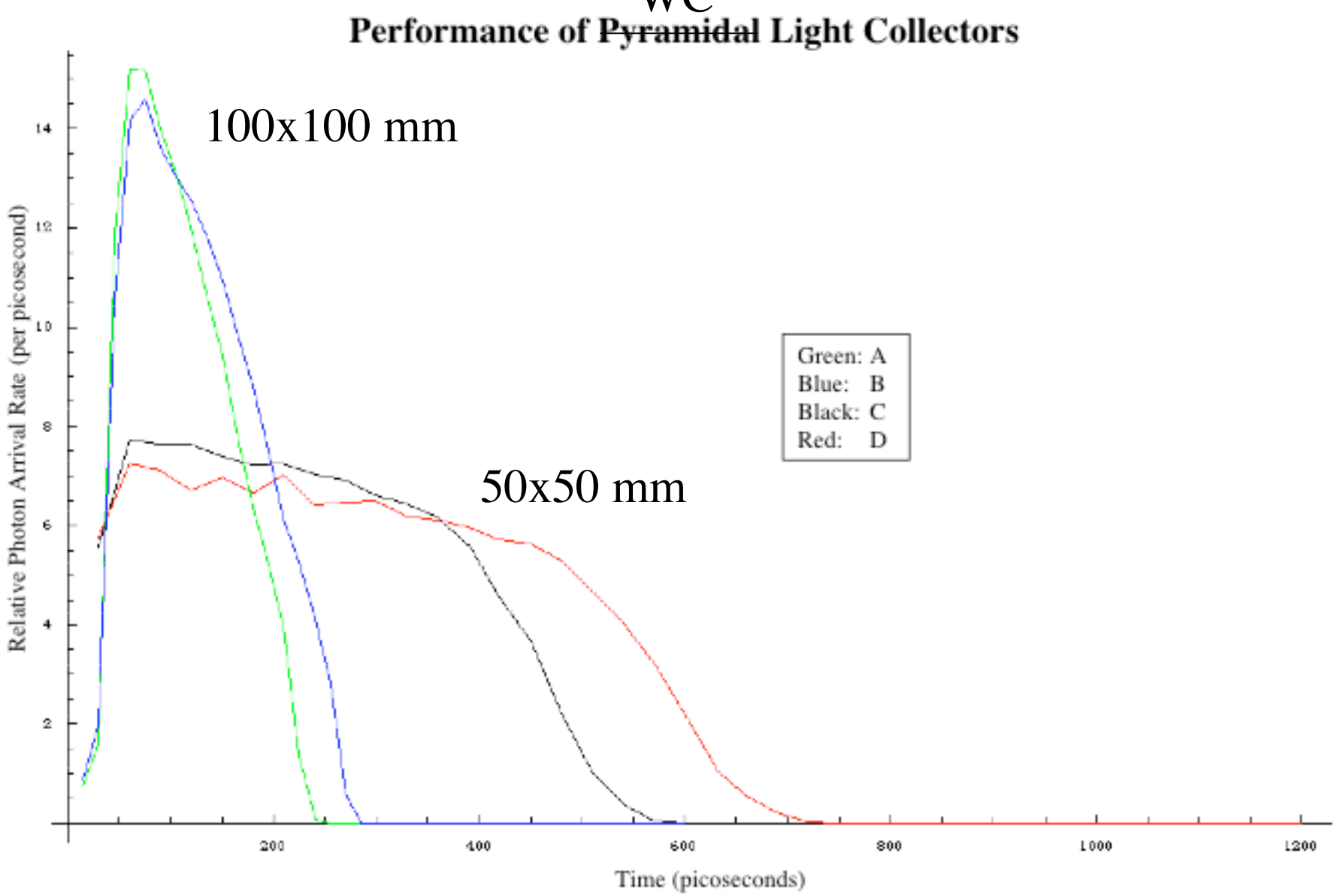
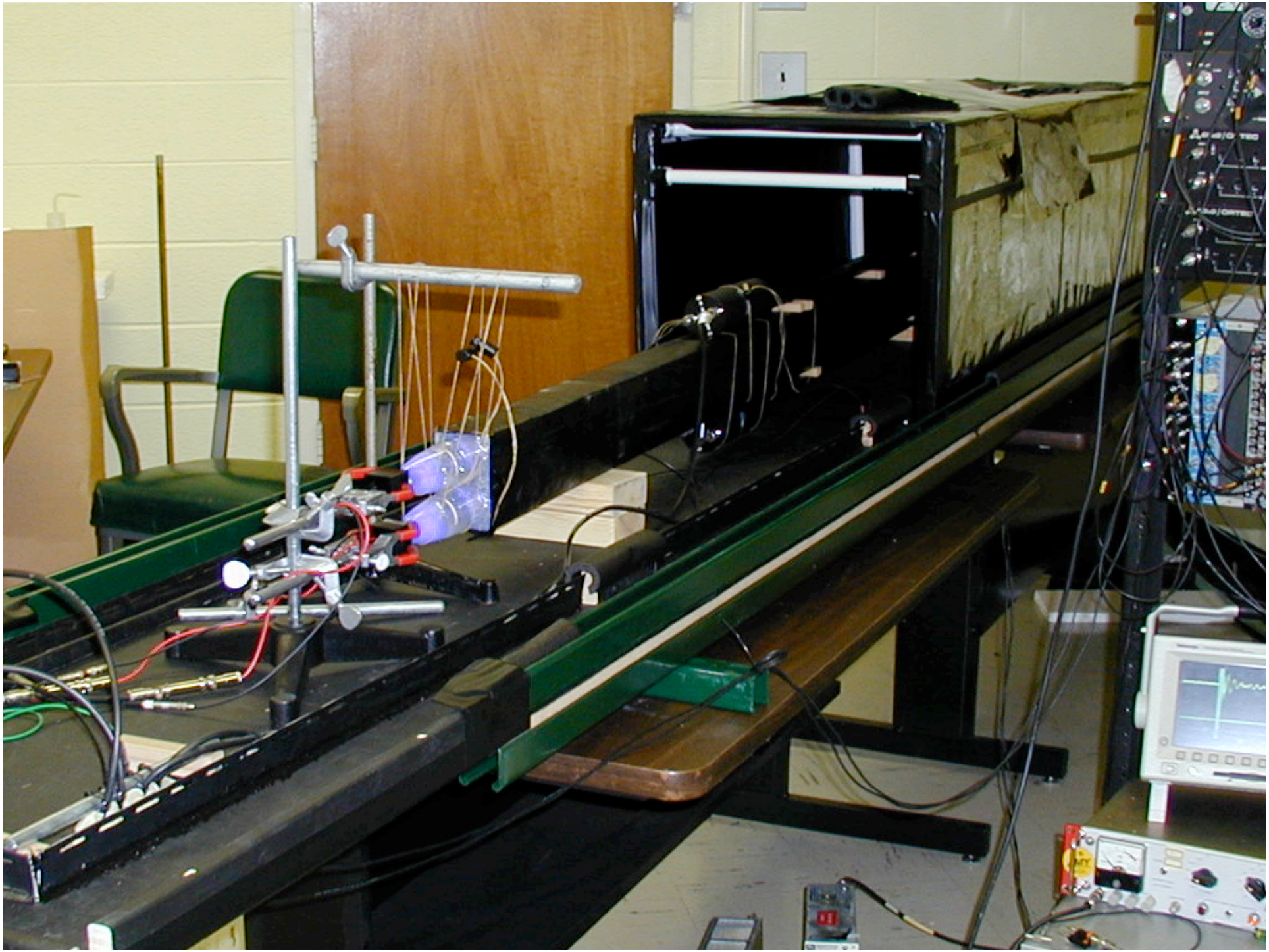
- How do we know what resolution to expect?
- We take guidance from two sources:
  - Optical system simulation
  - Measurements
- Next: representative optical simulation results.

