High power target design and operation considerations for kaon production

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Outline

- AGS proton beam, days gone by
- LESBIII – a state of the art low energy kaon beam line
- Optics considerations for kaon beam line target
- LESBIII kaon production target/issues

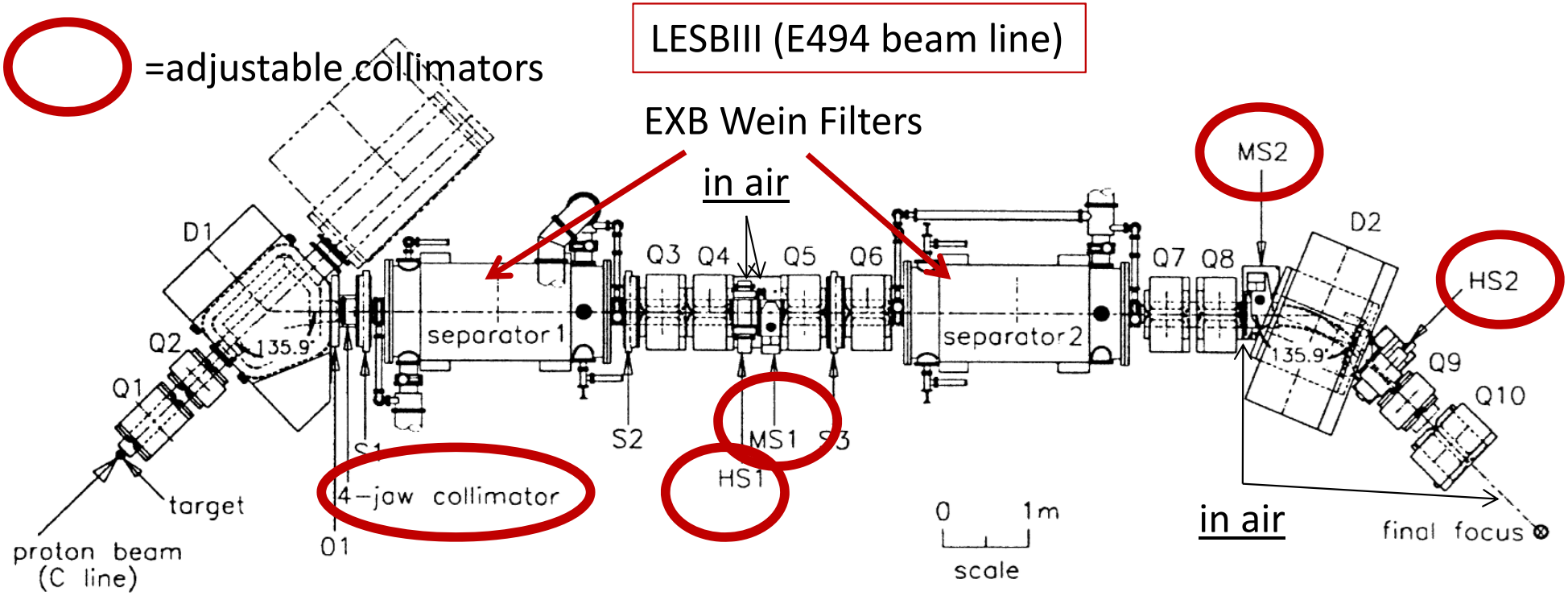
AGS performance

T. Roser

PROTON BEAM	**FY96**	**FY97**		**FY98/99**		**FY2000**	**FY2001**	**FY2002**
	SEB	**SEB**	**FEB (g-2)**	**SEB**	**FEB (g-2)**	**FEB (g-2)**	**FEB (g-2)**	**SEB**
Beam Energy	24 GeV	24 GeV	24 GeV	24 GeV	24 GeV	24 GeV	24 GeV*	22 GeV*
Peak Beam Intensity	62 x 10^{12} ppp	62 x 10^{12} ppp	46 x 10^{12} ppp	72 x 10^{12} ppp	58 x 10^{12} ppp	61 x 10^{12} ppp	63 x 10^{12} ppp	76 x 10^{12} ppp
Total protons accelerated	0.9 x 10^{20}	0.4 x 10^{20}	0.1 x 10^{20}	0.9 x 10^{20}	0.4 x 10^{20}	0.5 x 10^{20}	0.6 x 10^{20}	0.7 x 10^{20}
Spill Length/Cycle Time	1.6 sec/3.6 sec	1.6 sec/3.6 sec		2.8 sec/5.1 sec				2.4 sec/5.4 sec
-> Duty Cycle	44%	44%		55%				44%
Spill Structure Modulation (peak-average) /average	20%	20%		20%				20%
Average Availability /Best Week	76% / 92%	71% / 79%	58 % / 67 %	71% / 88%	55 % / 83 %	74 % / 87 %	83 % / 88 %	85 % / 97 %
HEAVY ION BEAM	**Au**	**Au**	**Fe (NASA)**	**Au**	**Fe (NASA)**	**Fe (NASA)**	**Fe (NASA)**	**Fe (NASA)**
Beam Energy /nucleon	11 / 4 / 2 GeV	11 / 8 / 6 GeV	1.0 / 0.6 GeV	11 GeV	1.0 / 0.6 GeV	1.0 GeV	1.0 GeV	1.0 GeV
Peak Beam Intensity	4 x 10^{8} Au/p	17 x 10^{8} Au/p	20 x 10^{8} Fe/p	9 x 10^{8} Au/bunch	36 x 10^{8} Fe/p	17 x 10^{8} Fe/p	80 x 10^{8} Fe/p	49 x 10^{8} Fe/p
Spill Length/Cycle Time	1.4 sec/3.6 sec	1.5 sec/4.0 sec		1.2 sec/3.0 sec		0.9 sec/3.3 sec	0.9 sec/3.3 sec	0.9 sec/3.3 sec
-> Duty Cycle	39%	38%		40 %		27%	27%	27%
Spill Structure Modulation (peak-average) /average	<20%	<20%		<20%		<20%	<20%	<20%
Average Availability	80%	82 %	96 %	81 %	90 %	90 %	97 %	84 %

* Westinghouse Motor Generator

LESBIII (E494 beam line)

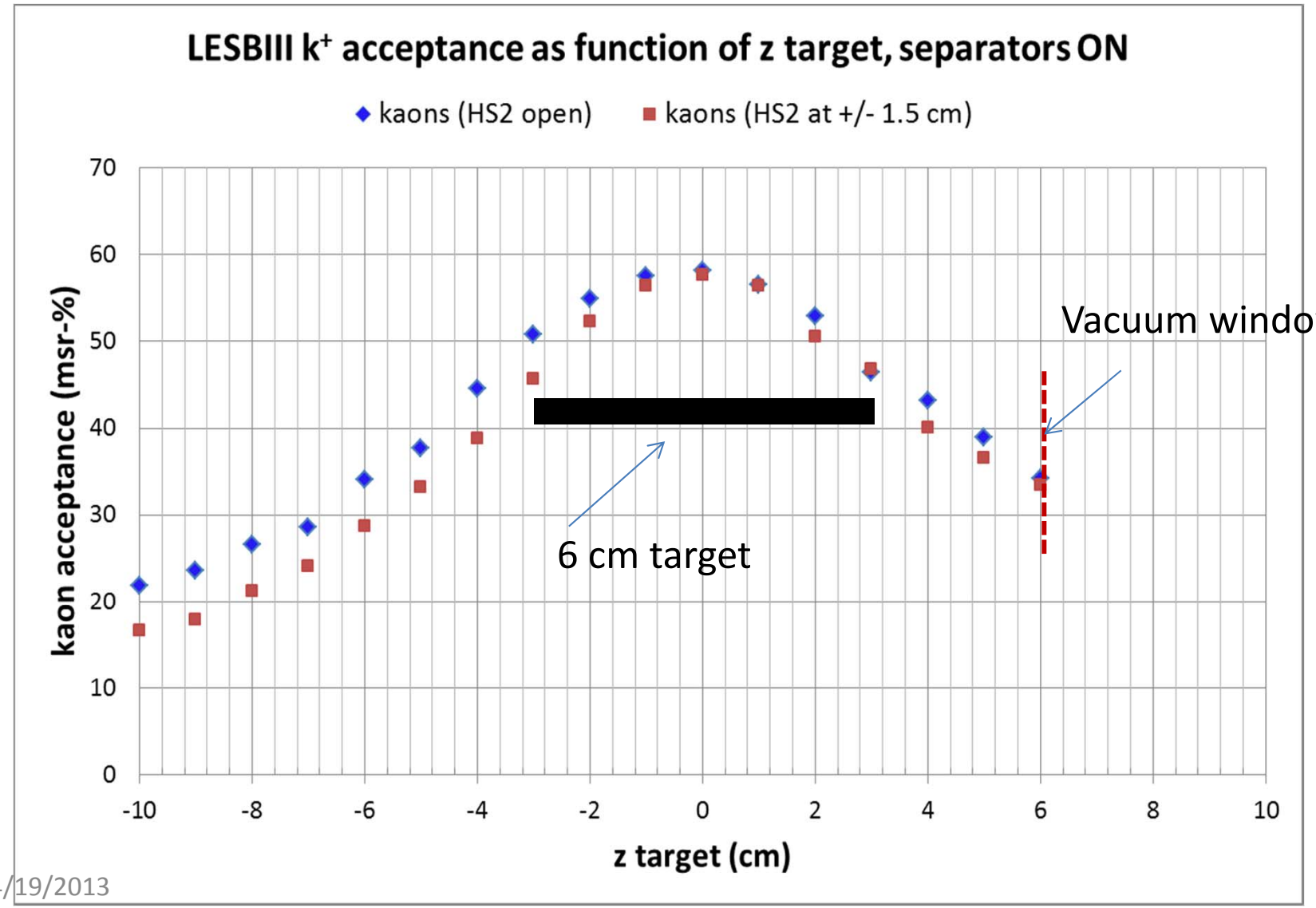


- **Maximum Momentum**: 830 MeV/c
- **Length**: 19.6 meters
- **Angular acceptance**: 12 msr
- **Momentum acceptance**: 4% fwhm
- **Beam Optics**: Corrected to third order
- **Movable Collimators**:
  - 4Jaw Theta-Phi Collimator
  - Horizontal Momentum Collimator
  - Two Vertical Collimators (Mass Slits)
  - Second horizontal collimator at achromatic focus

- **Electrostatic Separators**:
  - Two Stage Separation
  - < 625kV, 12.7 cm gap x 2.0 meter - #1
  - < 560kV, 10.2 cm gap x 2.0 meter - #2
- **Target**: - 2001-2002
  - 6 cm long platinum silver soldered to
  - water cooled copper base
  - Maximum ~30 x 10^{12} per second during spill
- **Production Angle**: 0 degrees
- **Particle Flux** (per 10^{13}, 22 GeV/c protons on target):
  - 710 MeV/c positive kaons – 2.0 x 10^{6} with 3:1 π/k

Longitudal acceptance for LESBIII for 800 MeV/c kaons and pions with EXB separators set to transmit kaons undeflected TURTLE Simulation

