

GLAST Large Area Telescope: Calibration Unit Beam Test Report

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on behalf of the beam test team

GLAST IFC Meeting
Paris 9/4/2006



Motivations for the CU Beam Tests

- A CU Beam Test is part of the LAT Calibration Strategy
 - see [LAT-TD-02152 Beam Test Rationale](#)
- Direct LAT calibration too demanding
- Most events on orbit contained in 2 towers
 - direct calibration with particle beam on a smaller unit is good enough
- Calibration Unit (CU) Beam Test Plan
 - build a fraction of the LAT using available flight spare modules
 - expose CU to variety of beams (CERN + GSI)
 - tagged photons, electrons, protons, positrons, heavy ions
 - energies from 100MeV to 300GeV
 - many different configurations (angle, impact point)
 - directly measure CU performance
 - validate full LAT Monte-Carlo simulation



Why test the CU at CERN



e and hadron beams available

- high energy available
- past experience (INFN-Bari + AGILE γ -tagger at T9, GLAST-CAL at SPS)
- optimization of resources with LAT I&T and ramping up to ISOC only if european GLAST members lead CU beam test

- H4 line - CERN Prevestin (FR)
- Beam extracted from SPS
- e, p , π 10-280GeV
- clean high E beams available
- scheduled 4-15/9

- T9 line - CERN Meyrin (CH)
- Beam extracted from PS
- e-, p , π 0.5-10GeV
- *cocktail* beams
- completed



Calibration Unit Beam test Milestones

- Organization and meetings *charge on 9/2005 collaboration meeting*
 - Coordination group, VRVS biweekly, mailing list
 - 3 operations workshops hosted and chaired by INFN-Pisa
- Hardware integration and test
 - CU I&T at INFN*-Pisa
 - New CAL MGSE from INFN-Pisa to insert CAL from bottom
 - ISC + OSC design and construction at INFN-Pisa
 - ISC (Inner Shipping Container) for CU operations
 - OSC (Outer Shipping Container) for storage/transportation
 - XYZ θ CU scanning table design and construction at IN2P3/LLR
 - Ancillary detectors and DAQ from INFN
 - γ -tagger from INFN-Trieste
 - Trigger (external) and ancillary DAQ from INFN-Bari
 - DAQ computers and network from SLAC
- Software
 - EGSE DAQ from SLAC + script customization for CU from INFN-Pisa
 - LATTE 4.11, flight design GASU
 - Data streams from CU and AD online merge from SLAC + INFN-Pisa
 - New Full online monitor from INFN-Pisa
 - Offline recon, process pipeline, Calibration DB from SLAC
- Operations *PS installation started 25/7*
 - INFN run coordination for PS (Latronico), IN2P3 for SPS (Lott)

The GLAST-LAT Calibration Unit

- 2.5 towers, ~1/8 of the LAT
- 110k Si strip
- 288 CsI logs

+ 5 ACD tiles on ISC

*Hardware from funding agencies
through LAT-I&T*

TKR 8

TKR 16

tower 3
CAL 101

tower 2
CAL 119

tower 1
CAL 109

bay 0

CU integration completed at INFN-Pisa may 19 2006

Arrival of hardware to CERN

T9 barrack

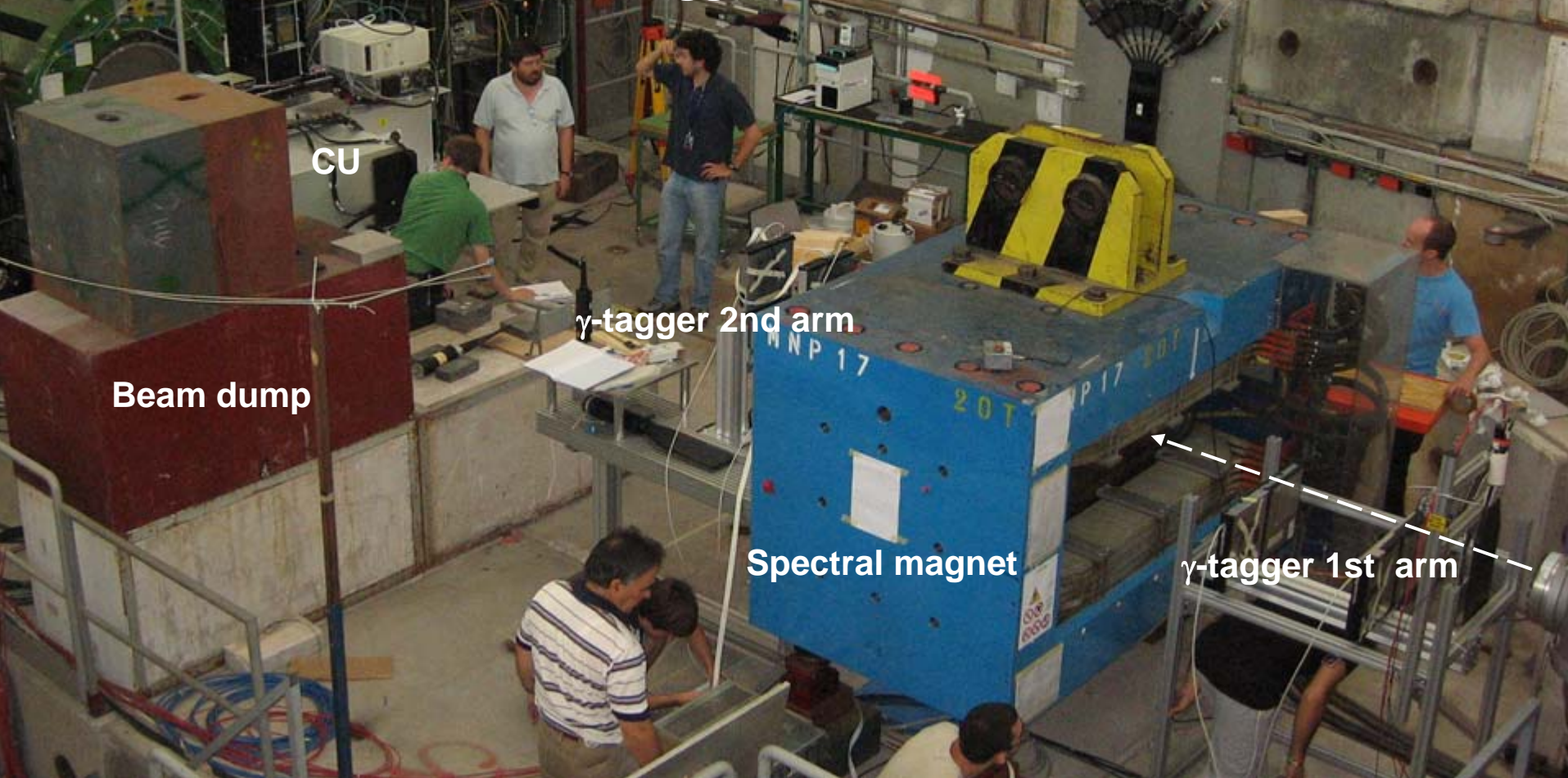
XYZ θ table

CU OSC



The CU in the T9 test area

- CU/ISC (750Kg) installation + integration with XYZ θ Table completed in 10 hours (from entrance to CERN to final cabling and 1st data)
- CU functional verification (CI test) after transportation immediately cleared
- Test runs with beam in self-trigger within few hours



