LABM at SuperKEKB (KEK, Puebla, Sinaloa, Tabuk, WSU)

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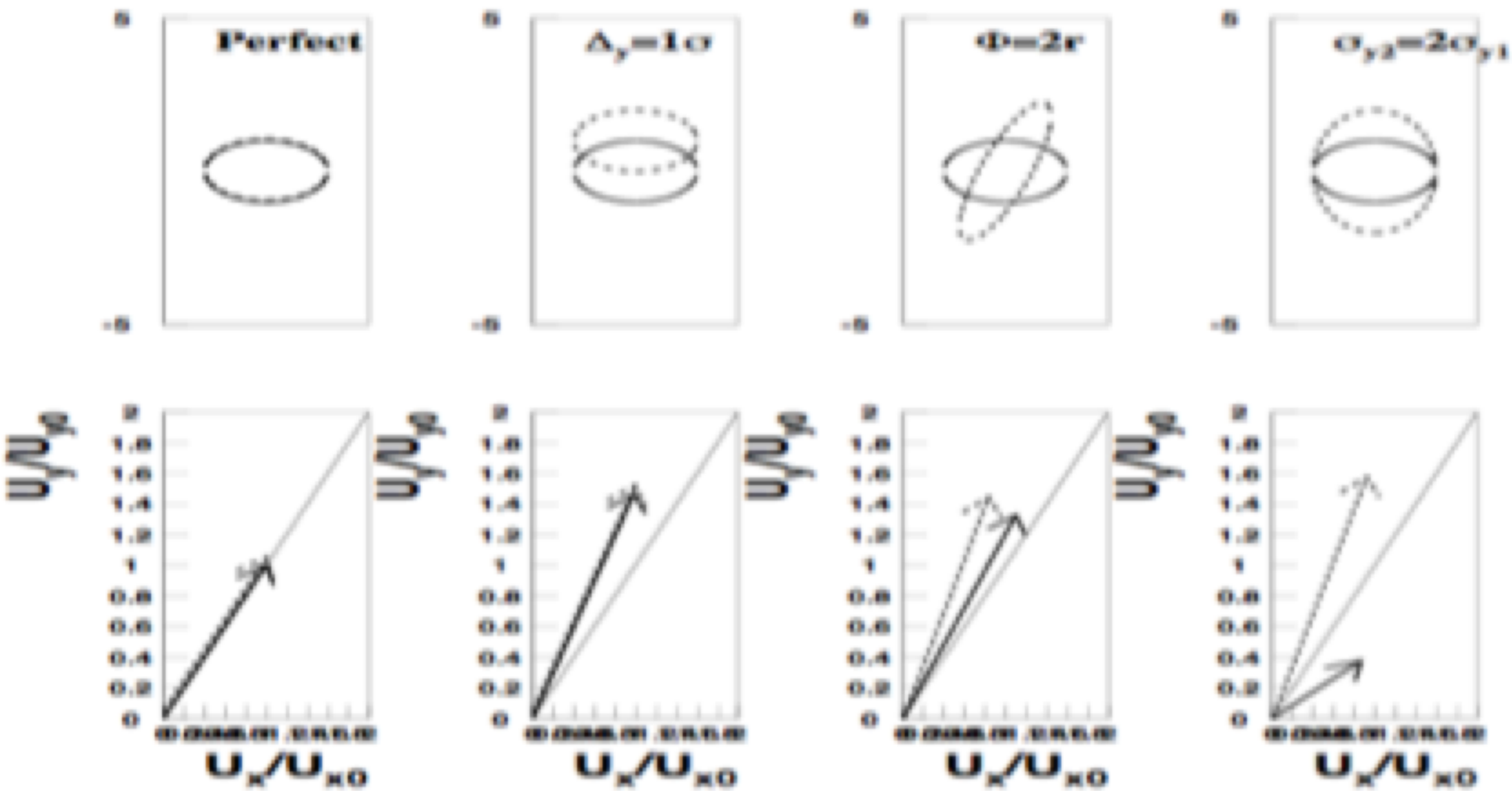