MS1 = 4 mm, MS2 = 5 mm, 4-Jaw and momentum collimators open, vary HS2



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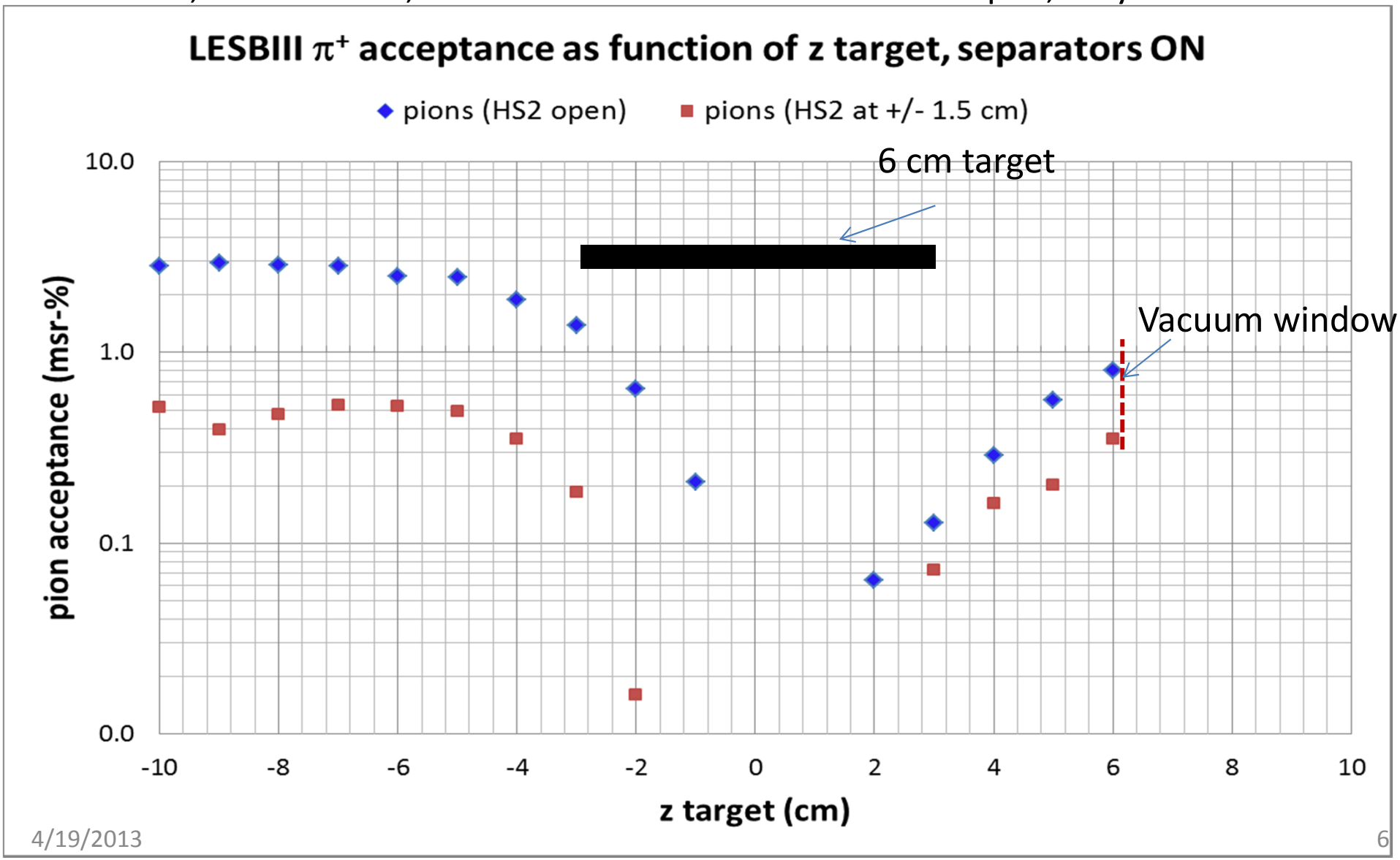
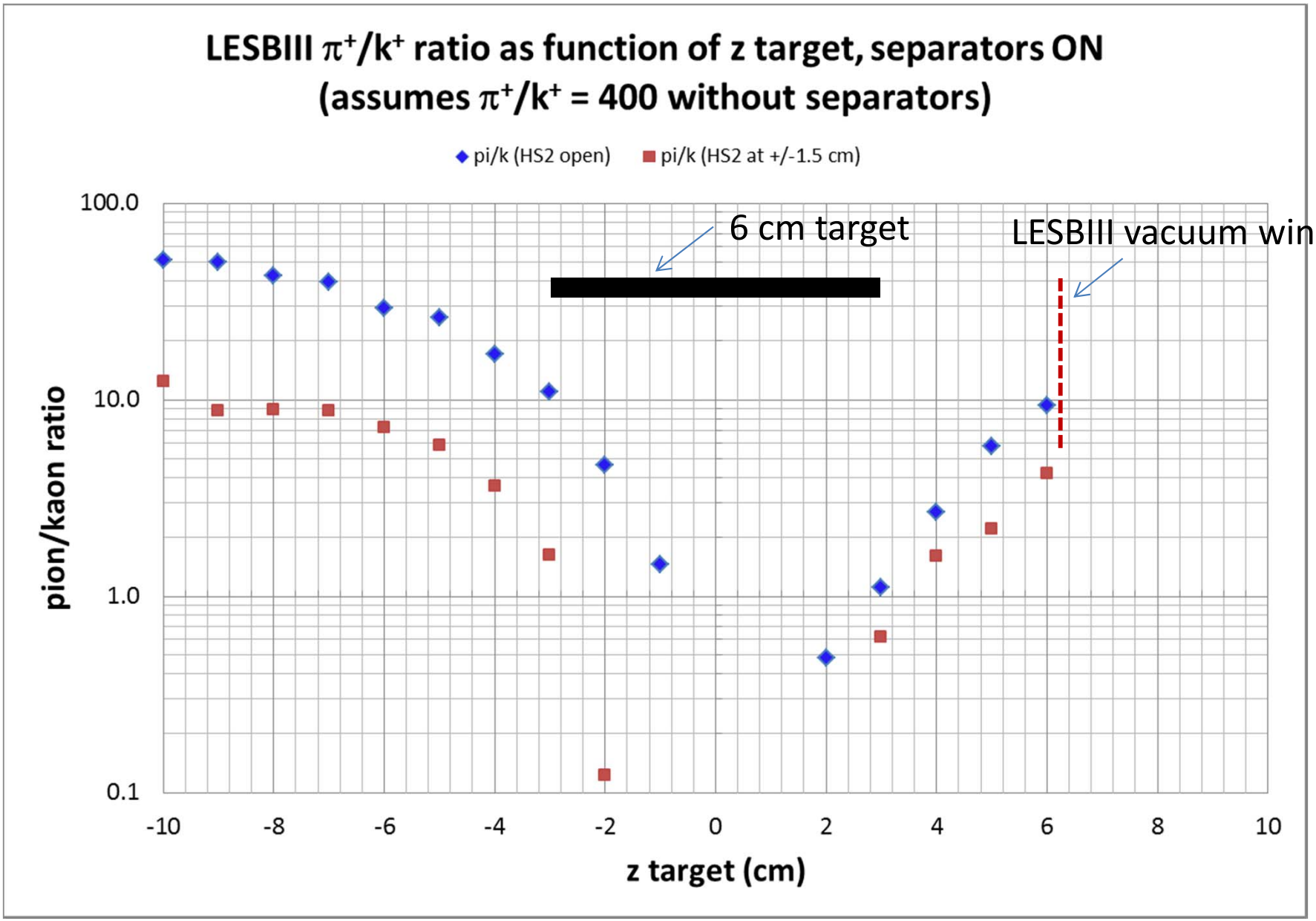
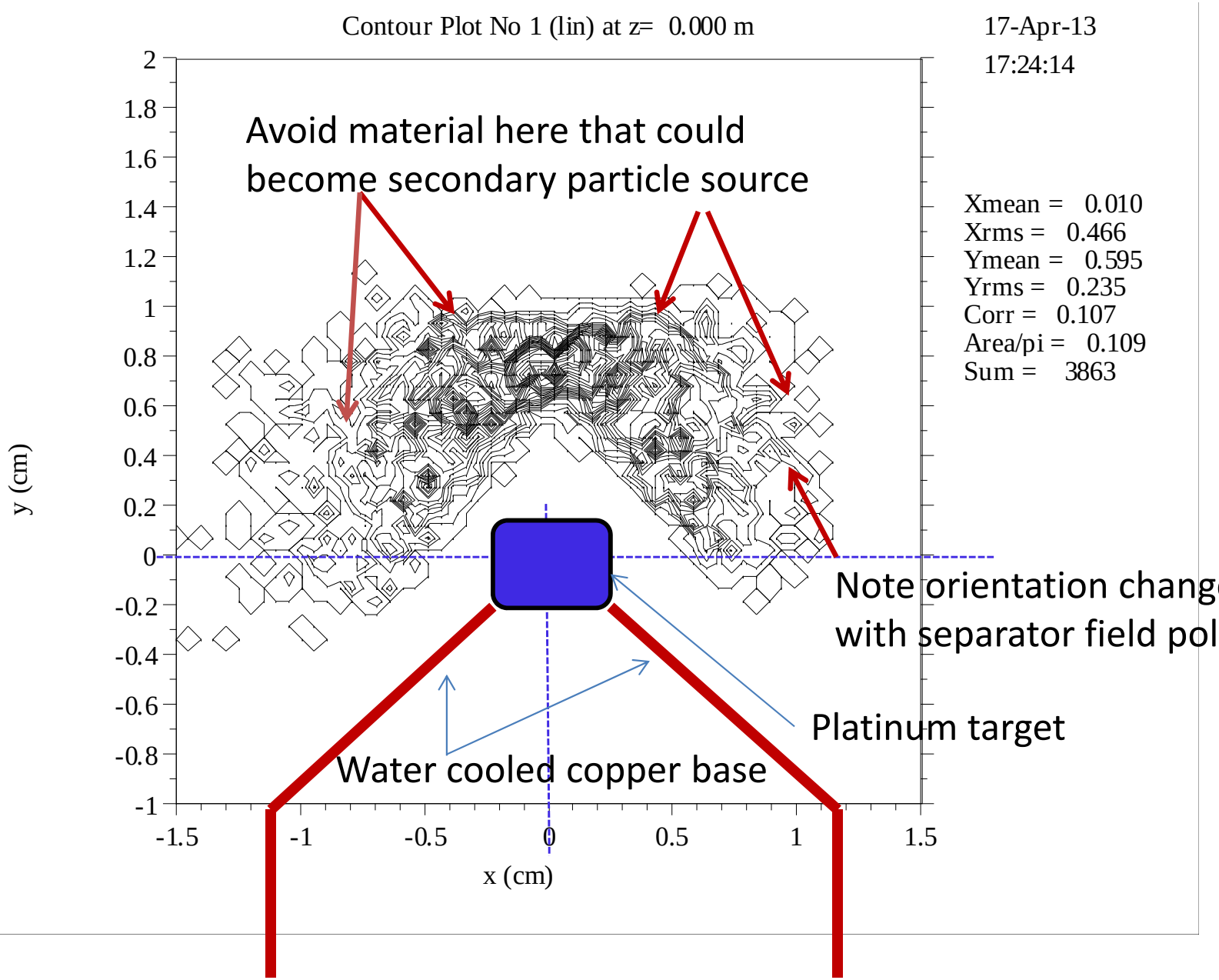




MS1 = 4 mm, MS2 = 5 mm, 4-Jaw and momentum collimators open, vary HS2

Turtle simulastion of “cloud pions” in LESBIII, MS1 = 4 mm, MS2 = 5 mm, 4-Jaw and momentum collimators open, HS2=+/- 1.5 cm, separators set to transmit kaons.

x,y event distribution at *center* of production target gated by events that make it to the end