CU

Beam dump

gamma-tagger 2nd arm

Spectral magnet

gamma-tagger 1st arm

+ upstream cerenkov to select e or hadrons

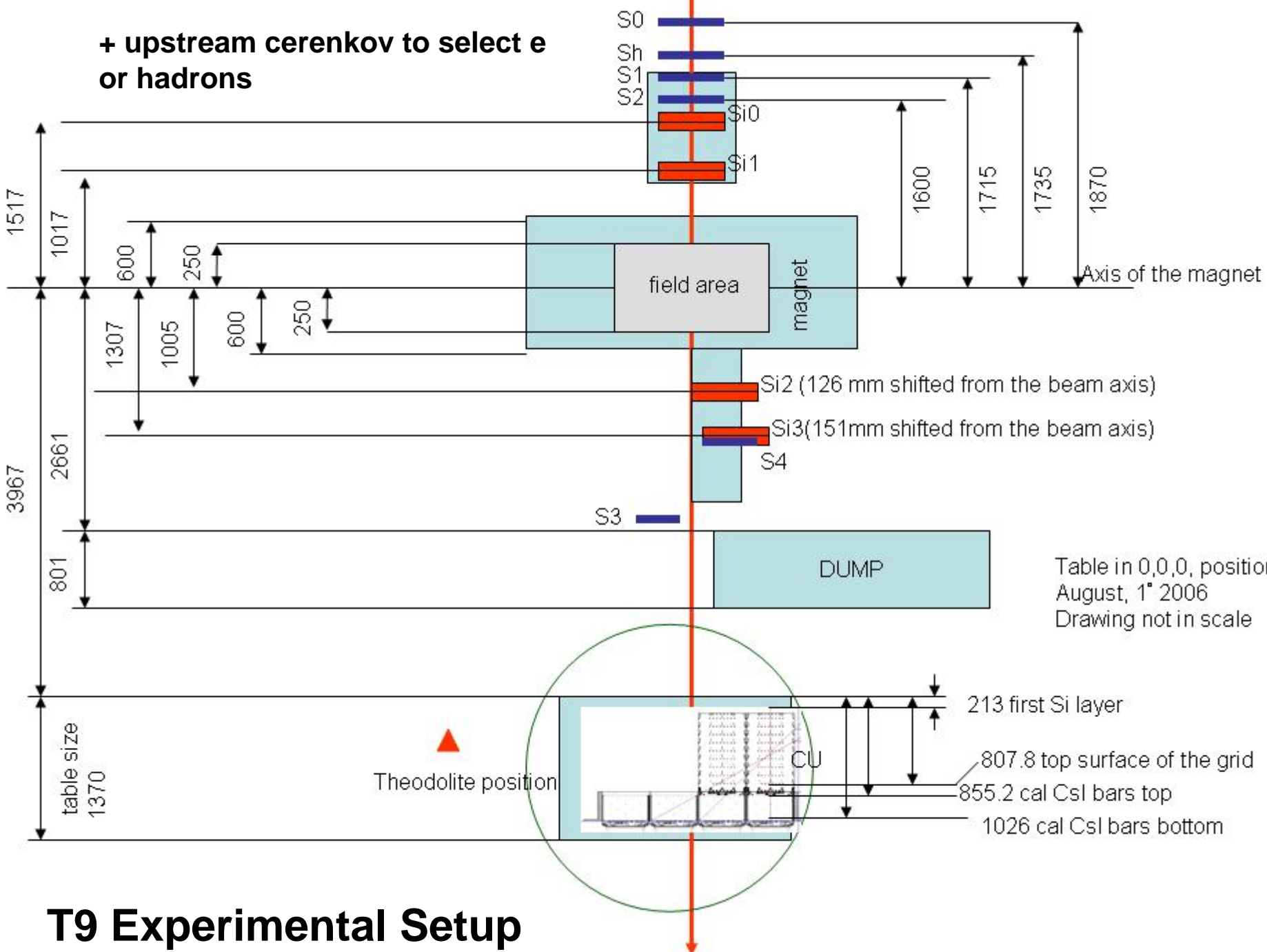
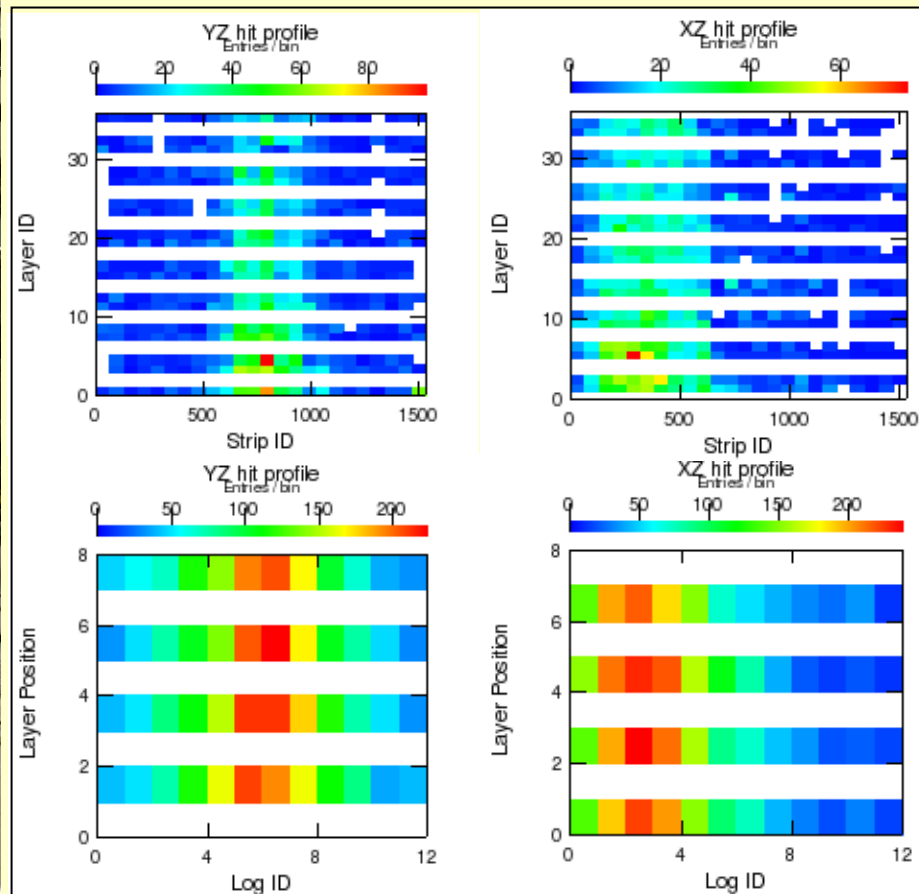
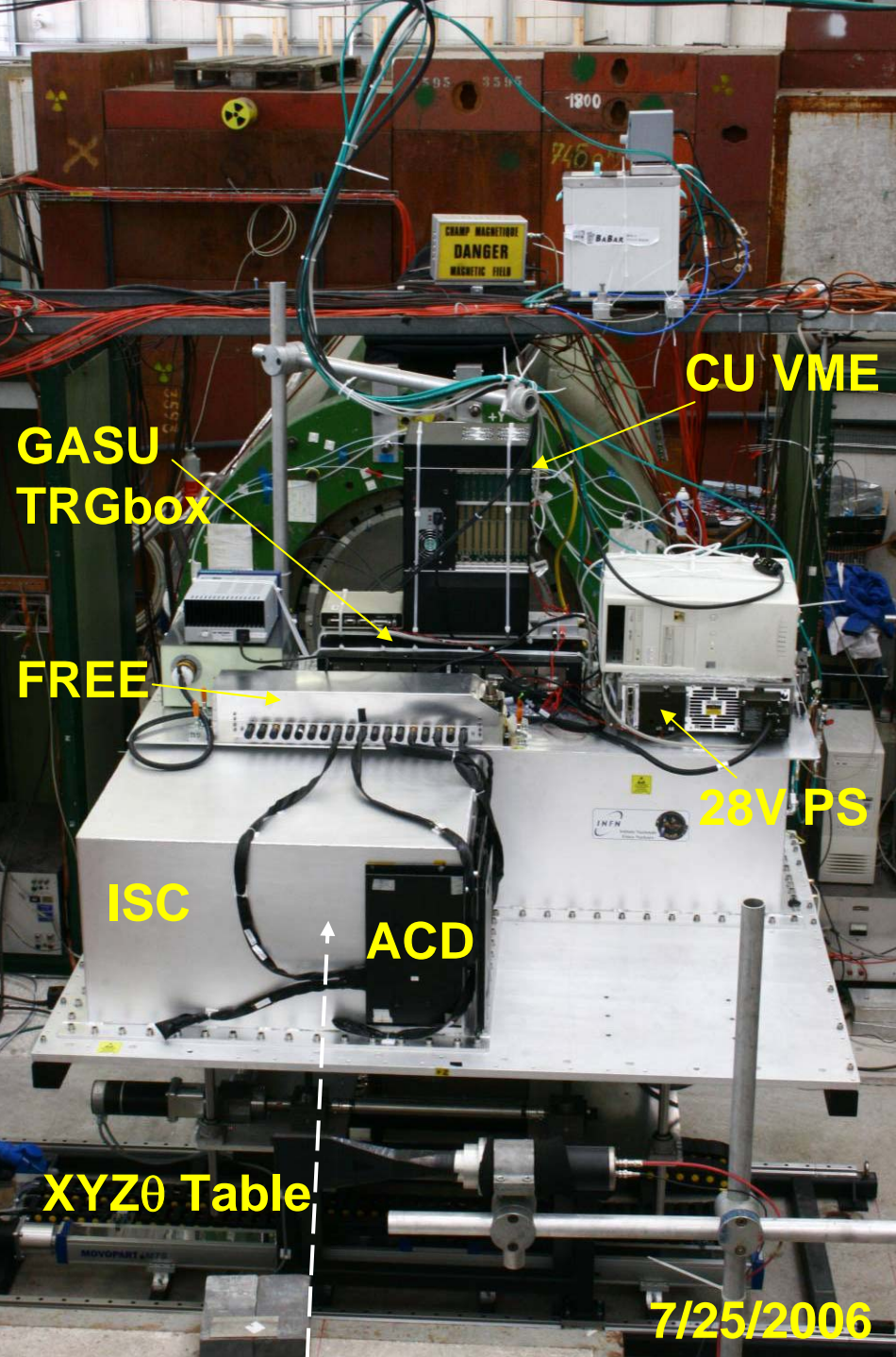