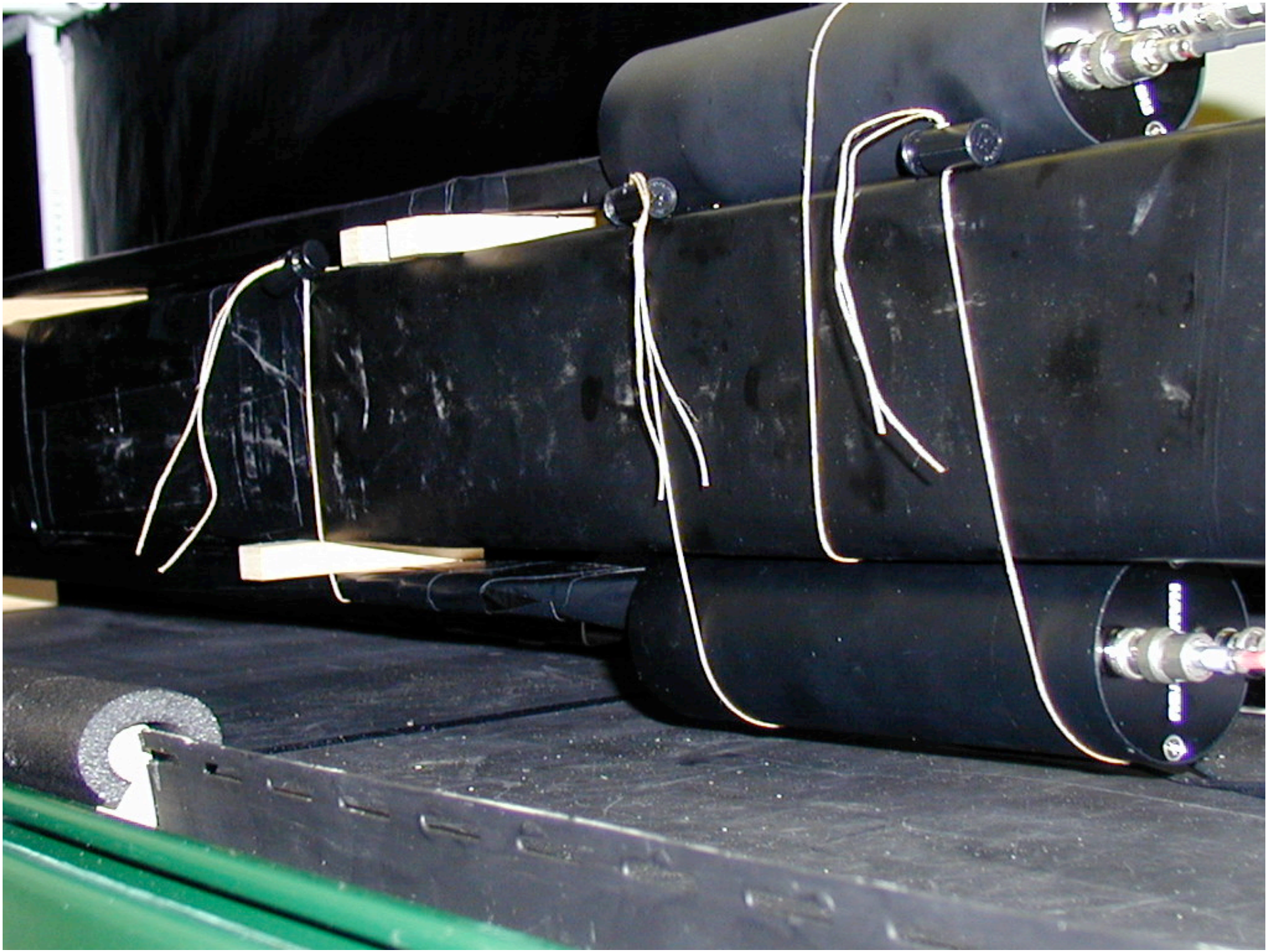

Performance of Winston Cone Light Collectors
Relative Photon Arrival Rate (per picosecond)
14
12
10
8
6
4
2
Black: A
Red: B
Green: C
Blue: D
500
1000
1500
2000
2500
3000
Time (picoseconds)