Target design considerations

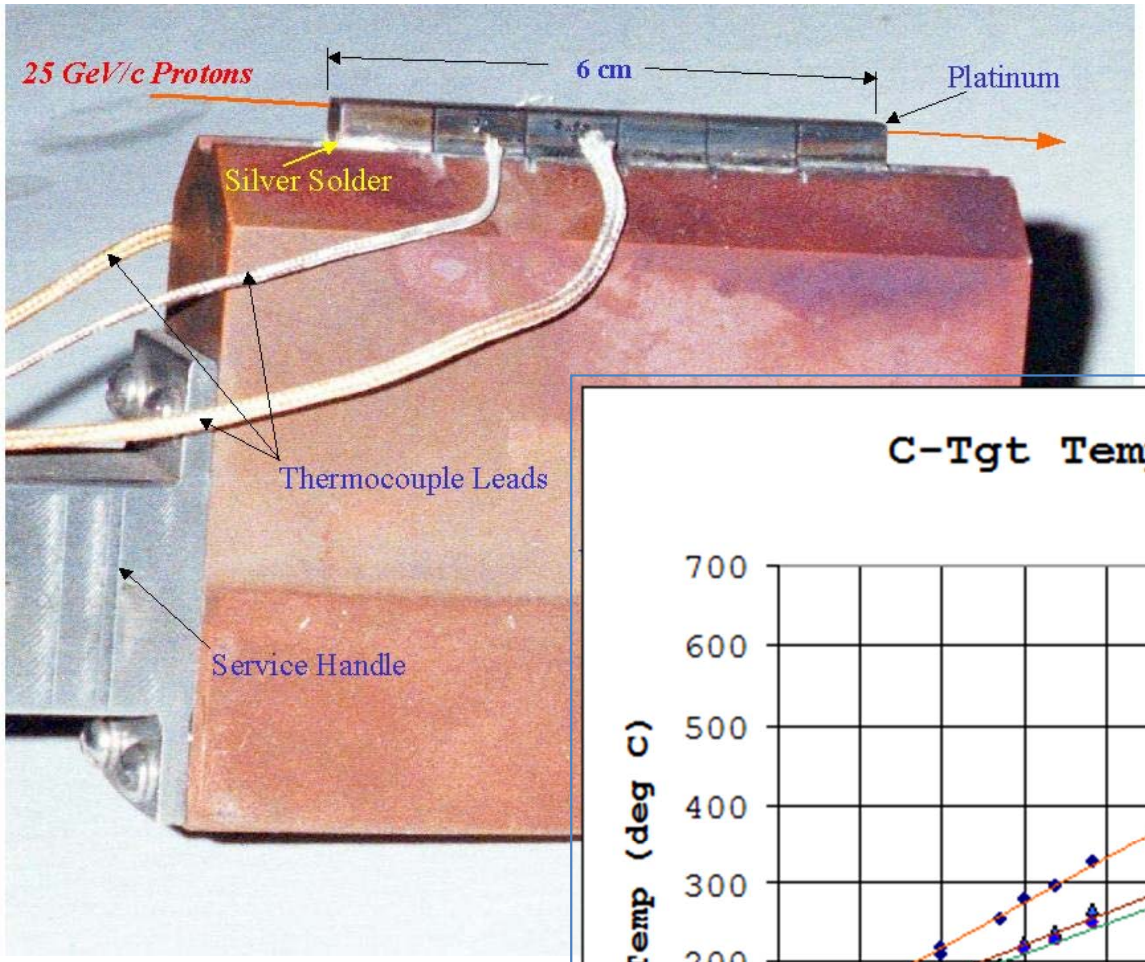
- Kaon beam optics
  - Short target favored due to longitudal acceptance and kaon beam purity
  - E949 settled on conservative 6 cm length
- K^+ production angle – peaked at 0 deg
- Target material
  - To maximize kaons flux consistent with short target need dense material, we picked platinum (21.5 g/cm^3)
- Kaon yield
  - Relative yields predicted by G4beamline (relative 600 MeV/c K^+'s in forward 45 deg cone with 24 GeV p's)
    - 6 cm Pt = 1.0
    - 6 cm Cu = 0.53
    - 6 cm C = 0.12
    - 6 cm Pt 95 GeV protons (ORKA) = 2.4

Some Target Issues

- Inadvertent short spills from the AGS
  - In 1997 installed a spill monitor on the AGS extraction beam secondary emission detector (C10 SEC)
  - tripped beam off in ~100 msec if rate is > 100 TP/sec..it worked…
- Inadvertent high intensity spill
  - C-target temperature limit set to trip at 1000 deg C (melting point 1772 deg C).
  - Trip point chosen so that stress on the platinum and copper is less than half the maximum hard tensile yield strength as predicted by ANSYS Finite Element calculations.
  - Trip response time ~ 200 msec.
  - Typical administrative temperature limit for normal spills was 700 deg C.
- Target station became contaminated with activated debris from targets
  - Target should be enclosed with controlled environment to contain contamination (ours were not)
- Unresolved issue:
  - Had thermocouple or perhaps deteriorating Pt-Cu bond issue with 2002 target resulting in higher temperature (100 deg C or so) readings for hottest segments late in the run – unresolved as to cause.

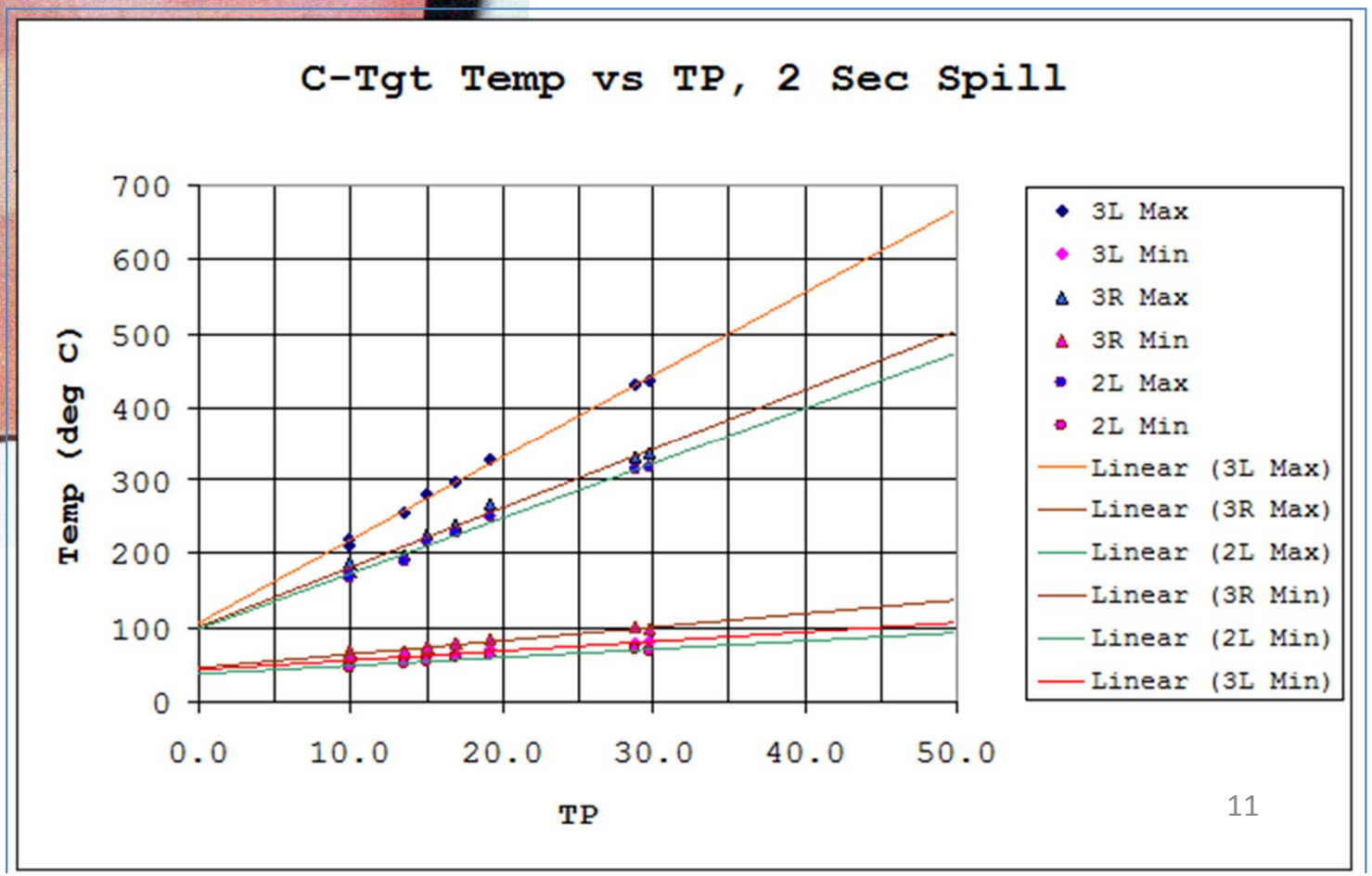
1998-1999 C-target (2490 hours of beam)

24 GeV protons, 2-2.8 sec spill every 4.3-5.1 sec, up to 72 TP available but shared with others, few x 10^{19} protons on target, admin. limit set at 50 TP for 2 sec spill at flat top (~700 deg C)



"Workhorse Target"

Pt, 5.1 x 5.1 x 60 mm (w x h x l)
Silver soldered to copper
5 slots, 6 Pt segments