Table in 0,0,0, position
 August, 1st 2006
 Drawing not in scale

T9 Experimental Setup

Very first e e events from the online

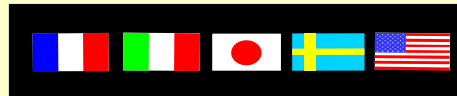


7/25/2006



The T9-PS Run

- **Collaboration effort for the T9 run**
 - **50 people worked at T9**
 - **Very dedicated and excited for a 24/7 experiment**
 - **All LAT collaboration represented at CERN (IT,FR,US,SW,JP)**
 - **Support from home institutions during data analysis**
 - **Valuable experience for ISOC**



Run coordinator: L Latronico
CU installation: A Brez
XYZ θ Table: P Bruel
CU DAQ: R Claus
Trigger and ancillary detectors: N
Mazziotta
Ancillary DAQ: F Gargano
Gamma-Tagger calibration: A Brez, L
Baldini

Online and data synchronization: L
Baldini
MC simulations: F Longo
Pipeline and recon management: Longo,
Kuss, Omodei
Local Offline: L Rochester (Socket
Gleam), INFN-PG (offline monitor)
TKR analysis: C Cecchi
CAL analysis: P Bruel
ACD analysis: E Charles



The original Beam Test Plan

Particle	Energy (GeV)	Angles (deg.)	#Positions per angle	Statistics	Trigger
tagged gamma-rays	0.3,1.,2.5 (incident electrons)	0,5,20,40,60	6	200 k	External
electrons	0.3, 1,5,15	0,5,20,40,60,90,180	6	200k	External
	15	0	60	40k	External
	15	0	1	> 1M	Internal (high rate)
hadrons	0.3, 1,5,15	0,90	2	1 M	External
muons	4	0	6	100 k	Internal+External

- After beam time reduction due to CERN problems we had to
 - Reduce number of angle and impact points
 - Add full-brem γ data collection to quickly cover full spectrum (G Godfrey)
 - Proceed with caution and first complete all data sets ($\gamma, e, e+, p$) with fewer configurations and statistics and only at the end explore phase space more
- Eventually it worked very well and managed to cover unforeseen configuration (e.g. Albedo γ)

The final T9-PS Run Schedule

	30	31	32	33	34
Week	7/24-7/30	7/31-8/6	8/7-8/13	8/14-8/20	8/21-8/27
Mo		PS restart		<u>Positrons</u> 1GeV e+ annihilation	<u>Photons</u> Low E tagged γ PS magnet
Tu	CU+table installation Initial debug Test self-trg data	DAQ sync test CU Timing Beam-line cleanup PS magnet glitch	Pile-up inspector <u>Photons</u> Tagger calibration Low E beams test Full brem γ	<u>Protons</u> 6-10 GeV p scan	<u>Special runs</u> FHE scan Random trig <u>Photons</u> VLE tagged γ
We	OK from safety AD installation	PS magnet failure	East Hall magnet failure		Dismantle and transport to H4
Th	Ext Trigger setup <u>Electrons</u> CAL calib 5GeV scan Magnet failure	Reduced noise in Si tagger detectors	<u>4th spill</u> negotiated with CERN	<u>Electrons</u> New 5GeV e scan <u>Photons</u> Tagged- γ Full Brem γ	
Fr	Magnet repair <u>Pions</u> ACD calibration		<u>Photons</u> Tagged- γ Full Brem γ		
Sa	general blackout			<u>Photons</u>	
Su				<u>Positrons</u> New setup	



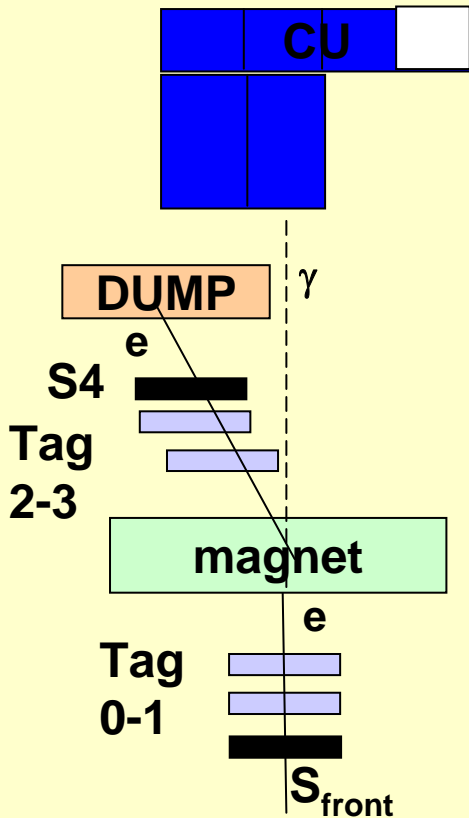
Photon data overview

- Full-bremsstrahlung

- Trigger on S_{front} only (+cerenkov)
- No AD DAQ \rightarrow KHz readout rate
- Full brem spectrum from 2.5GeV e
- Rely on nominal beam position, G4 bremsstrahlung spectrum, estimated radiator material

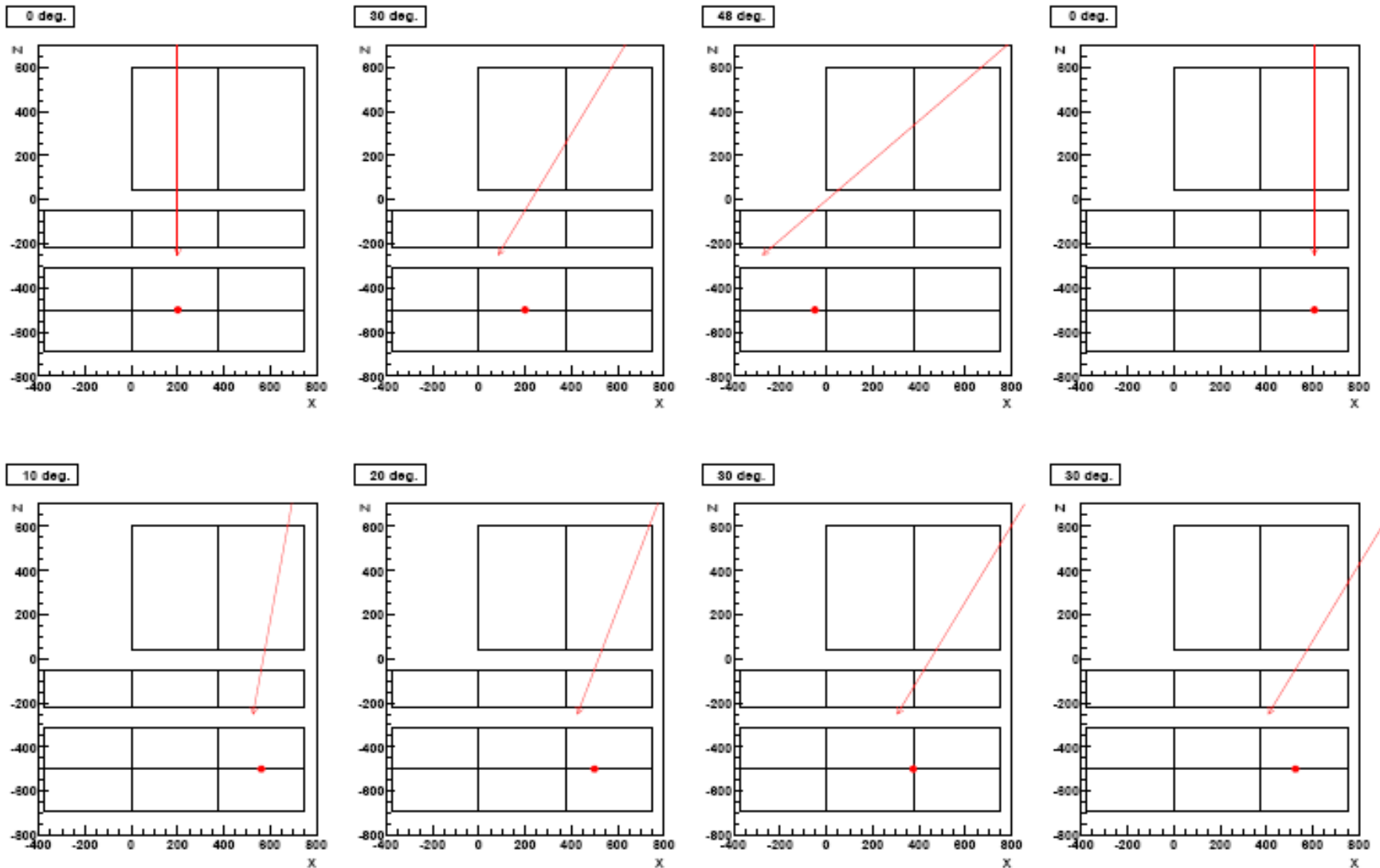
- Tagged photon

- Trigger on $S4 \& S_{front}$ (+cerenkov)
- Synchronized with AD DAQ \rightarrow O(100)Hz rate
- Record limited slice of spectrum
- Single γ energy and incoming direction