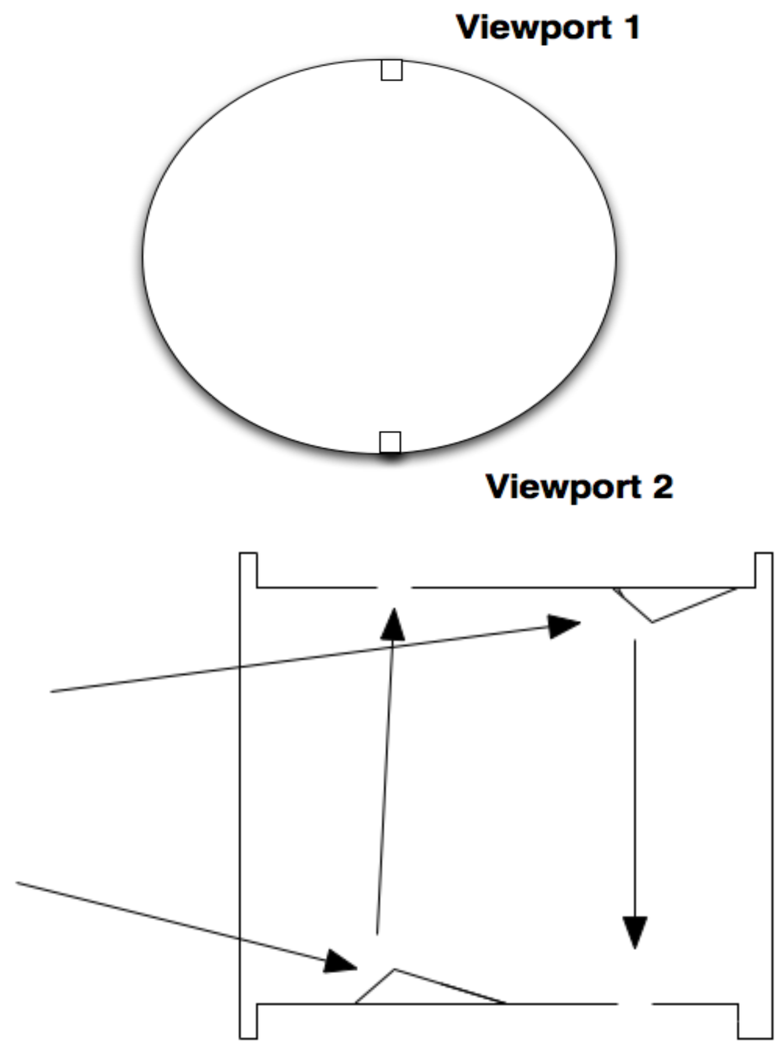
The LABM goal: make direct measurements of the beam parameters at the IP