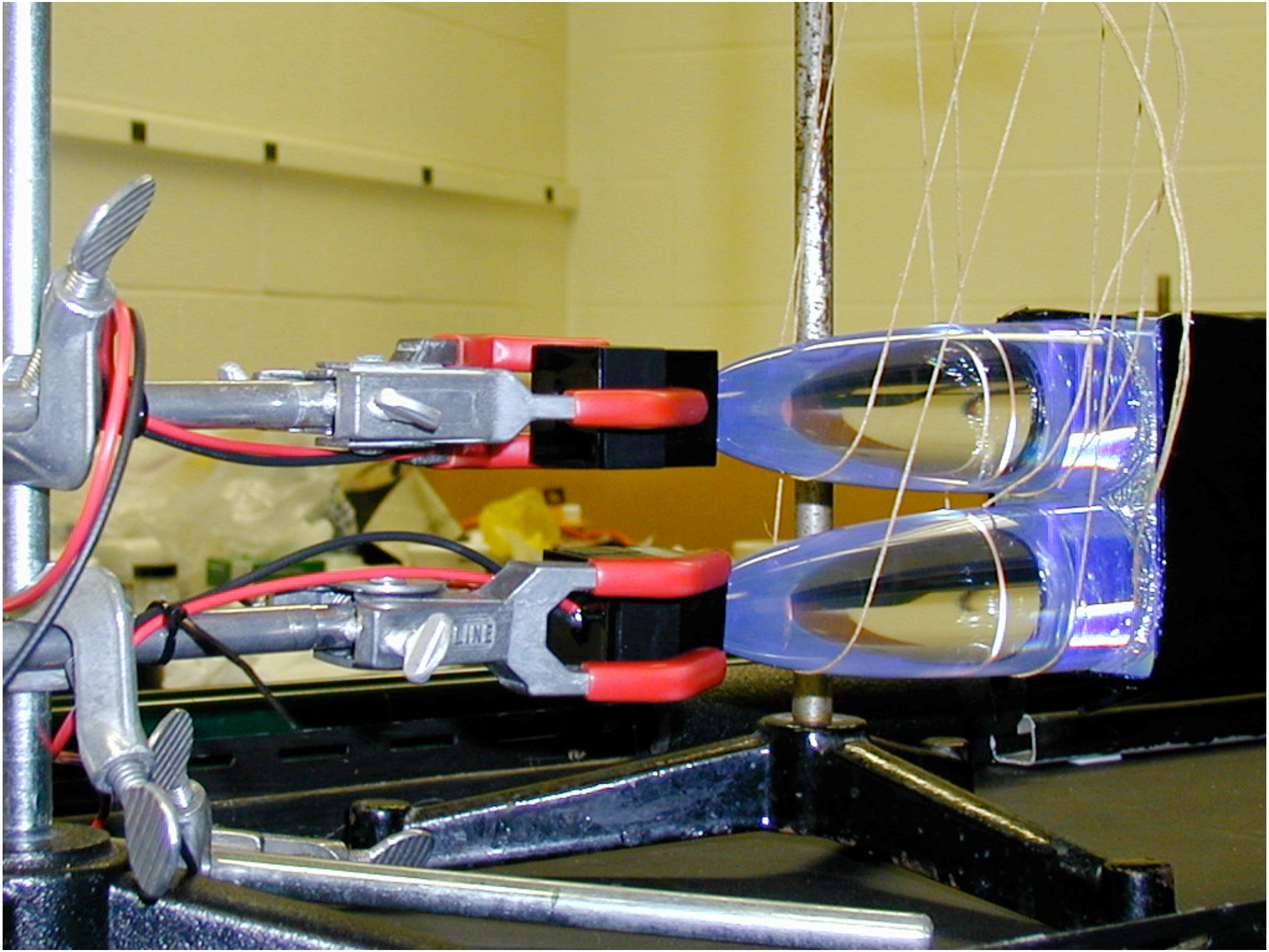
WC

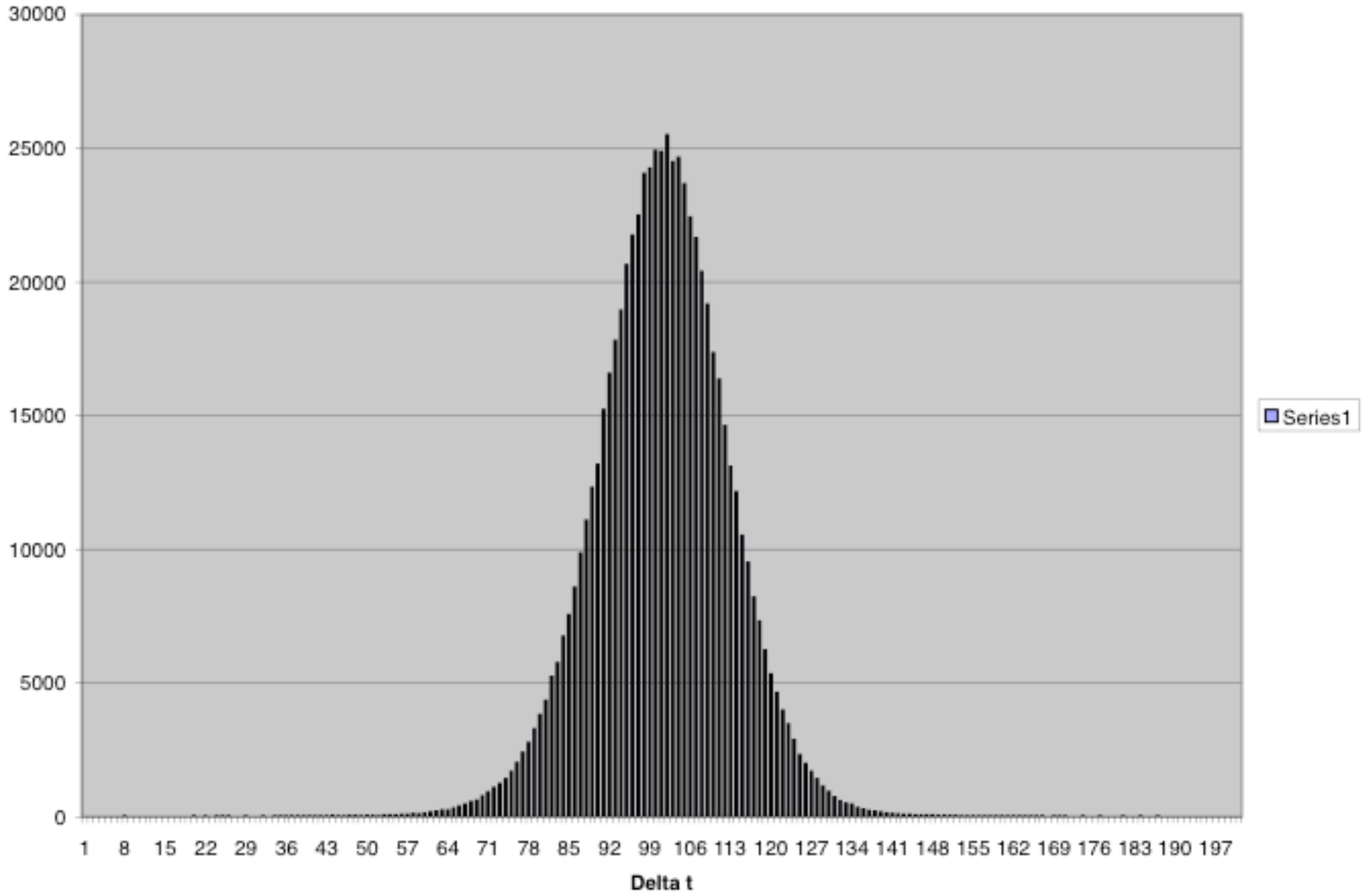

Performance of ~~Pyramidal~~ Light Collectors
100x100 mm
50x50 mm
Green: A
Blue: B
Black: C
Red: D
Relative Photon Arrival Rate (per picosecond)
Time (picoseconds)
2
4
6
8
10
12
14
200
400
600
800
1000
1200