Latest (Last) C-Target Design

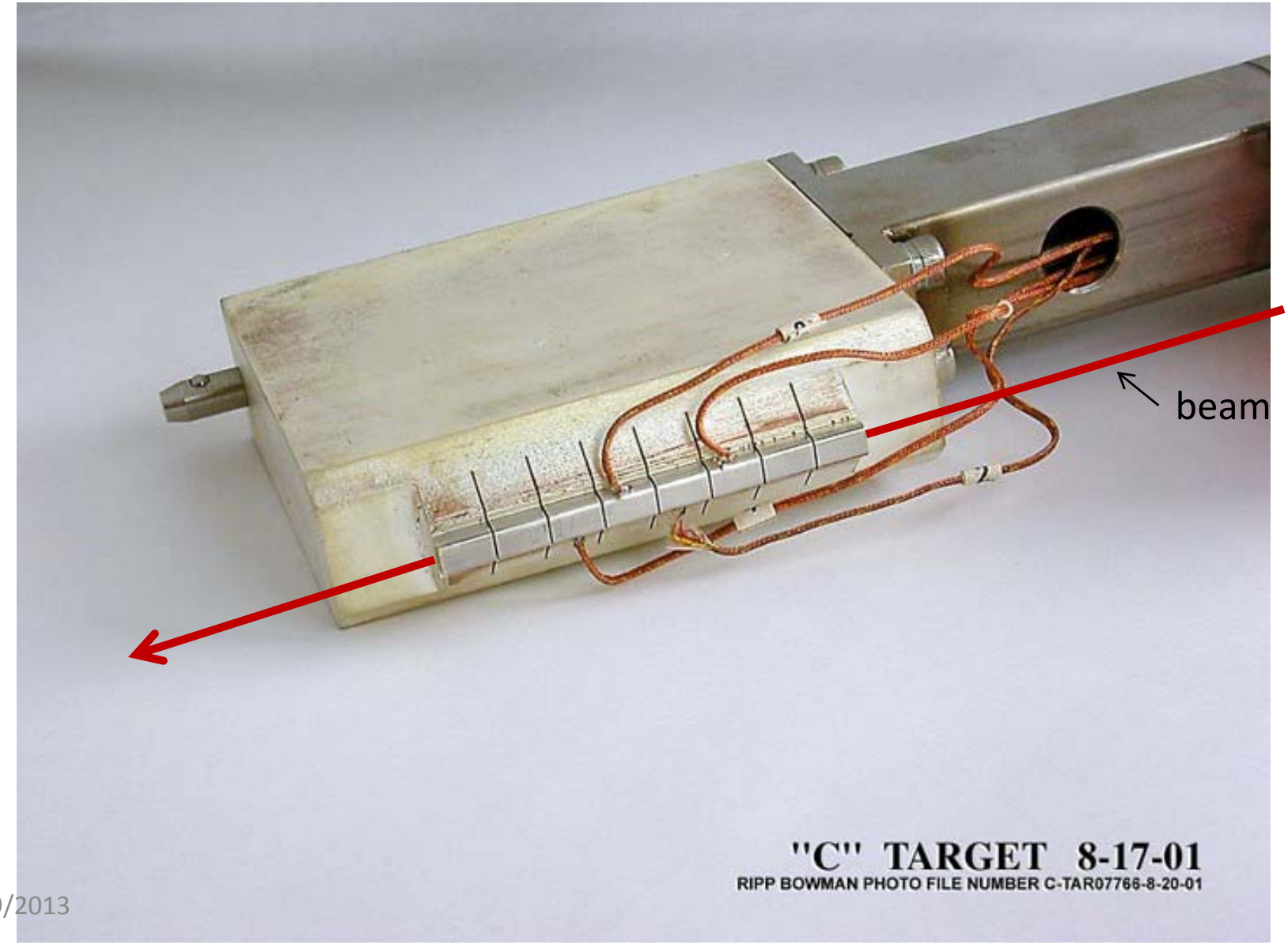
changes

C-Target: - 2001-2002

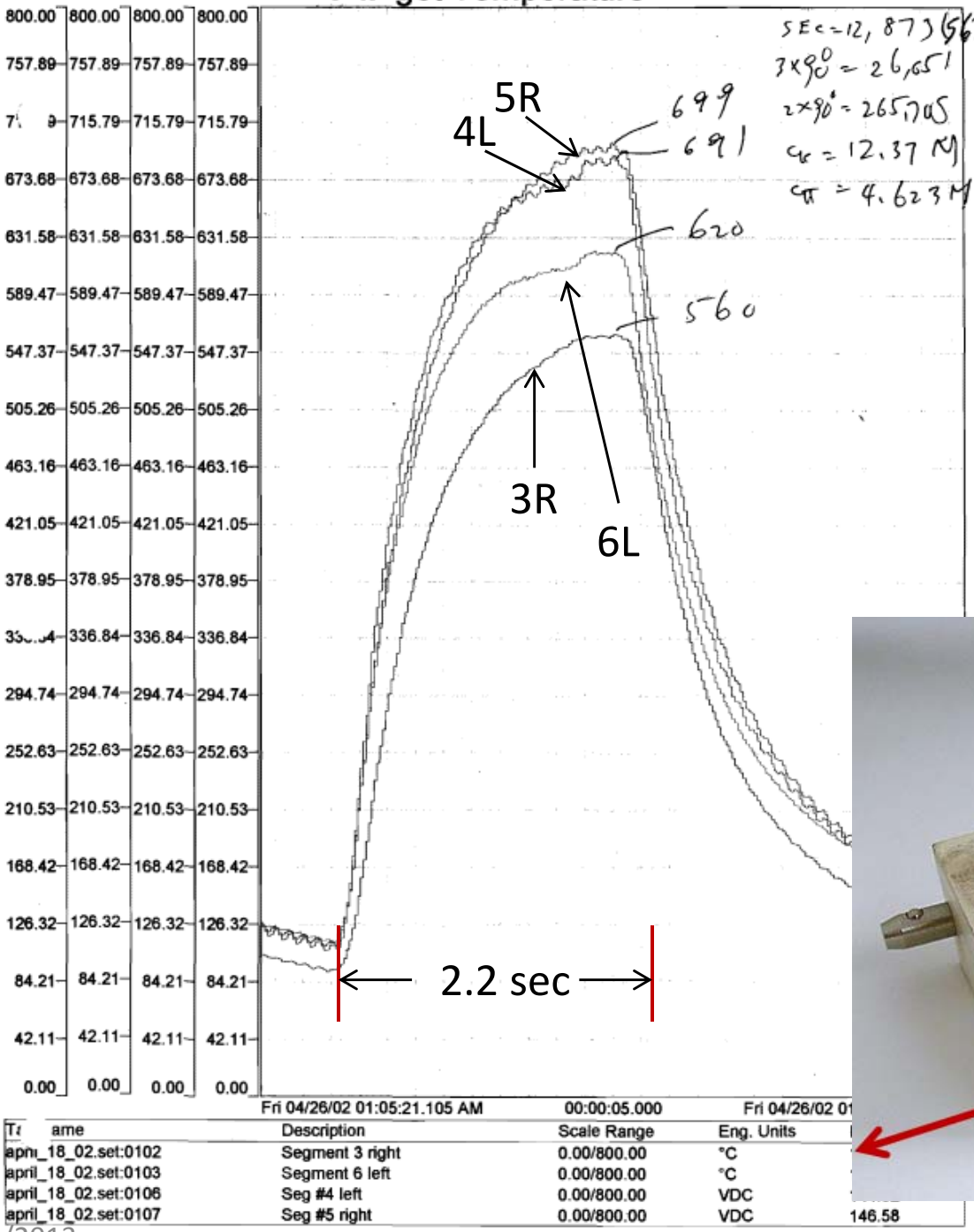
6 cm long 8 segment platinum, 5.1 mm wide x 3.8 mm high

Platinum silver soldered to water cooled copper base

Maximum ~30 x 10^{12} per second @ 22 GeV

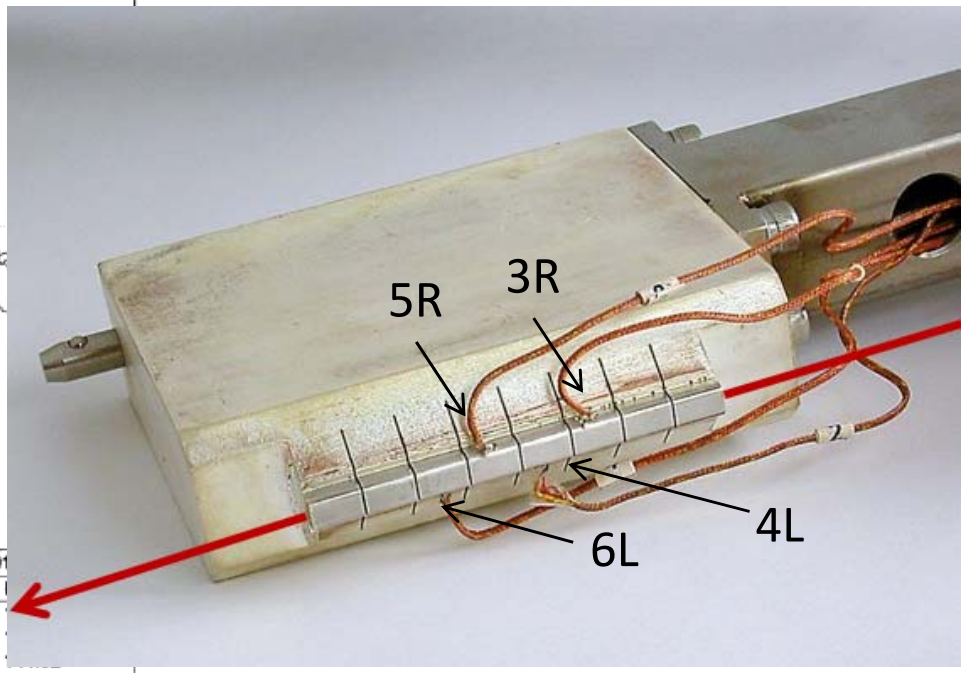


C target Temperature (as measured with type k thermocouples, drilled and peened into platinum)



18 April 2002
22 GeV protons
56 x 10^{12} protons per spill
2.2 sec spill every 5.4 sec (41% DF)

Maximum rate on this target was
~70 TP/2.2 sec flat top = 32 TP/sec
Avg Power ~ 45 kW, peak ~110 kW



E949 targets and ORKA

- **E949 target maximum protons per spill achieved (22 GeV beam)**
  - ~70 TP/2.2 sec spill with 5.4 sec repetition ~ 700-800 deg C temperature
  - Administrative limit was ~30 TP/sec at flat top
  - Peak power during spill = 110 kW
  - Average power = 45m kW

- **So with 1000 deg C limit for the 2002 E949 target**
  - The 2001 target design is good for ~ 90 TP or 40 TP/sec at flat top

- **ORKA initial plans**
  - 95 GeV protons
  - 48 TP/ 4.4 sec spill with 10 sec repetition
  - Peak power = 166 kW
  - Average power = 73 kW

- **So with E949 2002 target at ORKA**
  - Temperature ~ 166/110 x (700-800) = 1050-1200 deg C

- ***This target design might be considered as a "day one" target for ORKA….but see next slides…***

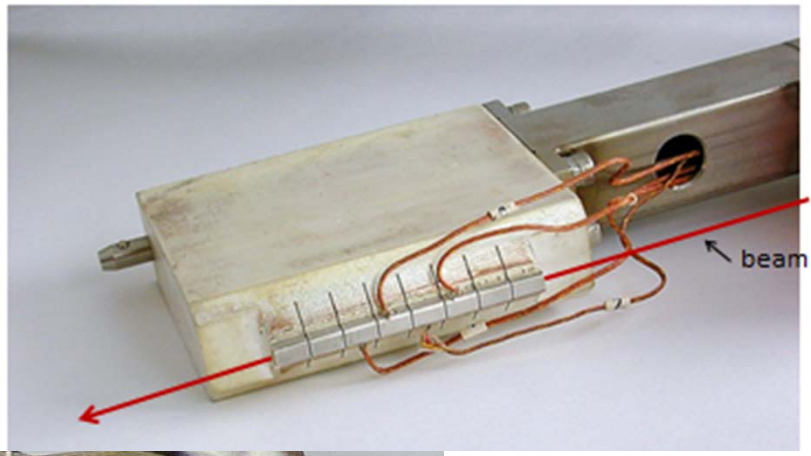
Some “Dirty” Laundry…….

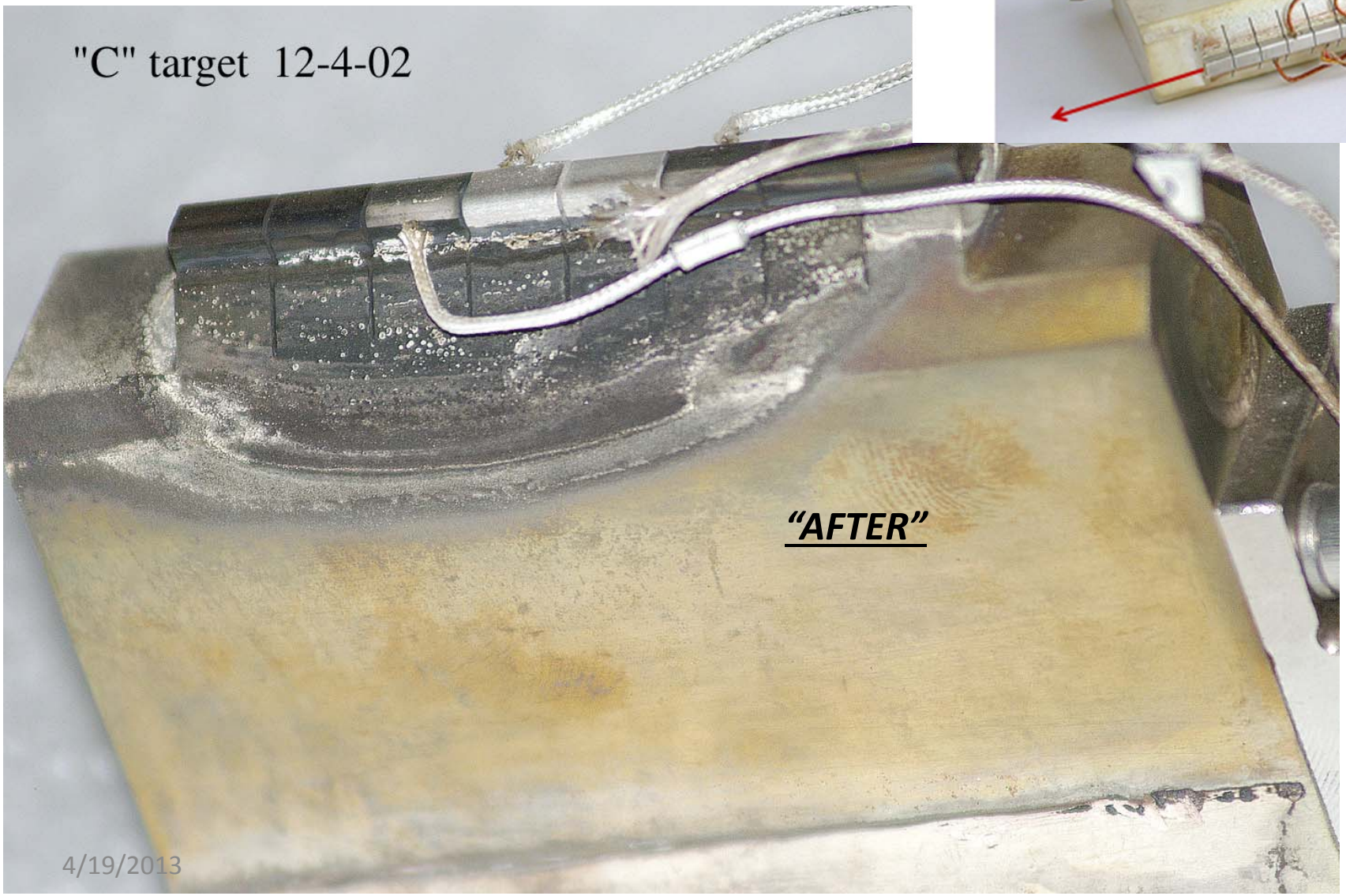
E949, last target design, 2002

~0.5 x 10^{19} protons
~30-70 x 10^{12} protons per 2.2 sec spill

C-Target: - 2001-2002
6 cm long platinum
water cooled copper base
Maximum ~30 x 10^{12} per second @ 22 GeV