Beam pipe insert

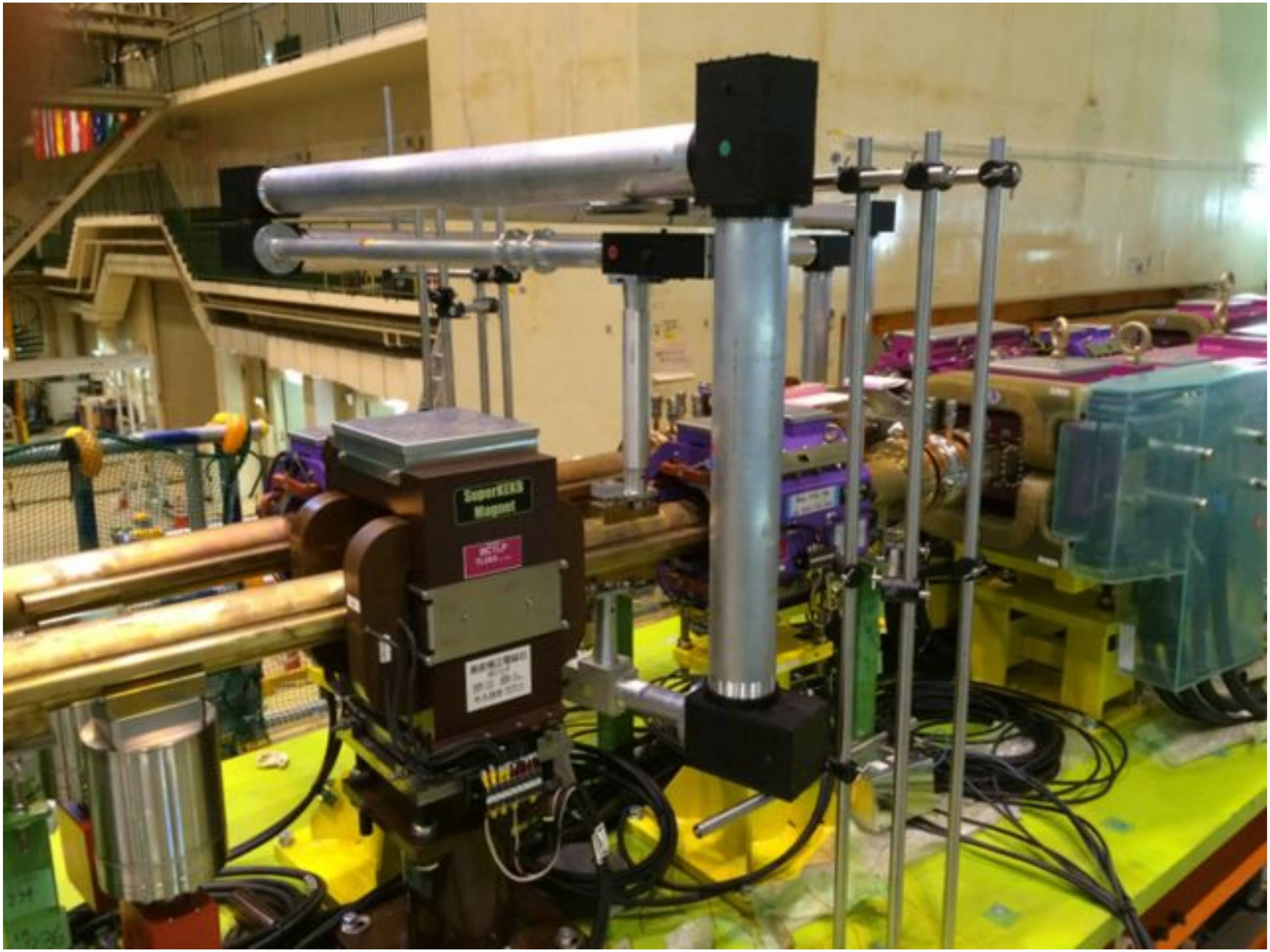
- View port location at ±90 degrees minimizes backgrounds, polarization measurement errors, and provides redundancy against beam orbit errors
- To be located anywhere between 5 and 10 mrad from the beam direction at the IP
- mirror and window sizes: 2X2.8mm2 and 6X6 mm2. Mirror is collimator 1
- Well measured distance between mirrors provides a constraint against beam pipe misalignments