Fragile!!!
Please do not touch
or lean on box.
TATIC SHIELD






LINE


30000
25000
20000
15000
10000
5000
0
1 8 15 22 29 36 43 50 57 64 71 78 85 92 99 106 113 120 127 134 141 148 155 162 169 176 183 190 197
Delta t
Series1

A Question of *t* Resolution

- A sample of results:
- For R5900U PMT on face of 60 x 100 mm scintillator bar, cosmic ray penetrates 100mm:
  - Observed σ of T2-T1 is 345 ps.
  - For individual counter σ (they are identical) deduce $345/\sqrt{2}=244$ ps.
  - In MIPP we will know the track position, so we will use the average of two counters. Projected σ is $244/\sqrt{2}=172$ ps.
  - With 100 x 100 mm counter in MIPP the amount of light collected would be down by factor 0.78.
  - Assuming rule of thumb that σ^2 scales like (intensity of light)$^{-1}$, predicted σ is $172\text{ps}*(1/.78)^{1/2}=195$ ps.

A Question of *t* Resolution

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  - Our data however does not fit the rule of thumb.
  - Two adhoc models that do fit our sparse measurements (two points) both predict
    σ = 238 ps.

- Corresponding argument for half-scale mockup of Winston cone collector starts with 434 ps from which adhoc models predict 182 ps and 189 ps.
- Previously reported result for 1m x 50 mm x10 mm bar (thin scintillator) is 135 ps, but the scintillator and collector were exactly as they would be in the experiment.

A Question of *t* Resolution

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- Vis-à-vis resolution,
  - Do we know exactly what the hell we are doing? Not yet.
  - Do we have a pretty good qualitative understanding of how things work? I think we do.
  - The thin design is probably the best because the thin section (very short bars) has confirmed excellent resolution.

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The Dark Side

A. Degradation of dp/p by multiple Coulomb scattering (MCS).

B. Extra conffusion in the RICH from g conversions and interactions in the TOF.

Sharon has already addressed B as well as we can today.

At USC we studied dp/p on two parallel tracks.

1. Adapt Raja's simulation code to include MCS in the resolution estimate.
2. Do a back-of-the-envelope calculation.

The Dark Side

These are complementary approaches.

With 1 we believe we obtain an accurate estimate of the "bottom line" p resolution.

With 2 we get a feel for how the TOF does its damage.

by the PDG:

$$\theta_0 = \frac{13.6MeV}{\beta cp} z\sqrt{x/X_0}[1 + 0.038\ln(x/X_0)].$$

ıe distance between the scintillator and the cham
in the resolution of the individual chambers set a
17.8cm, and 1595.3cm for the distances between
four, five, and six respectively. Thus we have th