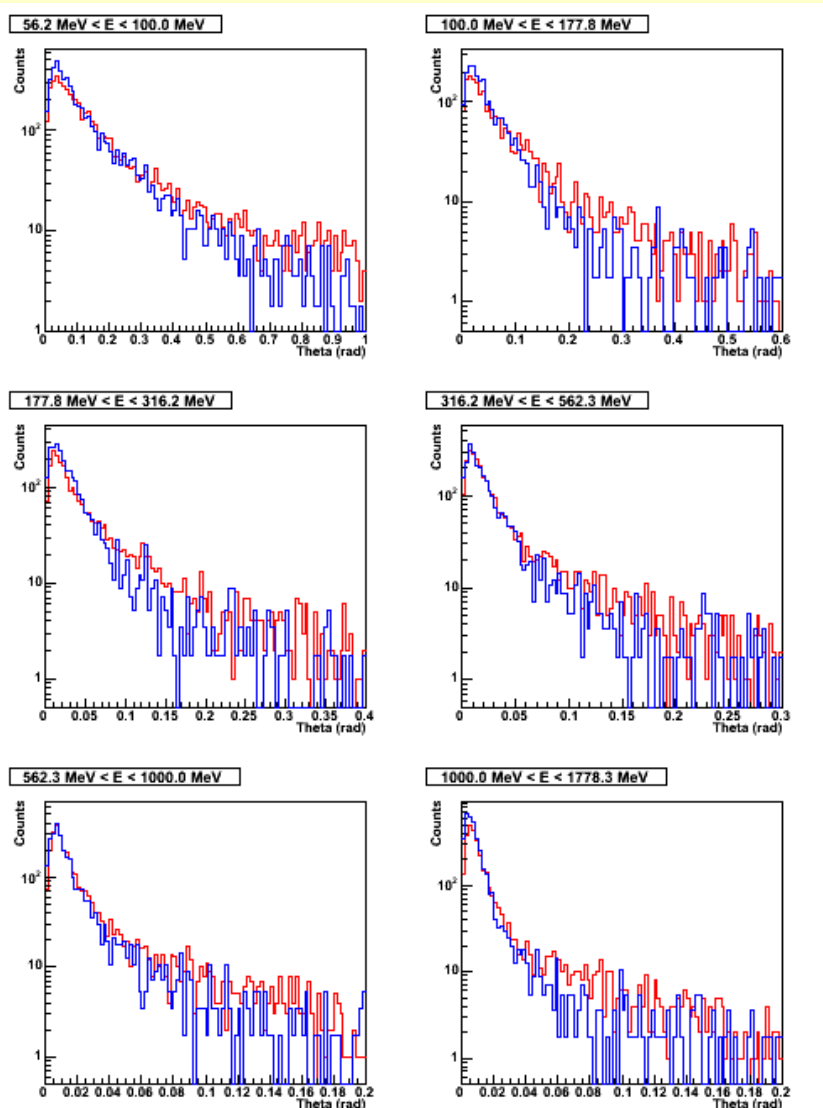
Photon data overview - configurations



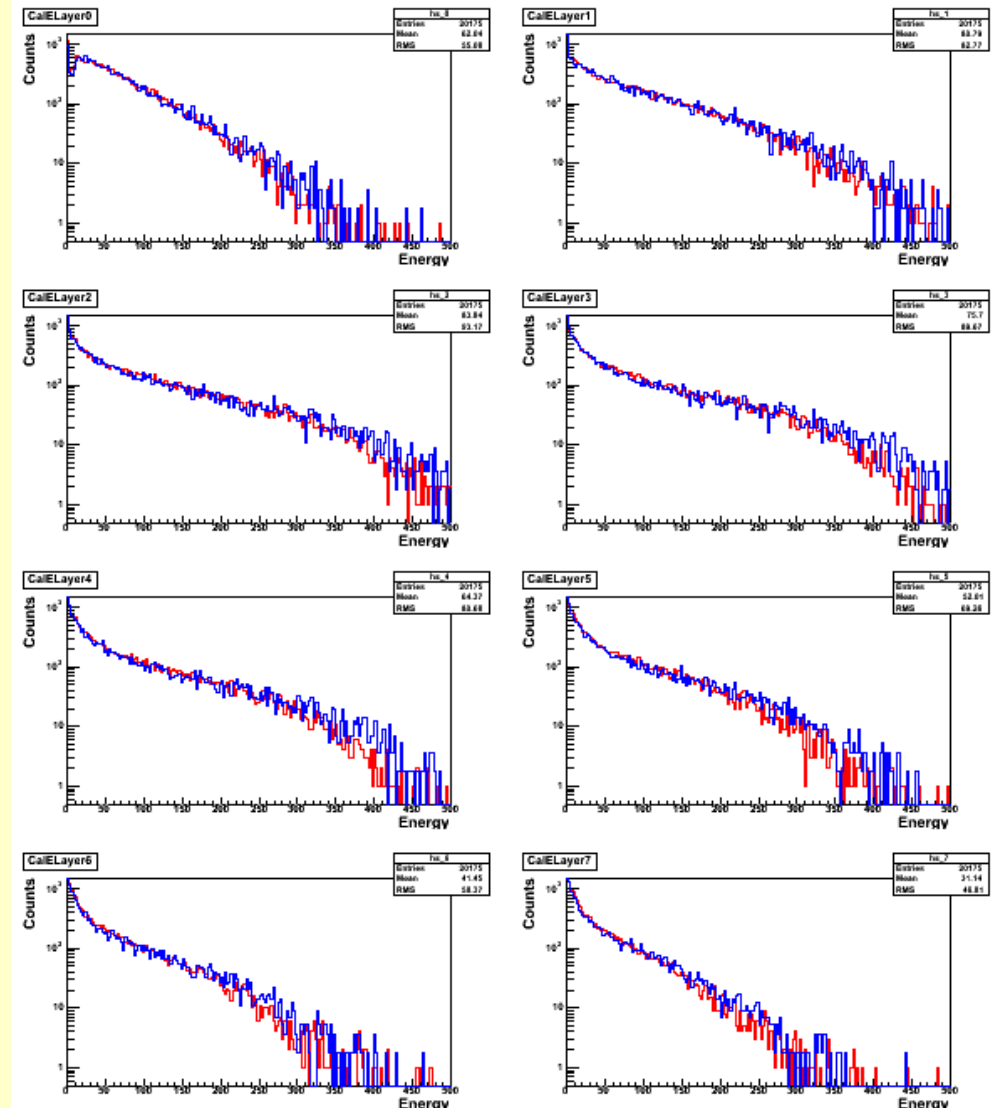
+ 2 *albedo* configurations shooting upwards γ at different angle, position