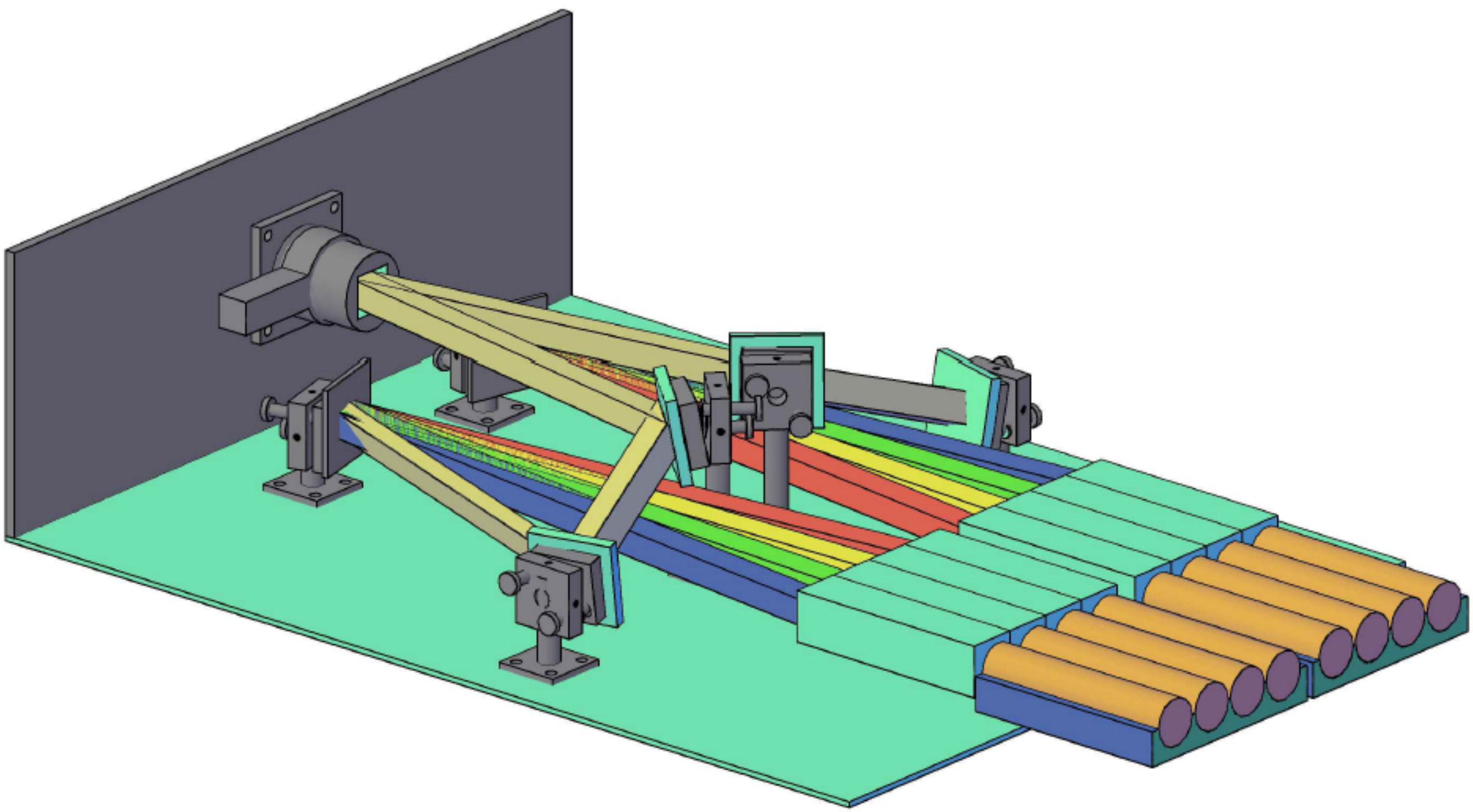
LABM installation and commissioning completed Jan. 20, 2016 (32 PMTs, 4 viewports)