"BEFORE"





"AFTER"

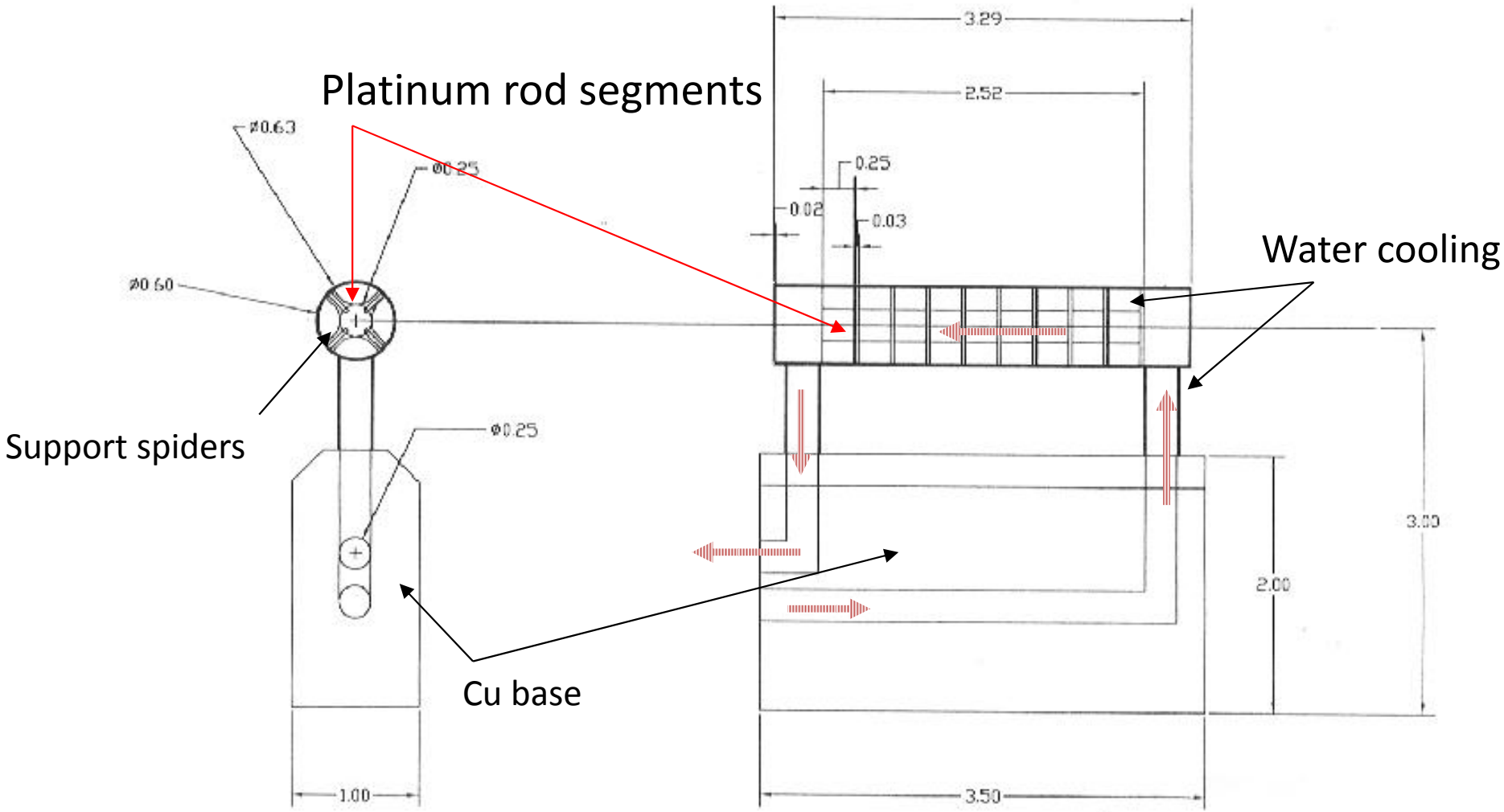
A-Target (E865 - Zeller) after ~10-20TP/spill for a ? years
15 cm long copper target and water cooled base

Path Forward…

This target design was under consideration for next generation C-target before DOE HEP lost interest in AGS experiments

3/6/01

(A. Pendzick)

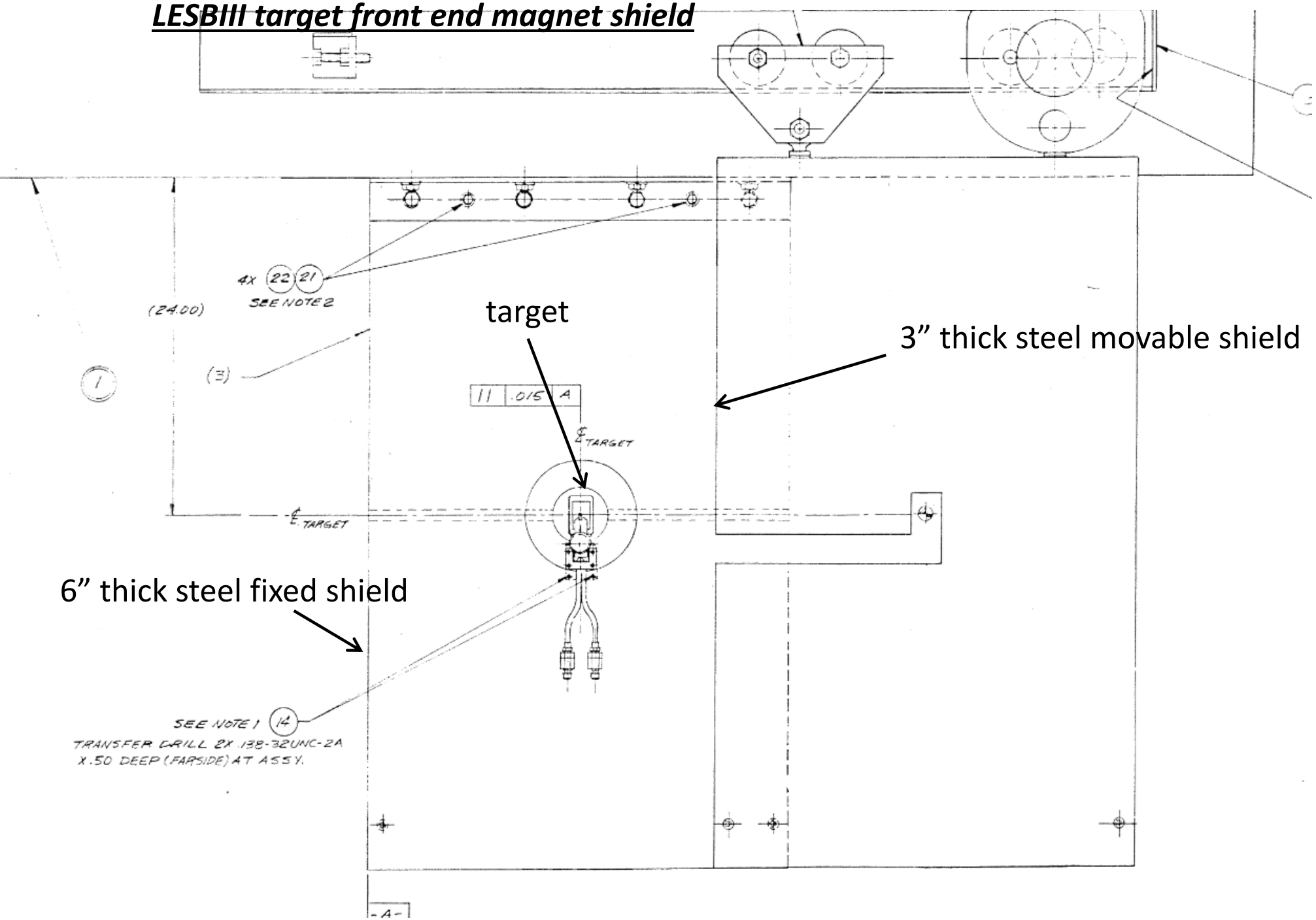


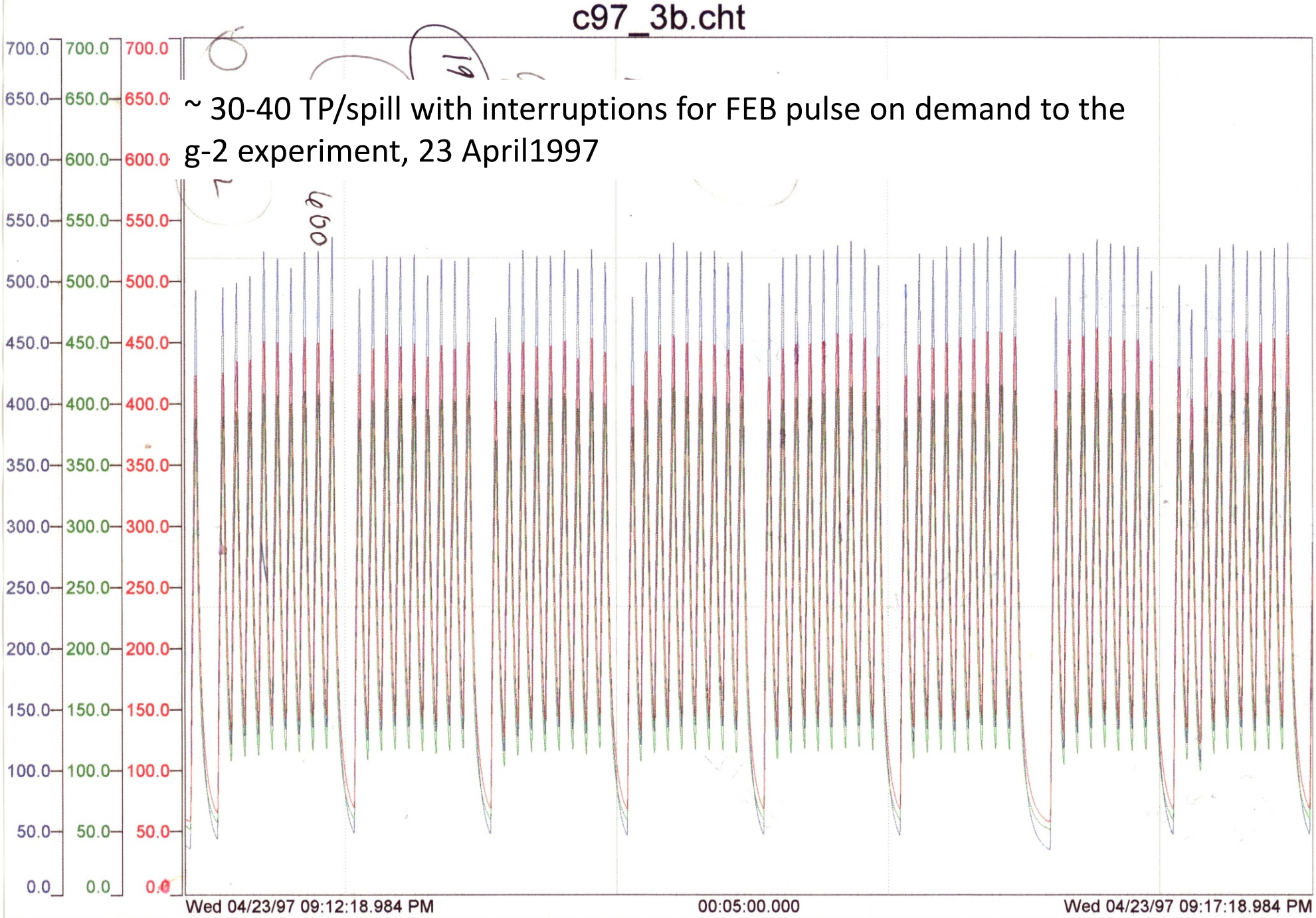
dimensions in inches

Thanks to I-H Chiang, Steve Kettell Charlie Pearson and Al Pendzick for helping remember the past!