First comparison of γ data with MC



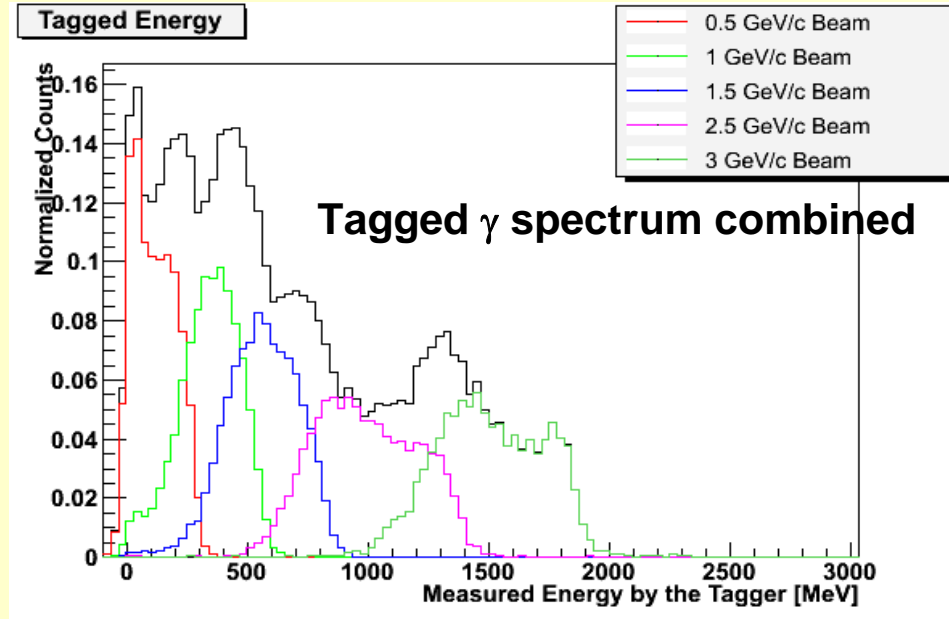
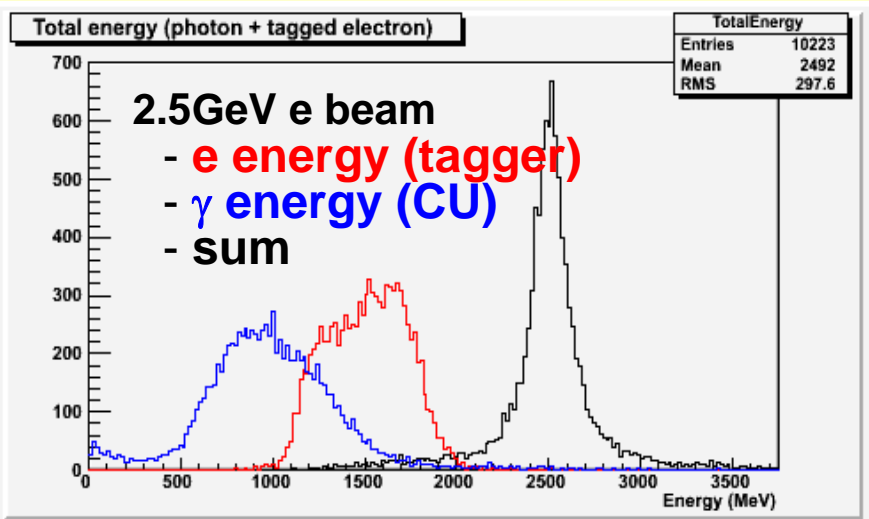
Full-brem data angular distribution



Full-brem data CAL log E deposit



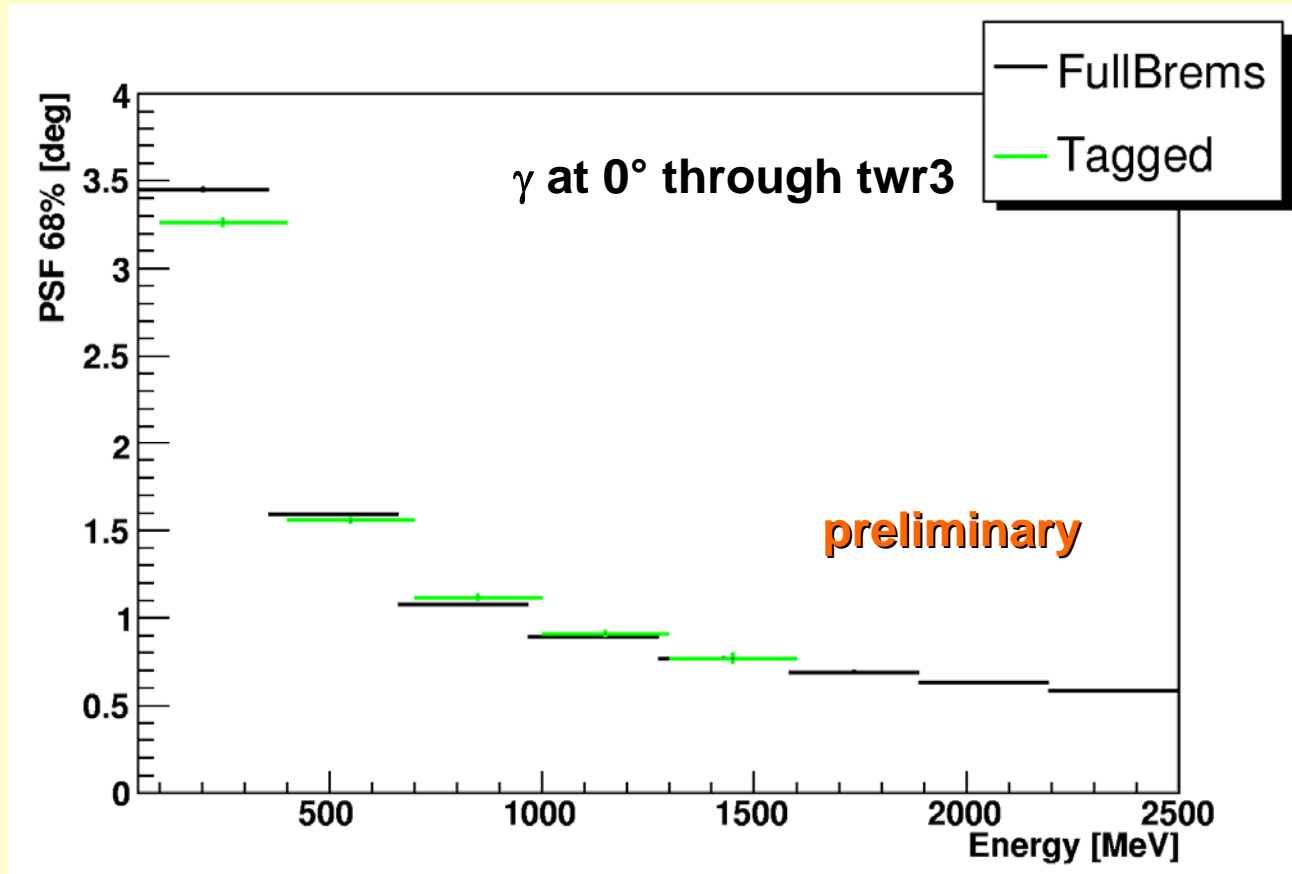
Gamma Tagger for photon data



- **Tagger operation**
 - Several E beam
 - Constant E/BL to preserve geometry
 - Resolution worse at low E
- **Modified geometry at the end for Low and Very Low E**
 - Carefully planned calibration strategy and online tools to minimize time to few hours
 - Maximum bending power with low E beam
 - Crucial for energy recon studies



Comparison with tagger data



- Tagged γ analysis
 - incoming γ direction and error from tagger
- Full-brem γ analysis
 - average beam line and dispersion assumed
- Can benefit from large statistics and acceptance of full-brem data for PSF

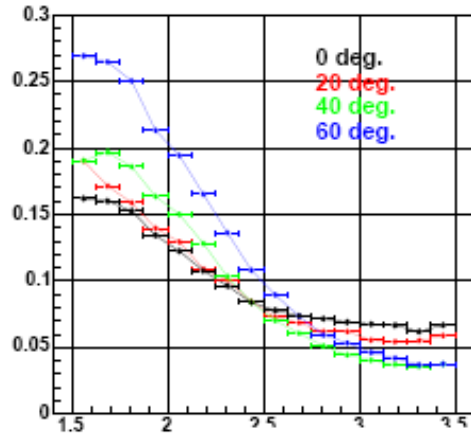


Energy Resolution

CU resolution 0 deg

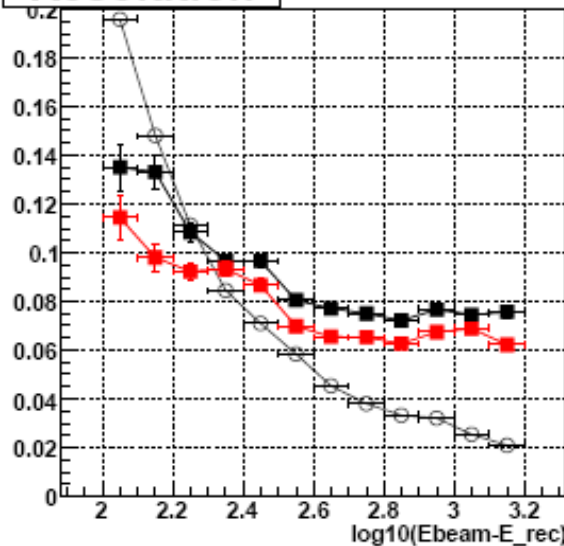
preliminary

CU energy resolution

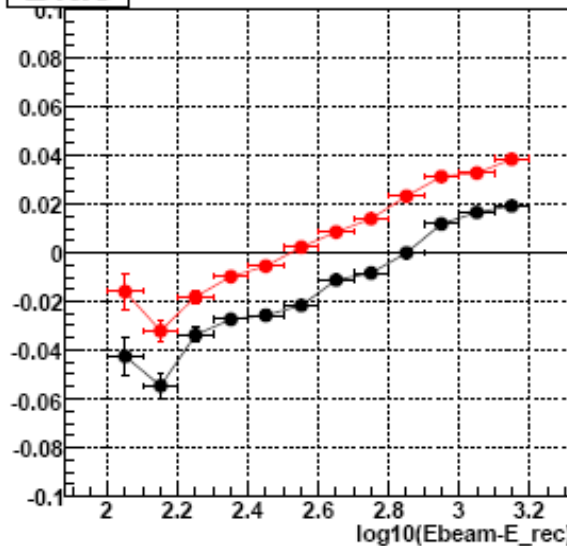


- empty circles : (beam+tagger) resolution
- black squares : EvtEnergyCorr corrected resolution
- red squares : CalLkHdEnergy corrected resolution