http://motor1.physics.wayne.edu/~fj0465/labm/home.html

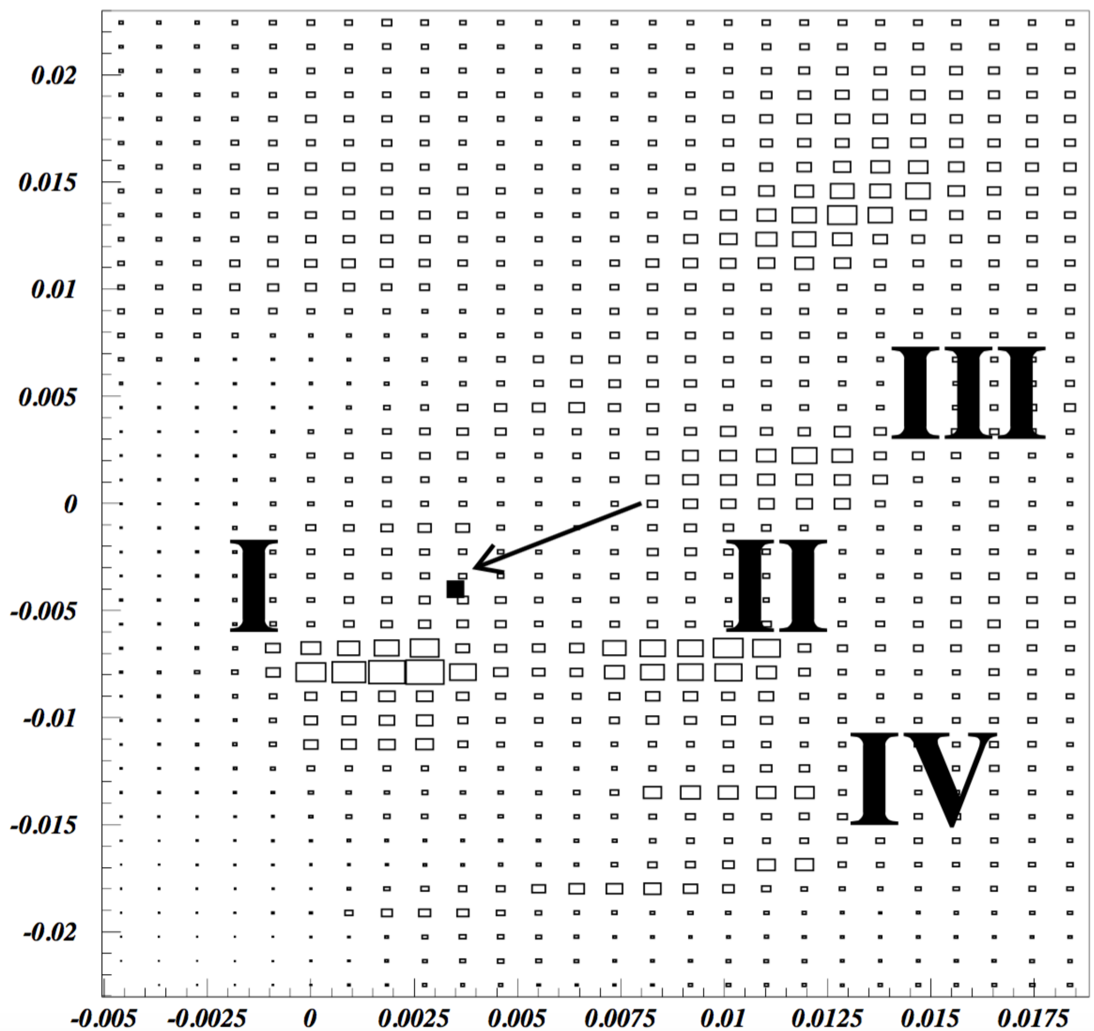
Optical Channels Oho side. Detector is quiet and dark. PMT and optical components efficiency measured in situ