Bone yard

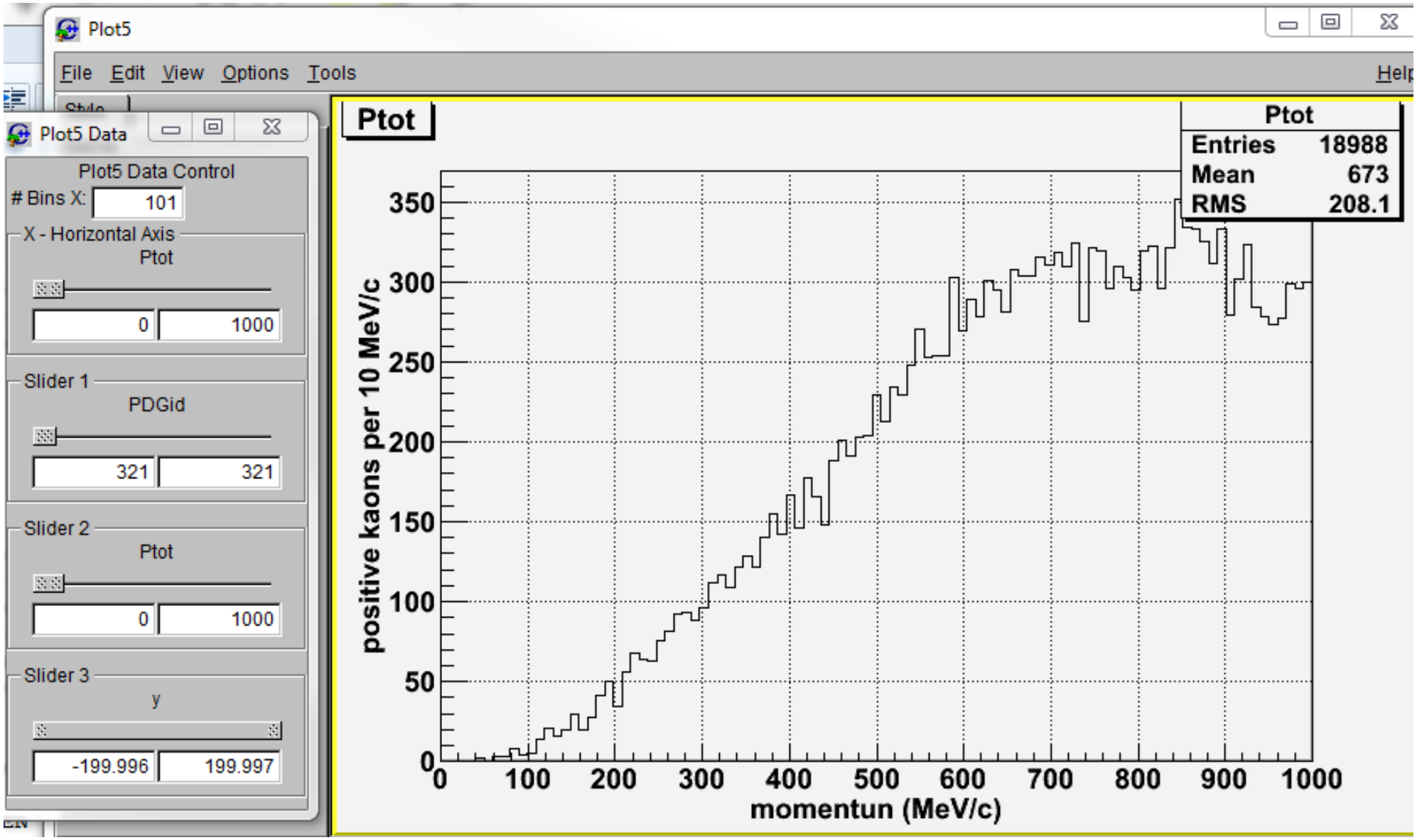
LESBIII target front end magnet shield





Tag Name	Description	Scale Range	Eng. Units	Last Value
c97_3b.set:0105	seg # 3 left	0.0/700.0	°C	385.4
c97_3b.set:0109	seg 2 right	0.0/700.0	C	306.5
c97_3b.set:0110	seg 3 right	0.0/700.0	C	324.8

1E6, 24 GeV protons on 5mm wide x 3.8 mm high x 60 mm long platinum target
200 mm radius detector 200 mm d/s tgt center



G4beamline

1E6, 24 GeV protons on 5mm wide x 3.8 mm high x 60 mm long platinum target
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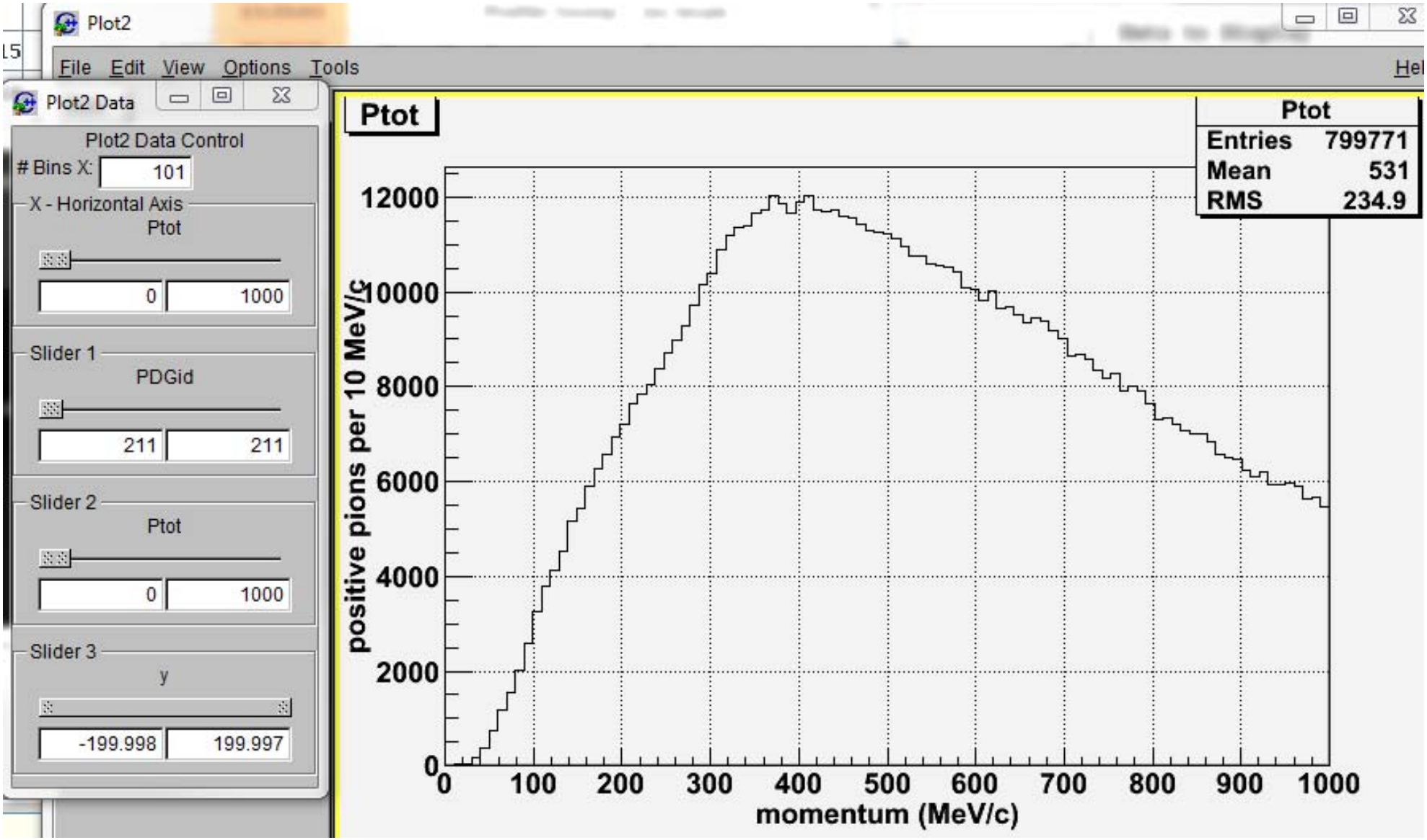