$$1/\sigma_p^2 = \sum_i (dx_i/dp)^2/(\sigma_i^2 + \theta_0^2 L^2).$$

procedure the momentum resolution was calcu

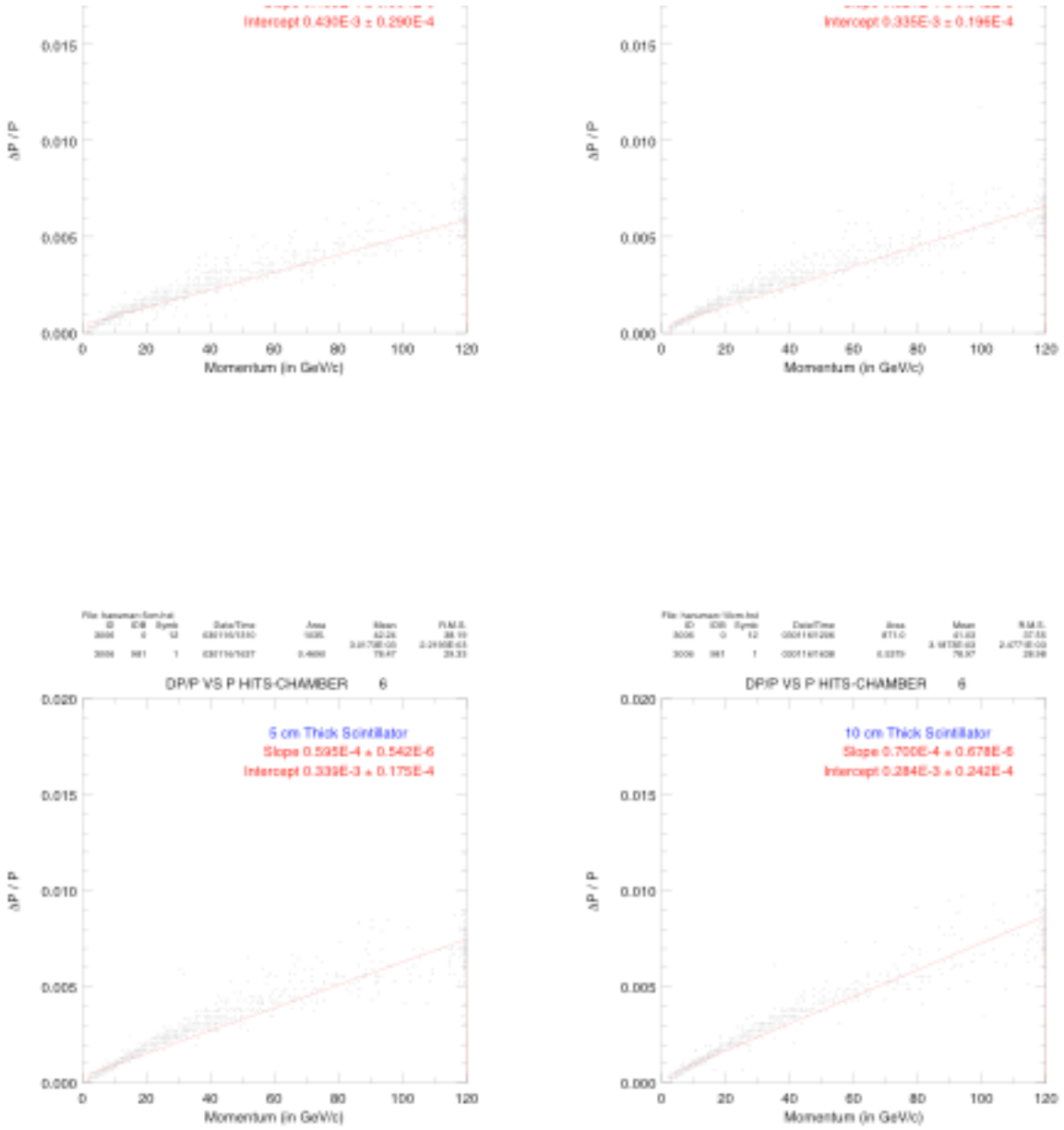


Figure 3: The momentum resolution $\frac{\Delta p}{p}$, vs the momentum for tracks going through all six chambers.

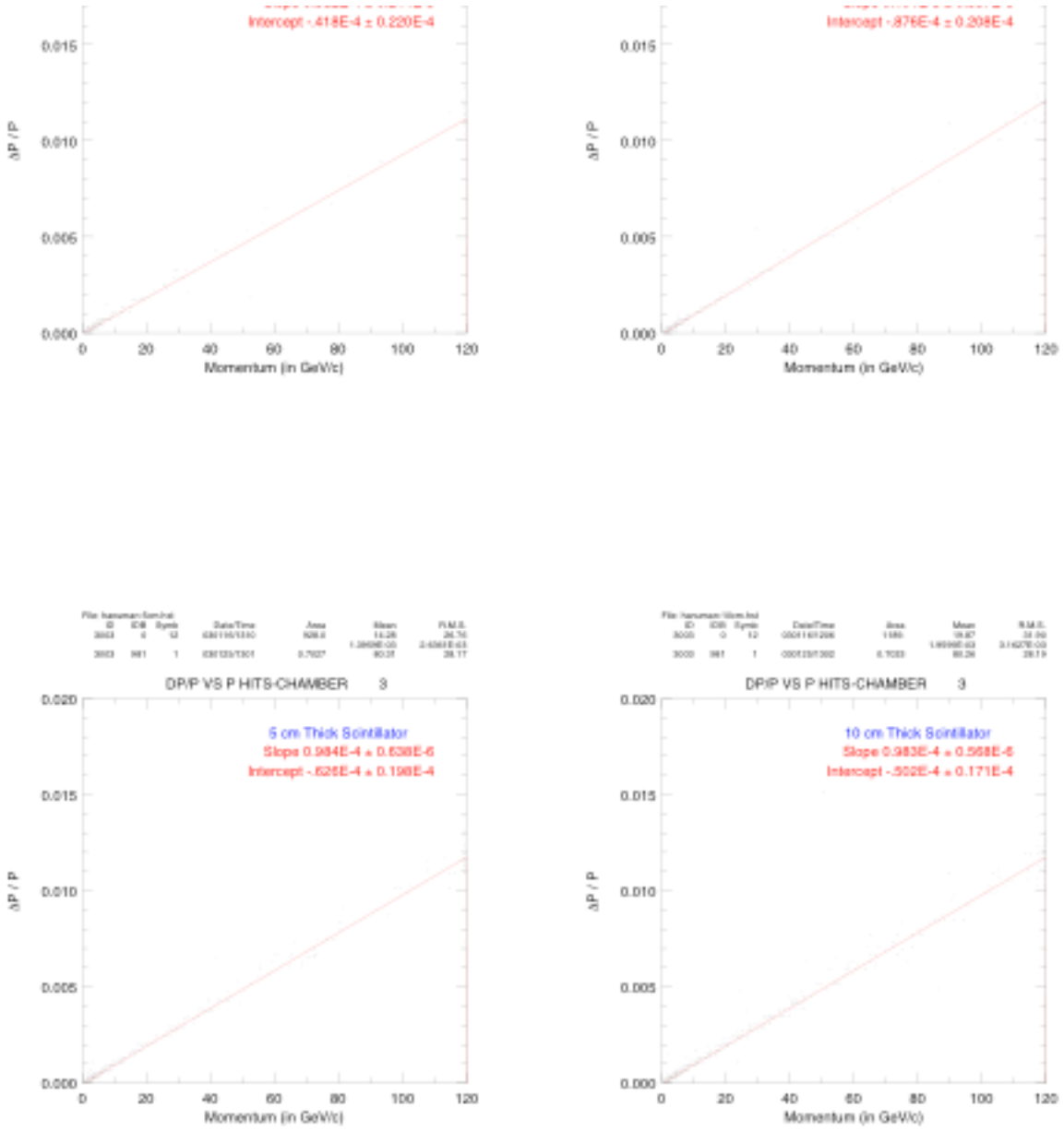


Figure 4: The momentum resolution $\frac{\Delta p}{p}$, vs the momentum for tracks going through three chambers and not the Time of Flight wall.

Fig. 1. Resolution from ROSIE using chamber downstream of RICH.