SuperKEKB
Magnet

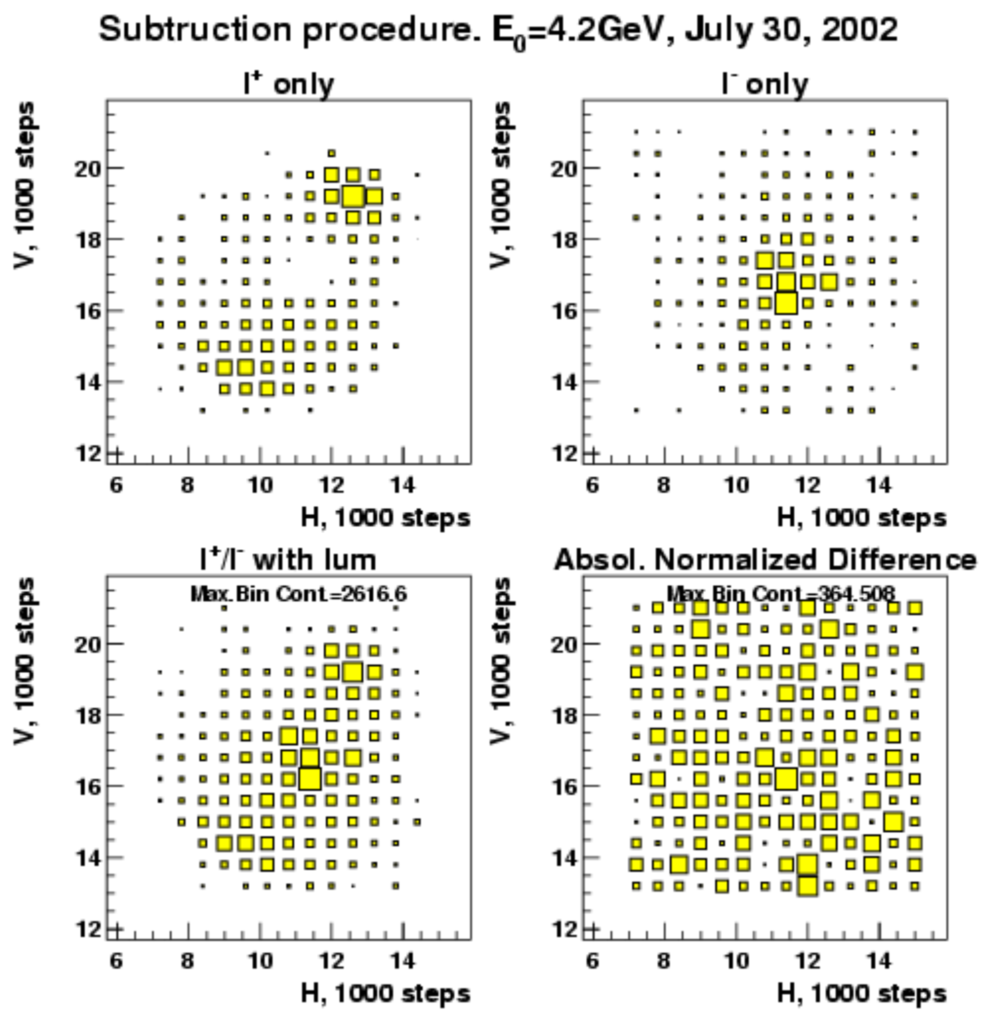
Optics Box



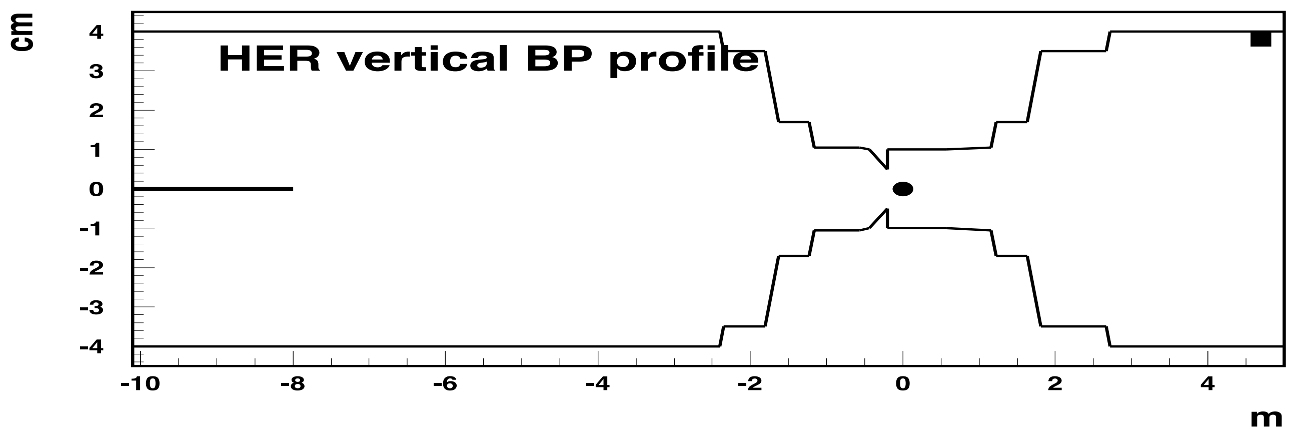
(Phase I)Positron Down angular scan shows IP finding procedure