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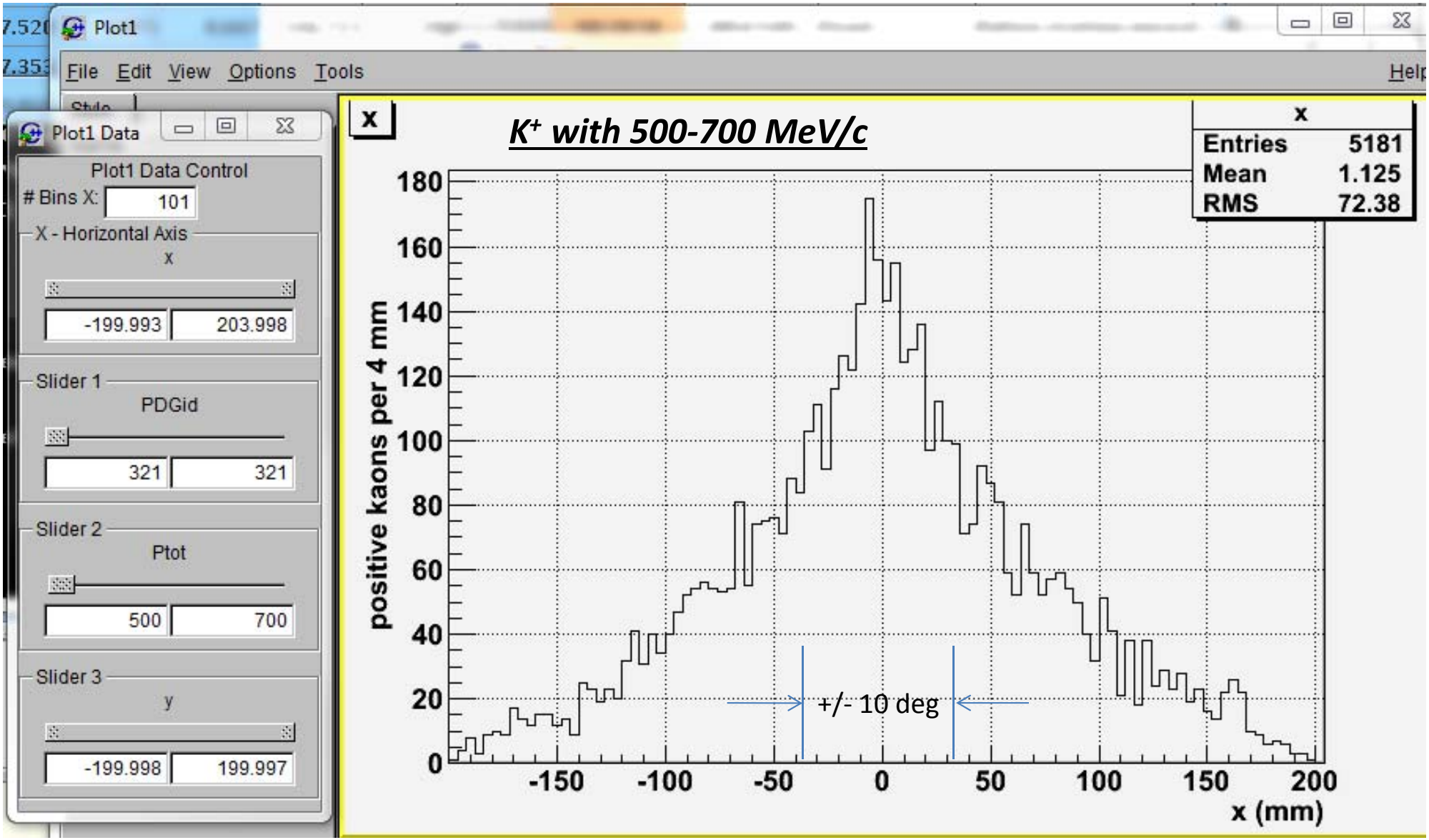
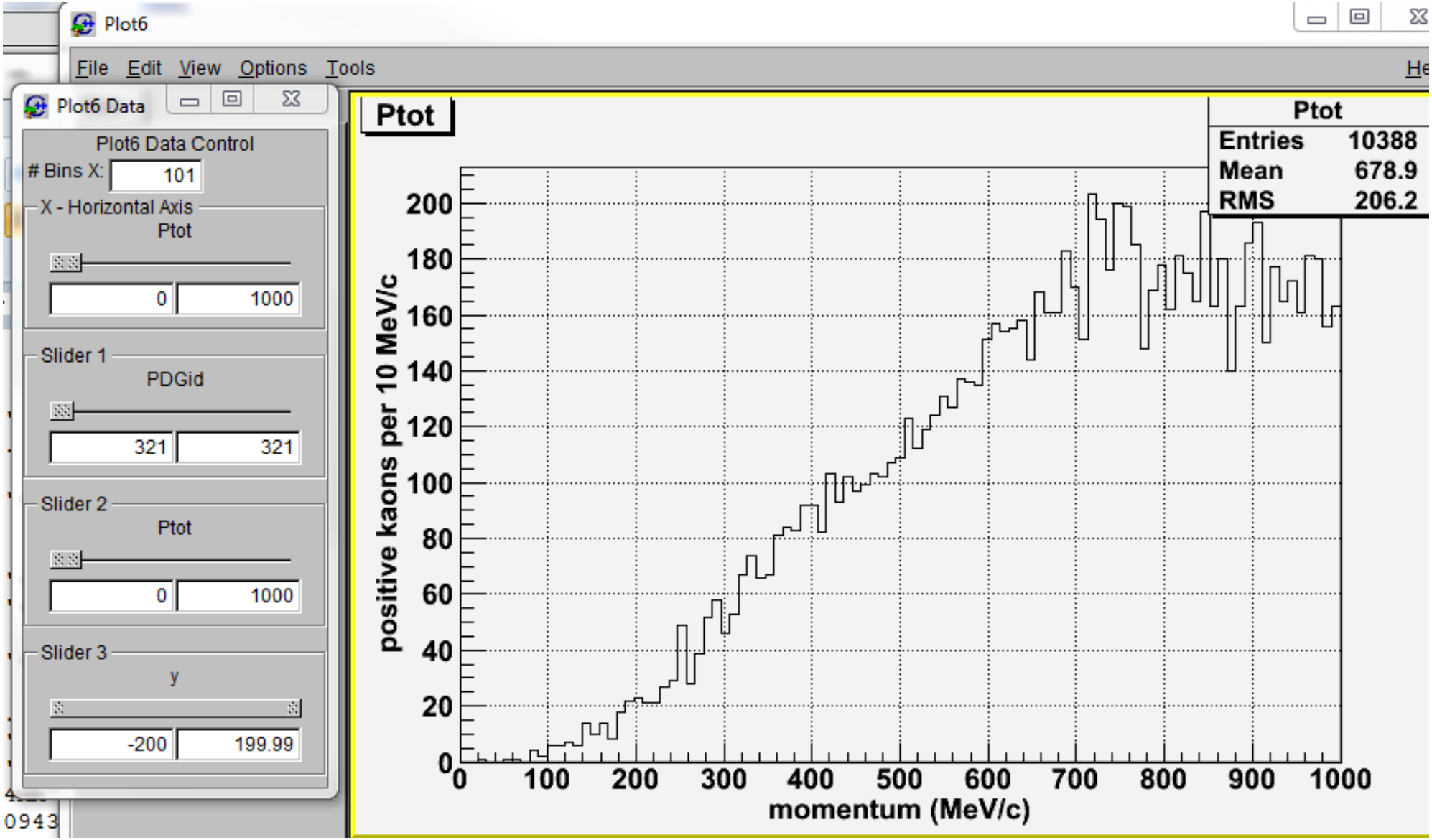


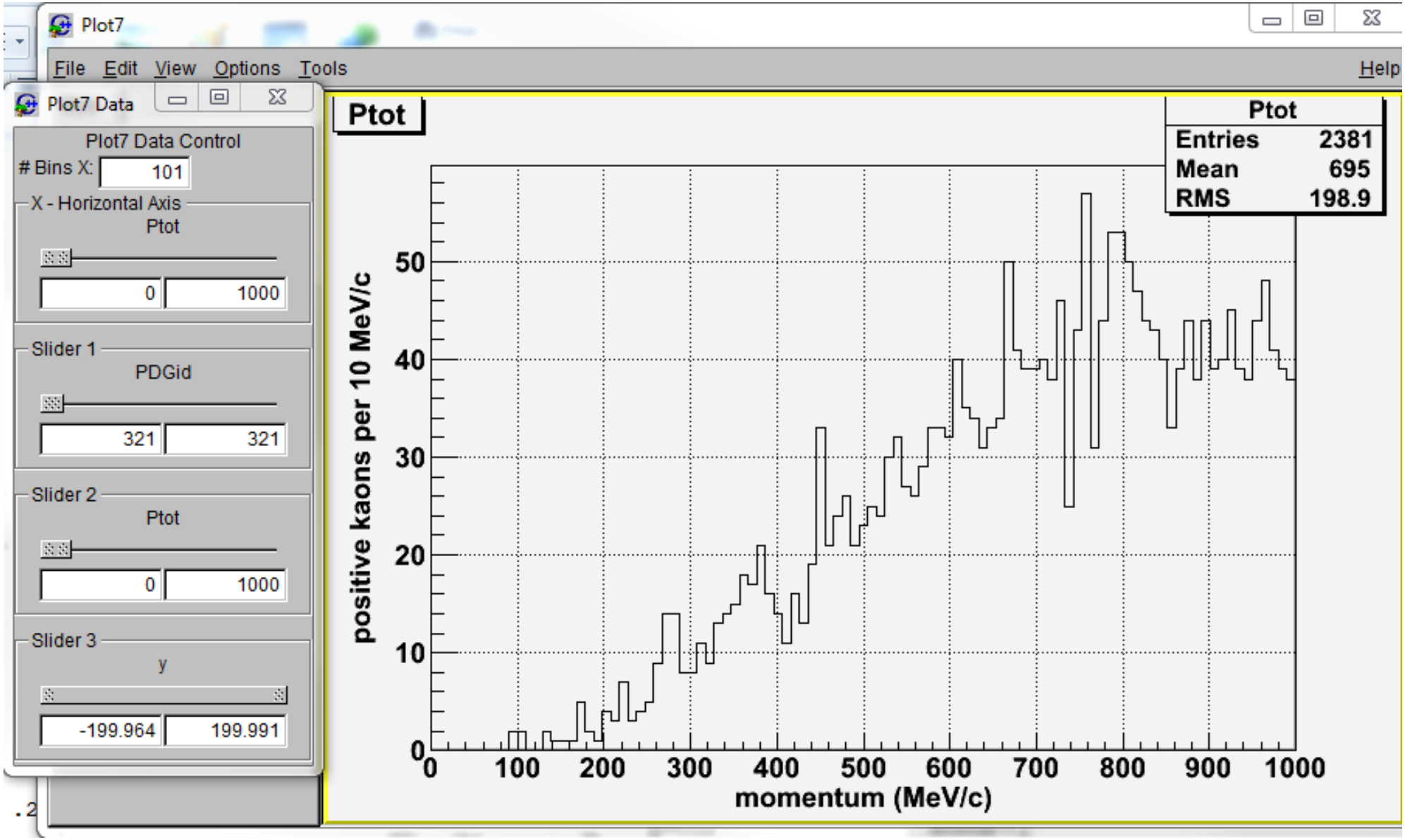
G4beamline

1E6, 24 GeV protons on 5mm wide x 3.8 mm high x 60 mm long copper target
200 mm radius detector 200 mm d/s tgt center



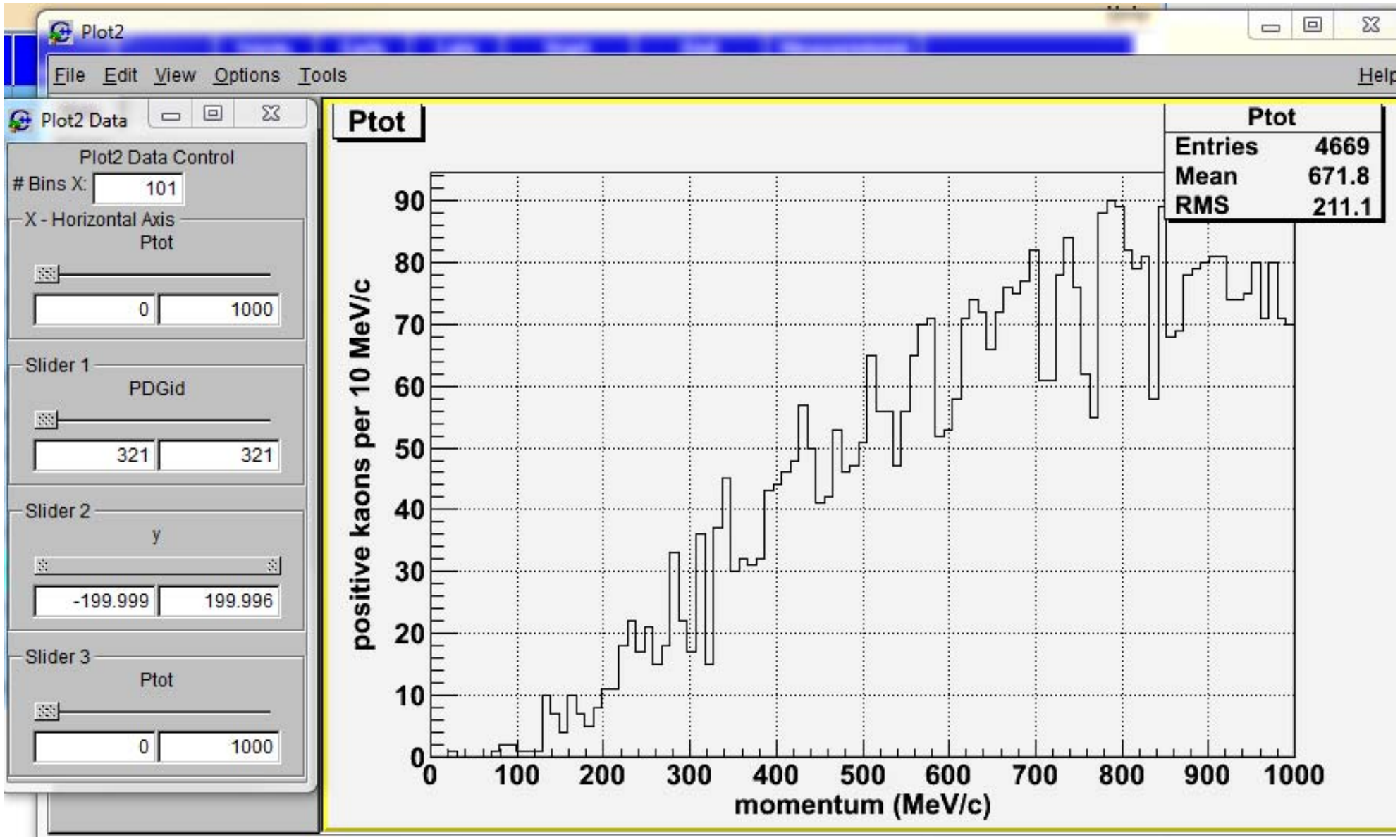
G4beamline

1E6, 24 GeV protons on 5mm wide x 3.8 mm high x 60 mm long carbon target
200 mm radius detector 200 mm d/s tgt center