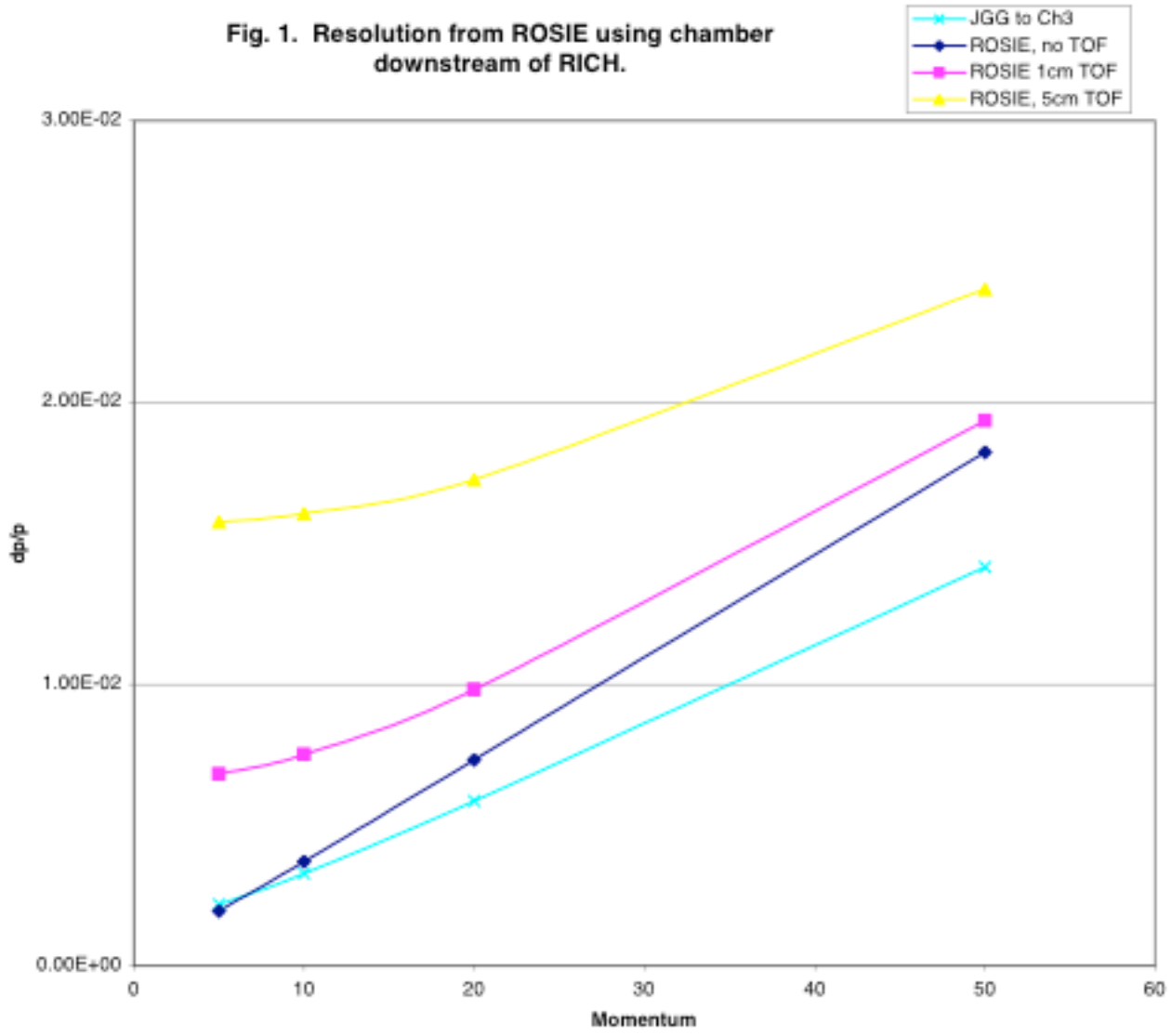


Fig. 2. Resolution from ROSIE using chambers upstream of RICH.

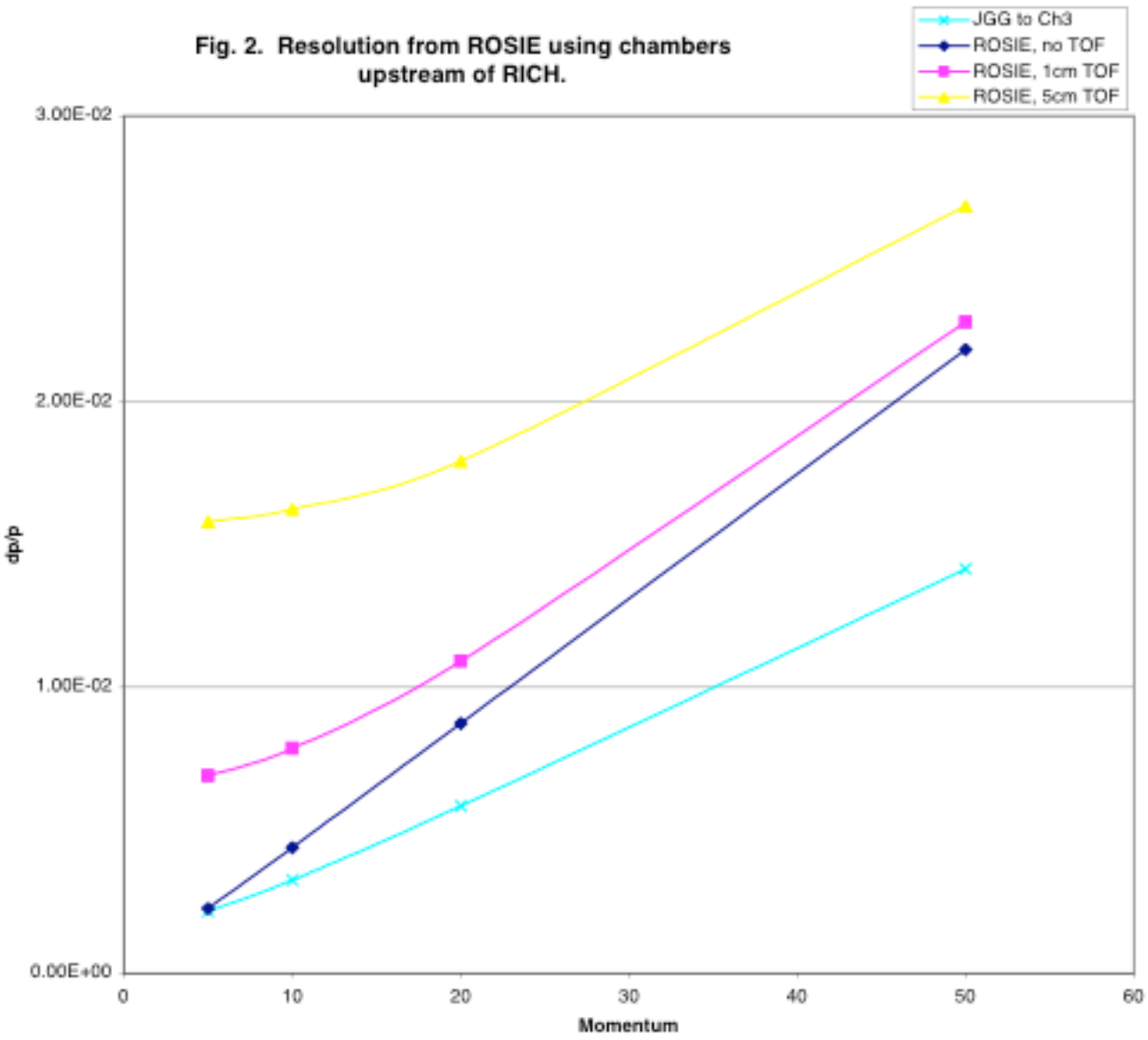


Fig. 3. Resolution from JGG using TPC and Chambers 3, 5, and 6 (ROSIE off, no TOF).