Resolution

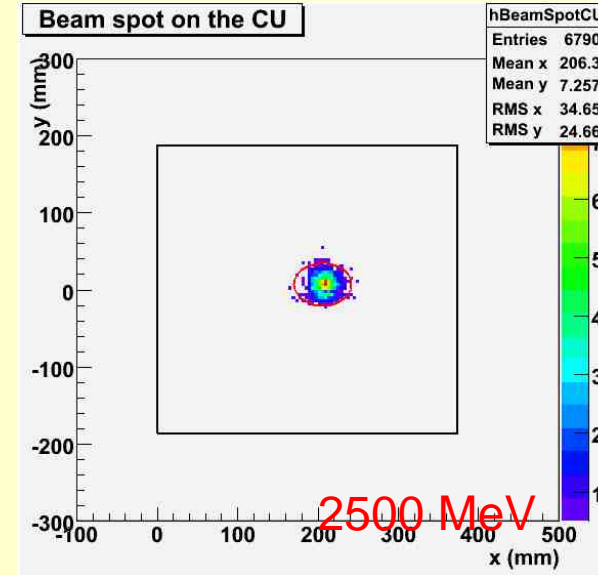
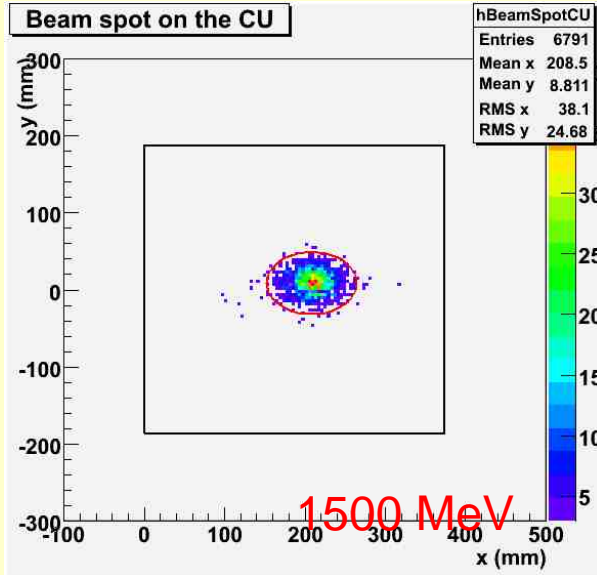
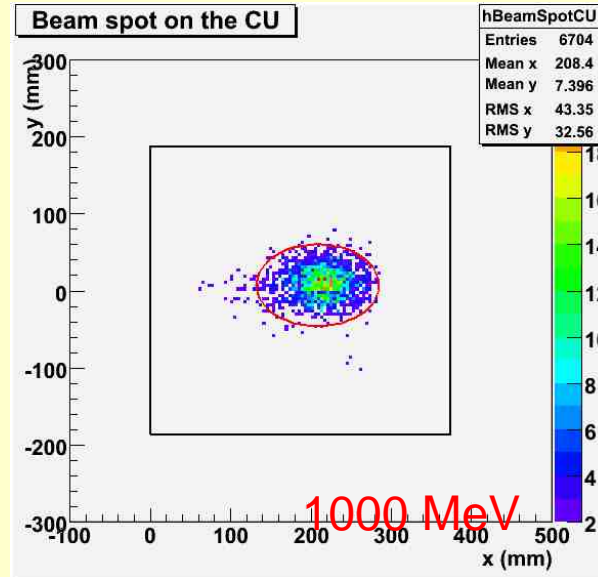
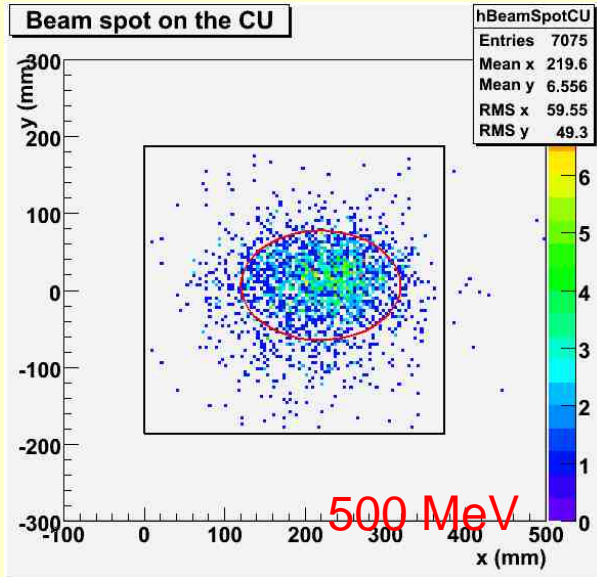


Bias





Photon beam dispersion

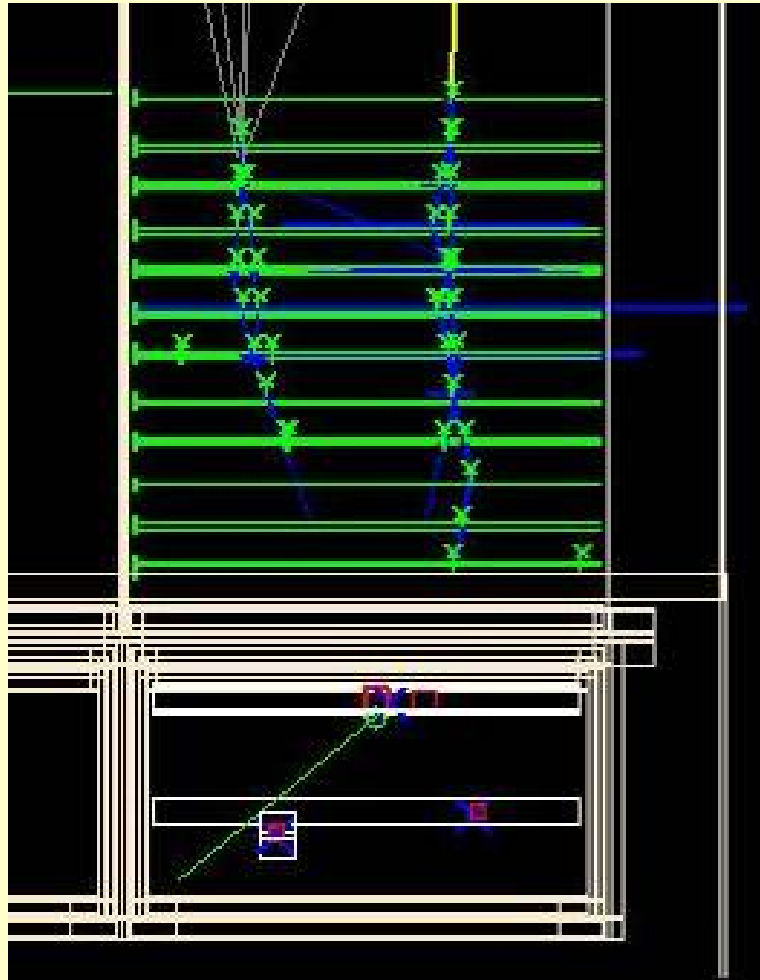


- 1 cm spot on tagger fiducial cut
- Red ellipse is the beam spot projected to the CU
- Data points are γ vertex positions
- Experimentally seen as beam dump was cutting γ beam when working at 500MeV e