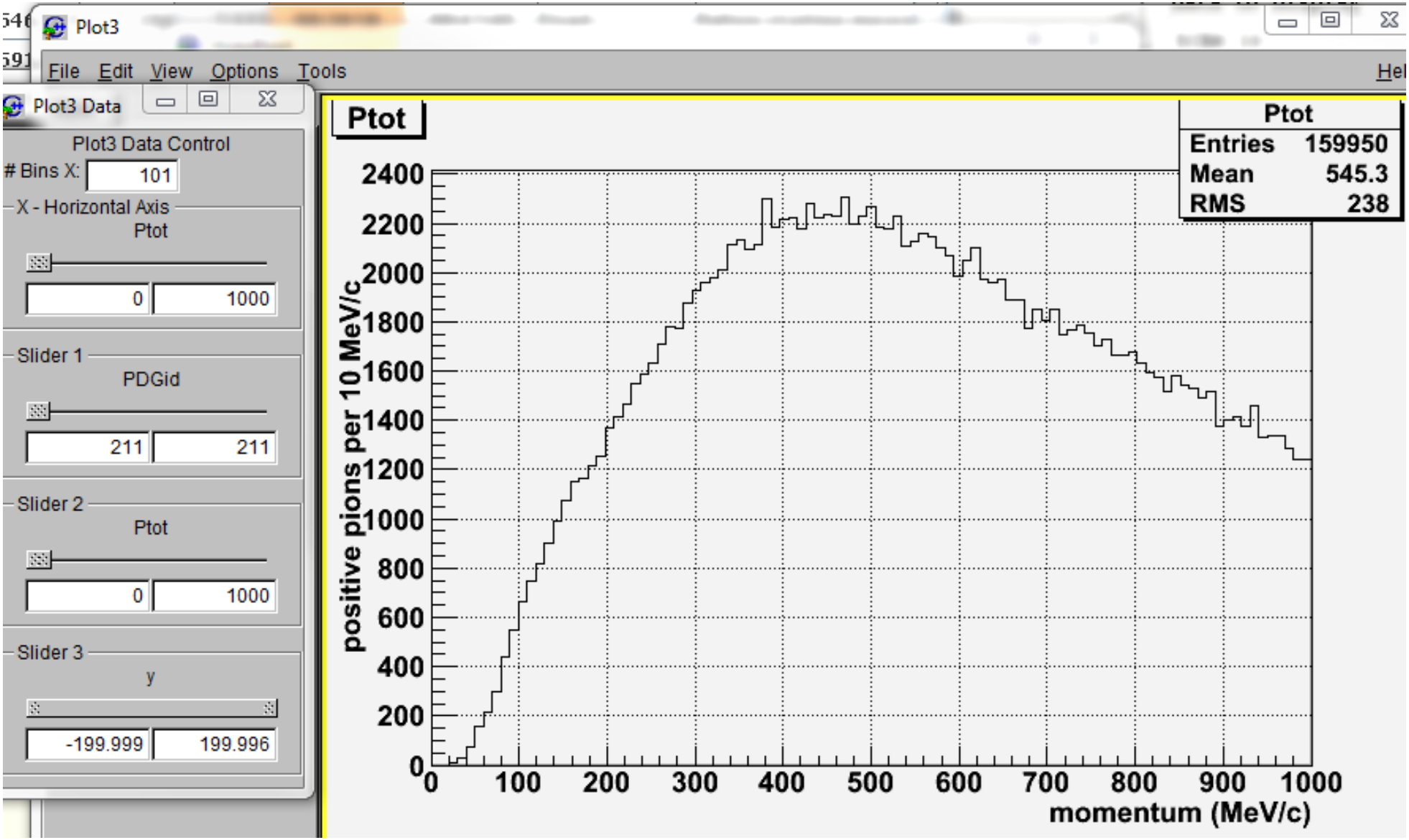
G4beamline

1E5, 95 GeV protons on 5mm wide x 3.8 mm high x 60 mm long platinum target
200 mm radius detector 200 mm d/s tgt center



G4beamline

1E5, 95 GeV protons on 5mm wide x 3.8 mm high x 60 mm long platinum target
200 mm radius detector 200 mm d/s tgt center



G4beamline

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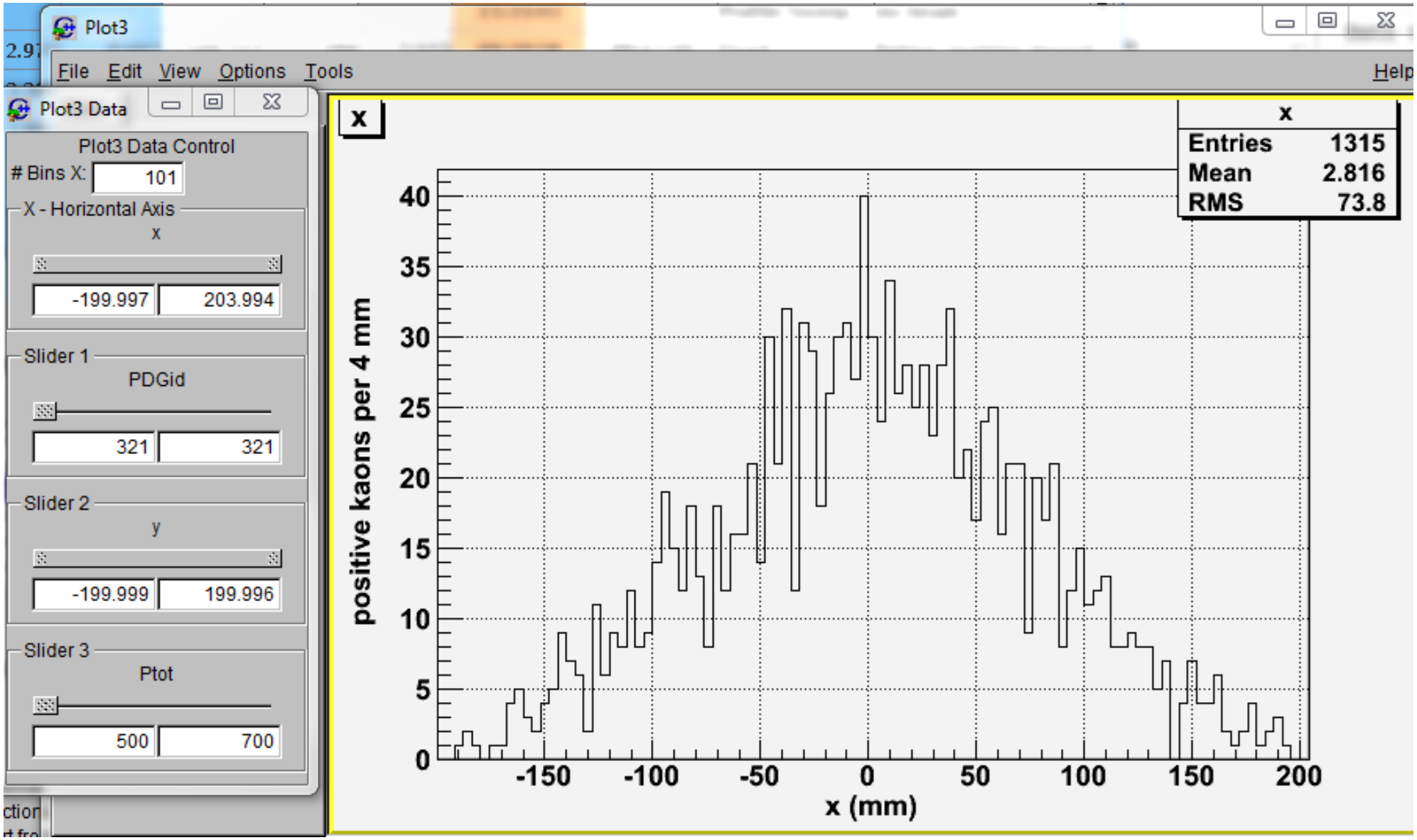
200 mm radius detector 200 mm d/s tgt center



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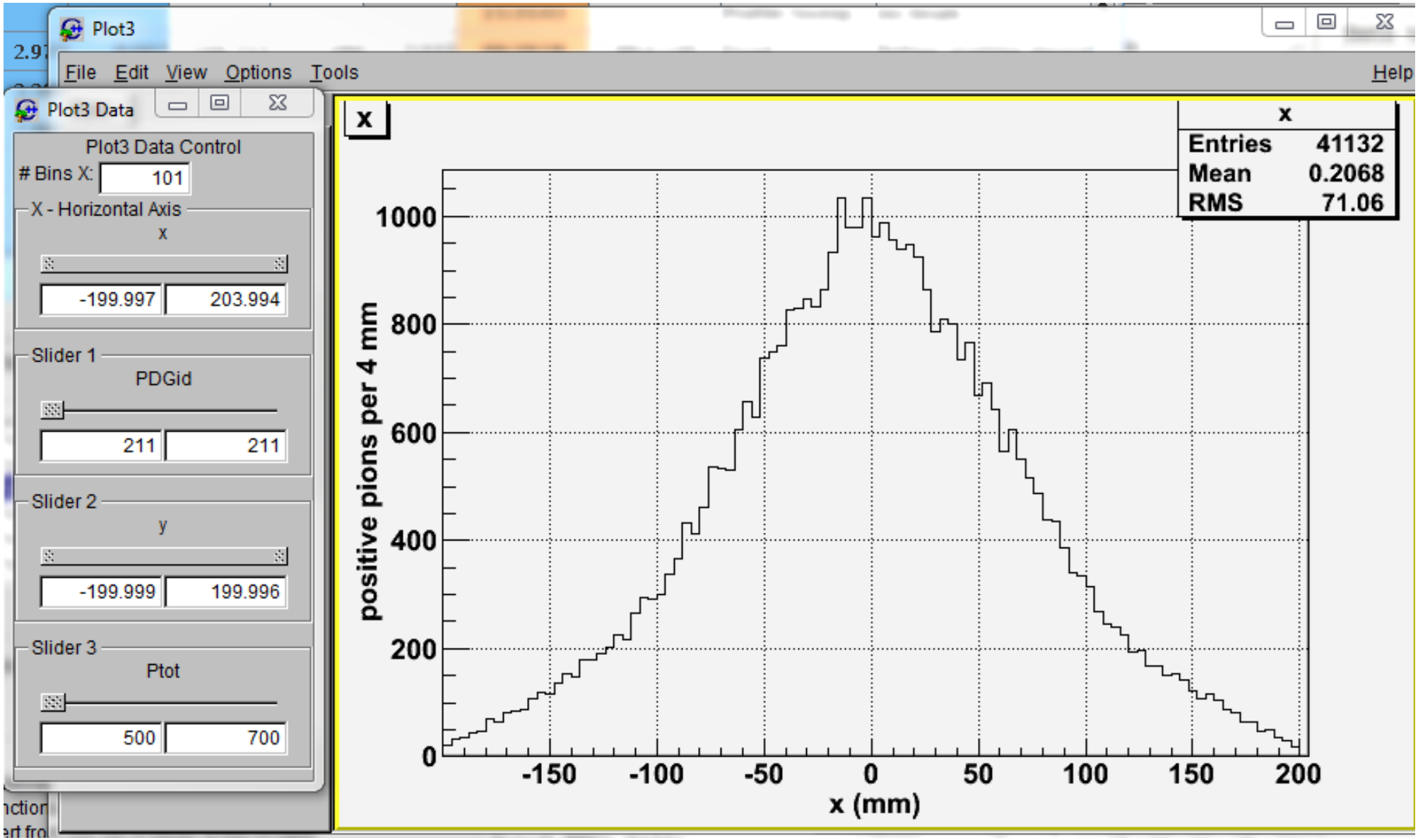

G4beamline