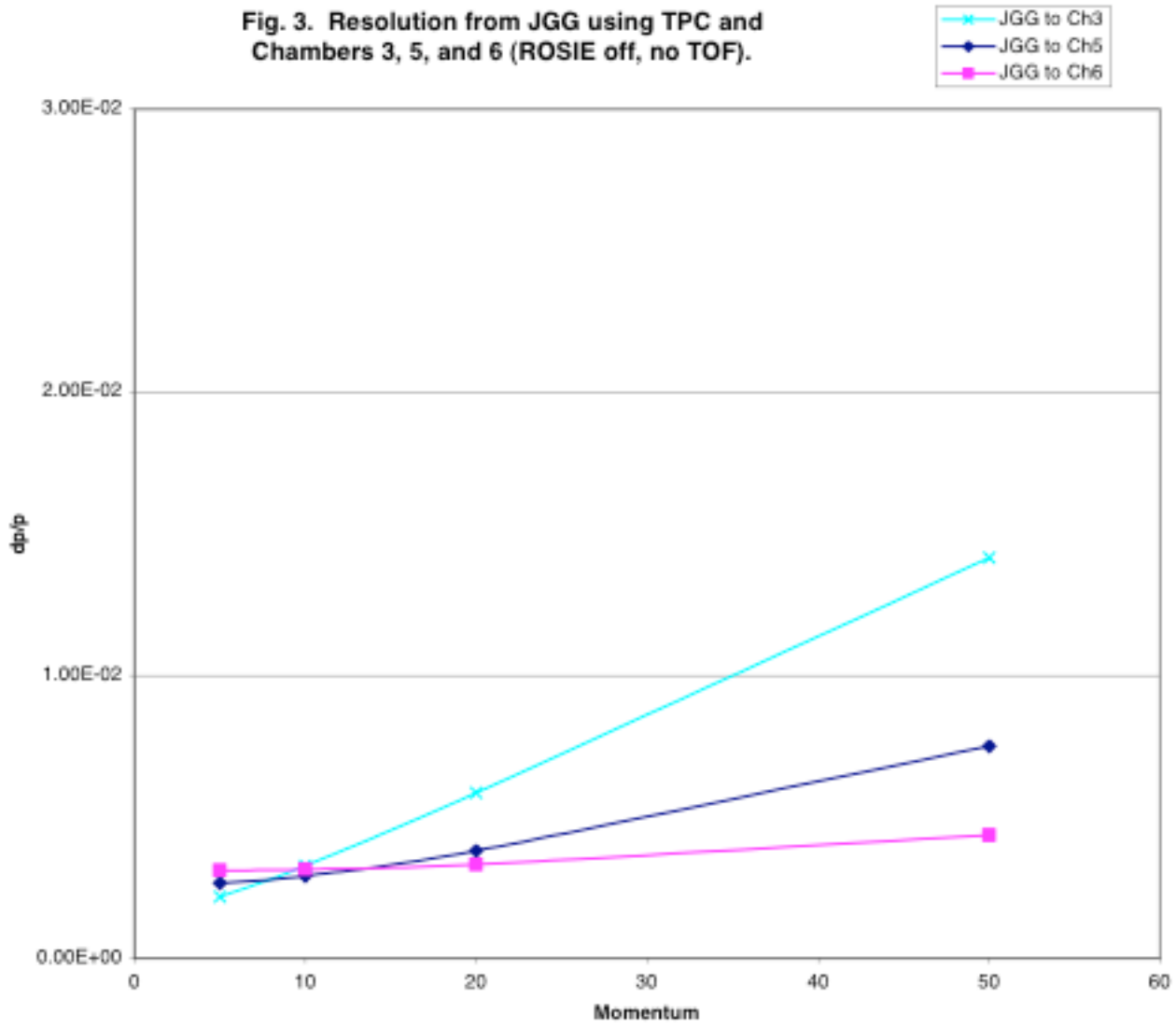


Fig. 4. Resolution from JGG using TPC and Chamber 5 (ROSIE off).