Must include beam dispersion in analysis and MC



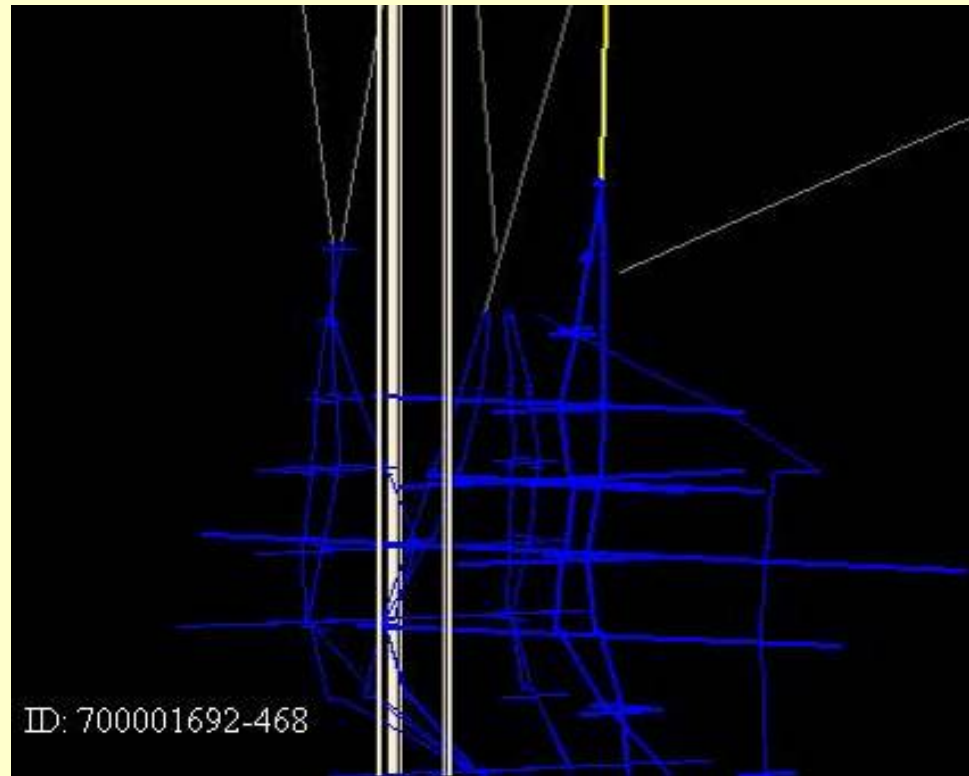
Double gammas in the CU



Could see these in real-time using Socket-Gleam

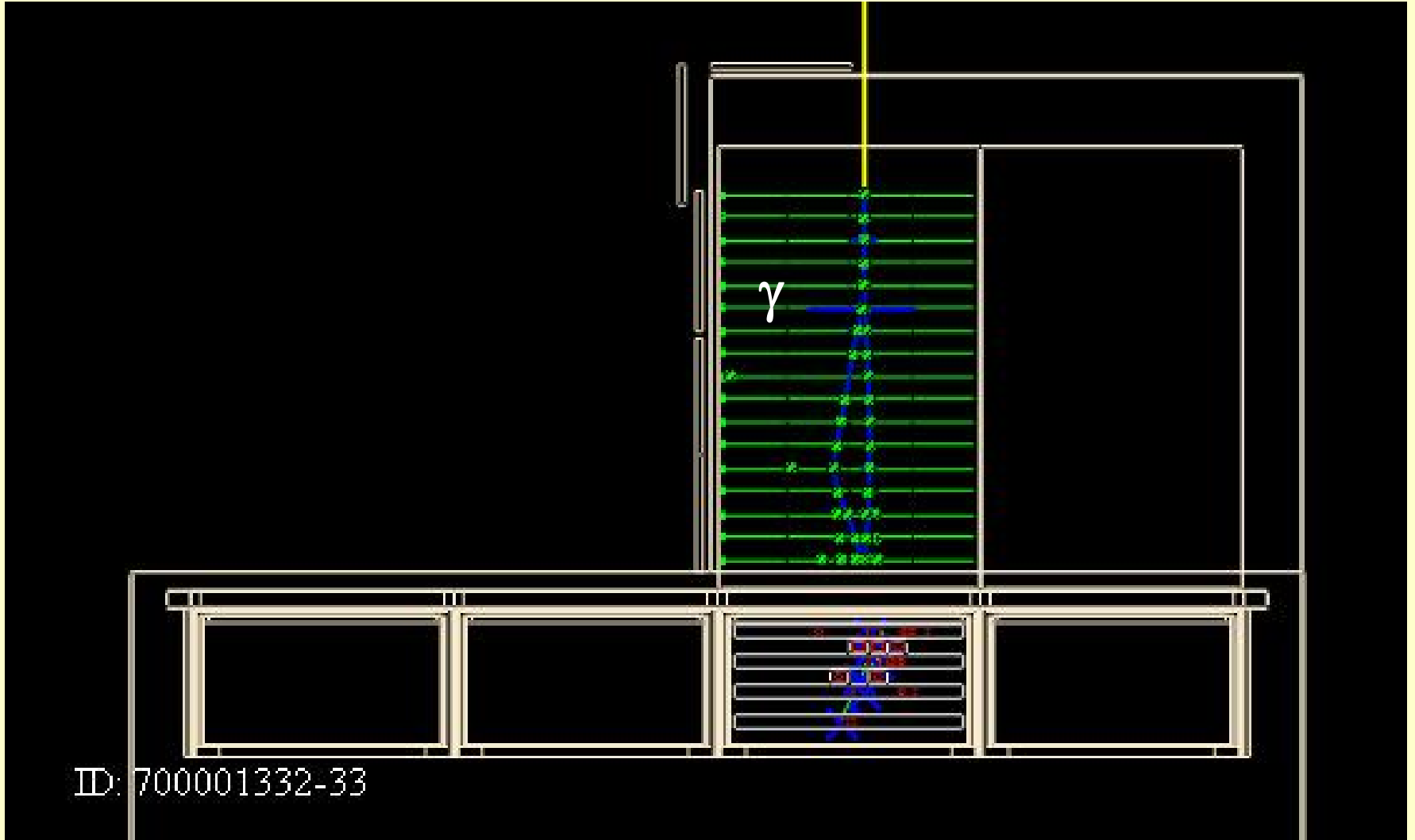
Must correctly simulate them and filter with proper analysis cut

From VLE tagged- γ



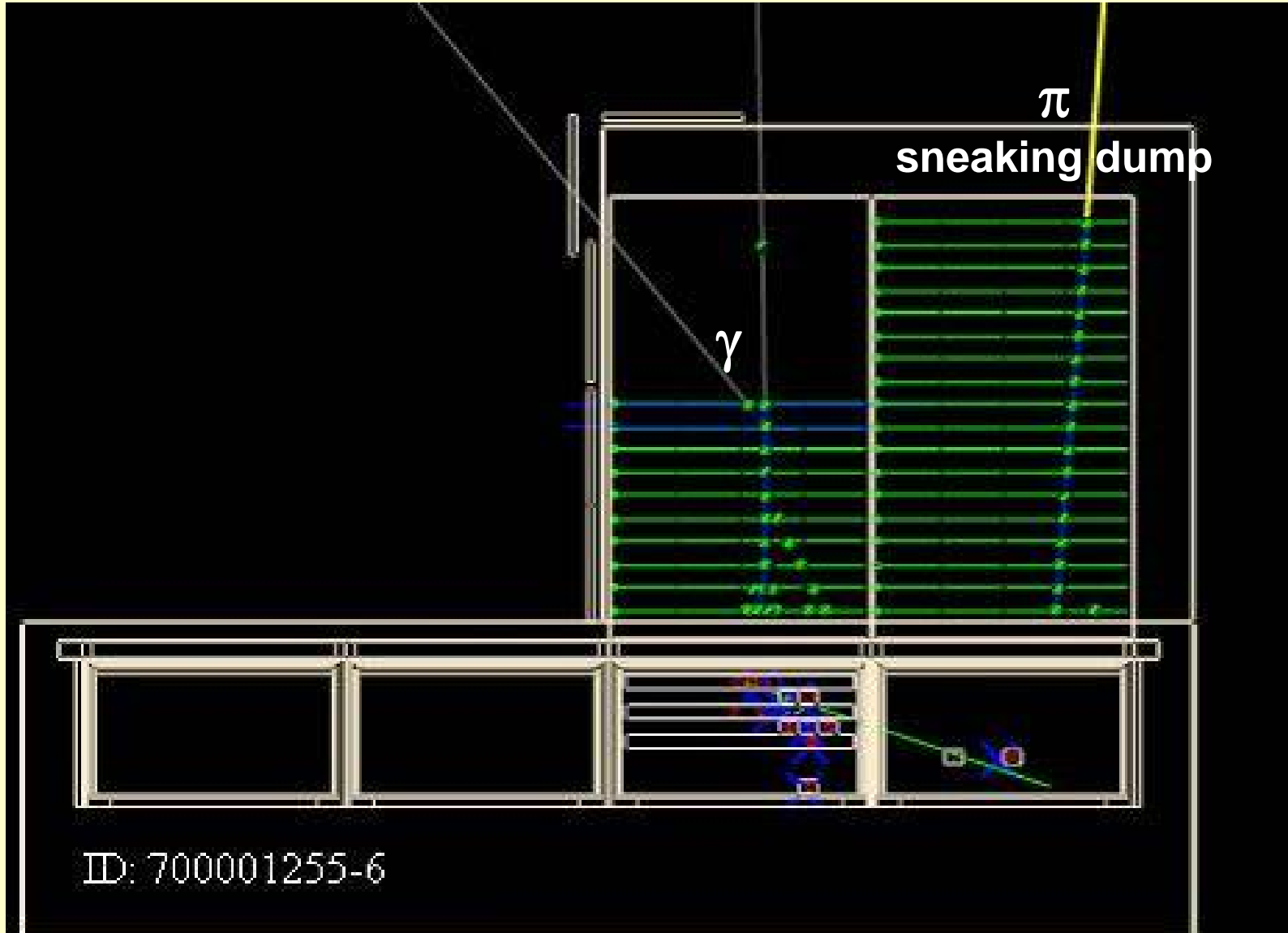


More photons





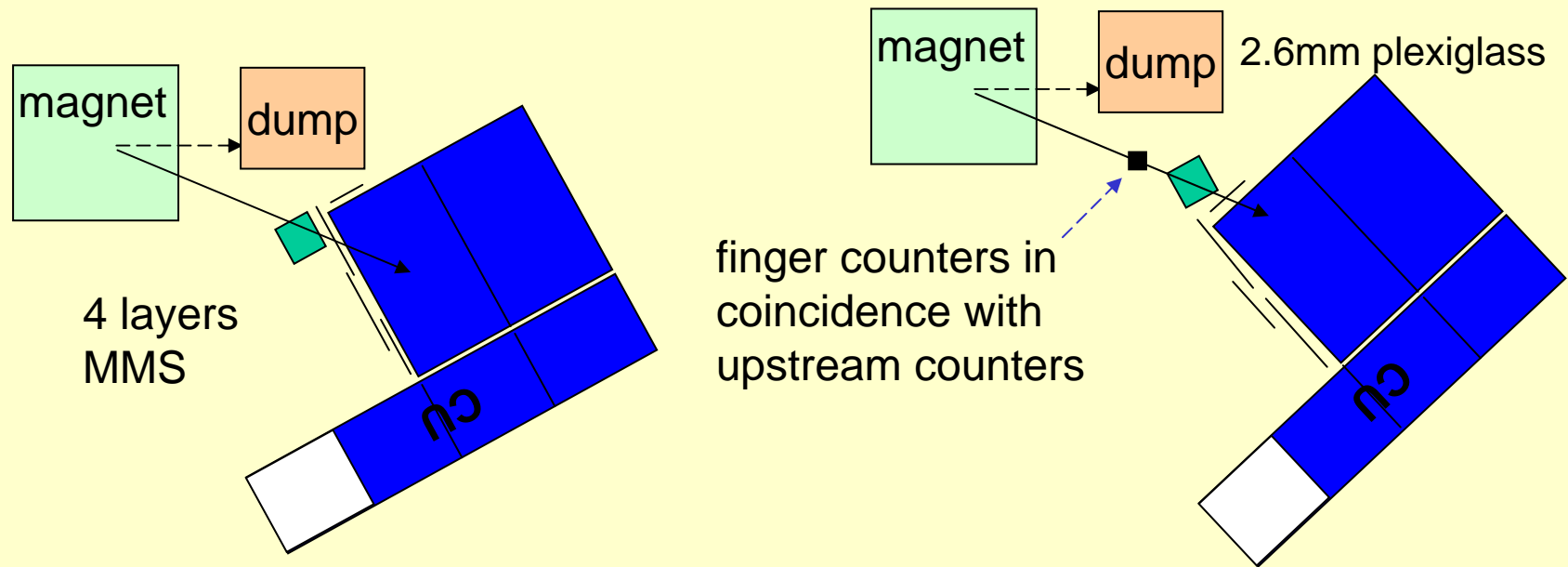
More photons





Positron runs

- Search for e^+ annihilation with target for $\gamma\gamma$ final state
 - Magnet ON and extended dump to stop brem γ from e^+
 - Collect 1M e^+ and 1M e at 1GeV for comparison
 - Rely on ACD veto power

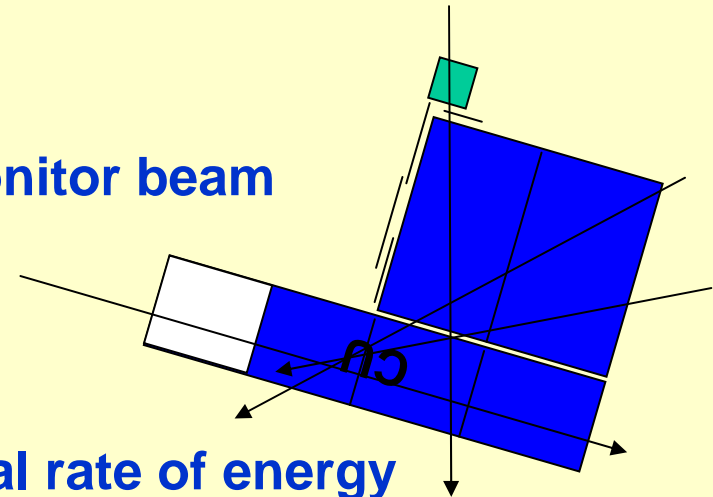


- Beam larger than target + ACD crack hit \rightarrow setup improved
- After cuts double γ clearly seen in event display and several σ difference between e^+ and e samples (preliminary)
- Ongoing analysis and MC simulation for correct setup



Proton runs

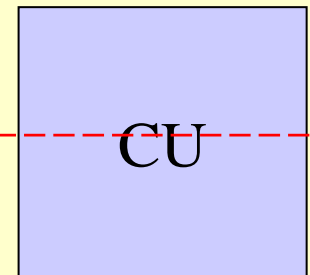
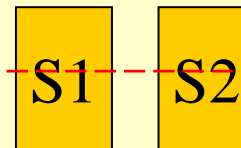
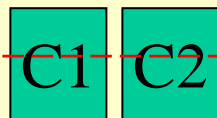
- Search for $p \rightarrow \pi^0 \rightarrow \gamma\gamma$ and hadronic interactions modeling in CAL
 - Collected 5M protons at 10, 6 GeV, several angle
 - Have to live with few % K contamination, while π are rejected by veto on cerenkov
- Collected high rate data, external trigger
 - LATTE peak rate over 4KHz
 - Pipeline test too
 - Running ancillary in parallel to monitor beam stability
- Issues
 - Some runs taken with ACD OFF
 - CAL pedestal drift due to high local rate of energy deposition in logs





H4-SPS Test status

- CU and electronics already in H4 since end of T9 run
- Installation starting next Monday 9/4 – everything ready
- 9 days for data taking until 9/15 (2 days MD)
- Clean high energy beams promised
 - Simple setup
 - No ancillary detectors other than trigger plastics and cerenkov for hadron beam (p/π discrimination)
- Same crew with Benoit Lott as run coordinator
- Focus on
 - High energy EM shower
 - High occupancy in TKR
 - ACD backplash



SPS-H4 setup
 e^- , π , p 10-300GeV



CU Beam Test at GSI

- **Motivations**
 - **TKR response to relativistic heavy ions**
 - TKR never tested with heavy ions
 - Spice simulations (R. Johnson) show that a heavy ion signal can saturate a strip amplifier, thus making the strip and few neighboring inactive for ms, and the layer trigger OR inactive for more than 100 μ s
 - **CAL response to relativistic heavy ions**
 - verification of the published CAL GSI beam test results with a flight unit
 - **Verify CNO operation for CAL on-orbit calibration**
 - ACD CNO triggering
 - TKR to track ion path to CAL
 - CAL calibration
- **Status**
 - **Ready to start in mid november**
 - No hardware/software development
 - Minimal team of experts for 2 days run
 - Details of installation to be agreed in a visit in early october

Conclusions So far

- First beam test completed at T9
 - Program completed (despite time lost for CERN problems)
 - High quality and high statistics data
 - γ in 100MeV-2.5GeV range (tagged+untagged)
 - e at 1,2.5, 5GeV
 - e+ at 1GeV
 - p at 6,10GeV
 - many CU configurations
- Preliminary analysis show very good agreement between data and MC and measured performances in agreement with the specs
- High energy e and p starting today at H4
- Ready for heavy ions at GSI in mid-nov
- Ongoing analysis for next 6-12 months