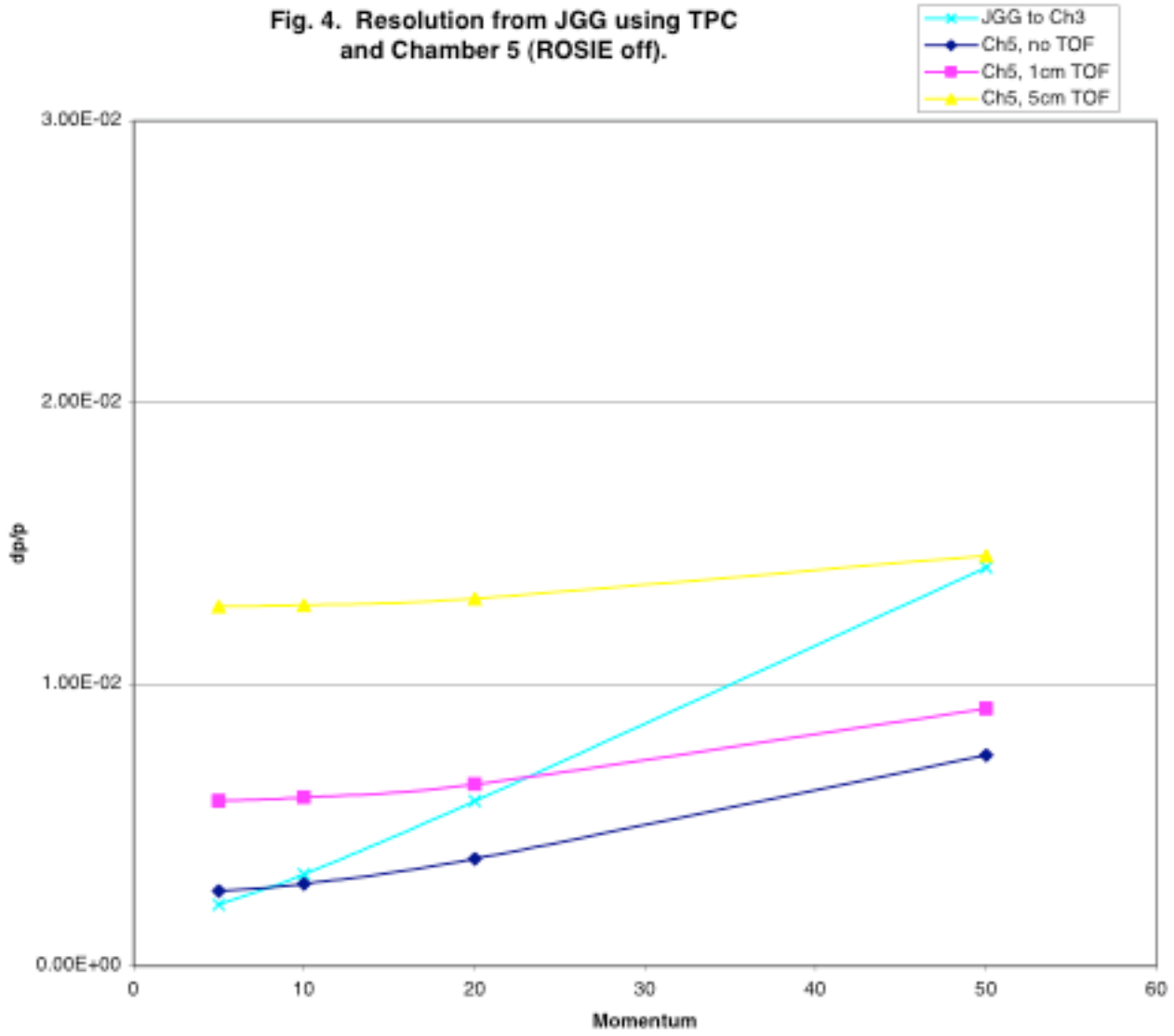
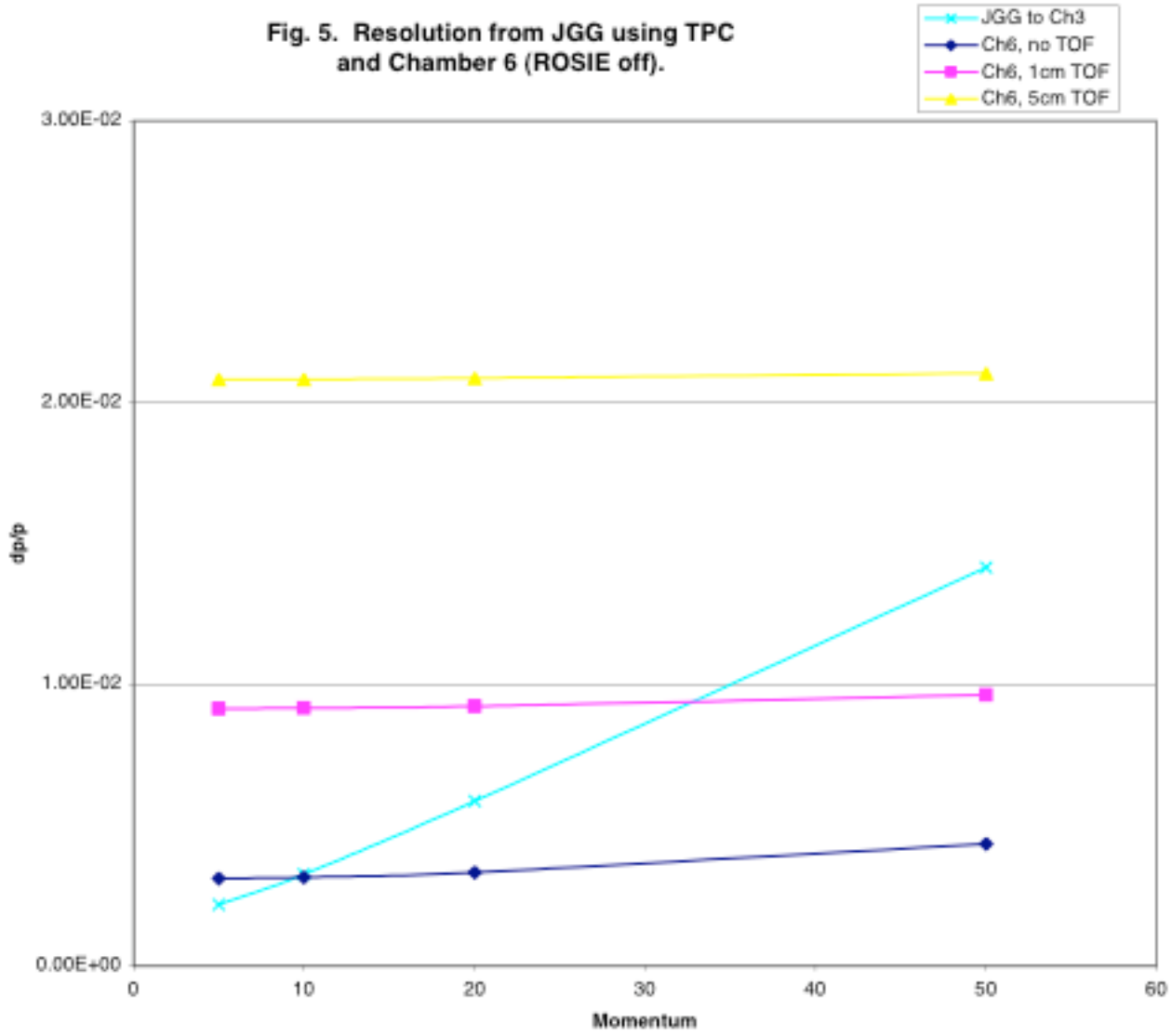


Fig. 5. Resolution from JGG using TPC and Chamber 6 (ROSIE off).



The Dark Side

- Radical conclusion: TOF does not terribly compromise the ultimate p resolution, but it does deeply erode the contributions from DC4-6.
- If a 5 cm TOF is acceptable, perhaps 10 cm is also acceptable, and Livermore would like to save $30K at the cost of increased fratricide.
- A provocative suggestion perhaps worthy of further study: If we agree to a 5 cm or a 10 cm thick TOF, perhaps we should delete ROSIE and move the RICH upstream 3.5 m, thus significantly improving the RICH acceptance.

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Status

- The Dean of USC's College of Science and Math has agreed to advance MIPP $185K on the understanding that Livermore will reimburse him in a couple of years.
- Livermore has agreed to ante up an additional $65K this year.
- 140 R5900U PMT's almost ordered (but within the next 8 weeks order can be reduced to 100 or increased to 180). Delivery from end of April to end of July.

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Status

- 16 101.6 x 101.6 mm bars of scintillator almost ordered. Scintillator delivery is more timely than PMT delivery.
- Testing will continue (where are all the new TDCs?).
- Design of supports for PMTs and scintillator bars is about to go on-shell.