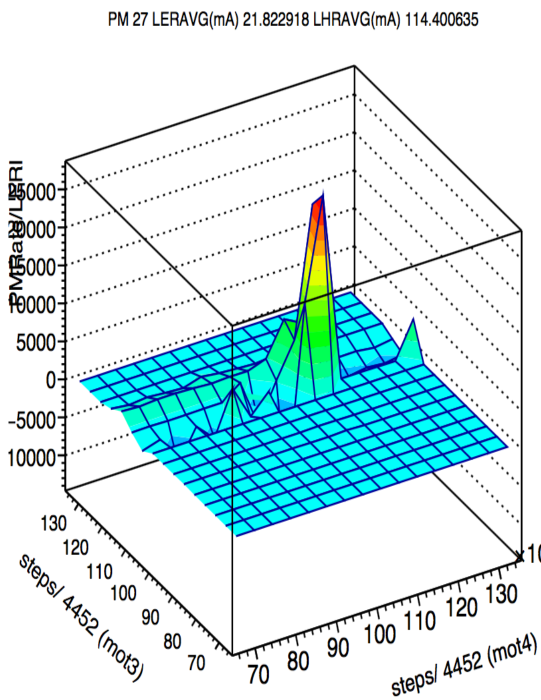


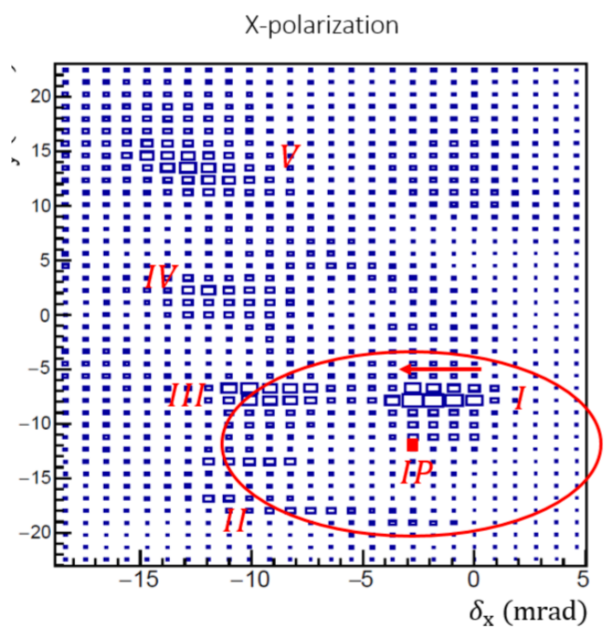
We have always had a pattern. Check for alignment @ 4.2GeV (CESR slide)

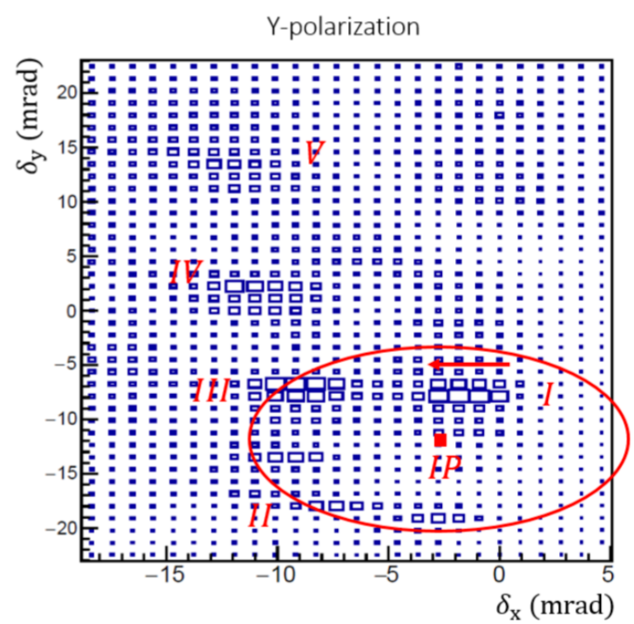


Vast background suppression from narrow Beam Pipe
– but loss of pattern recognition previously obtained (first big problem)

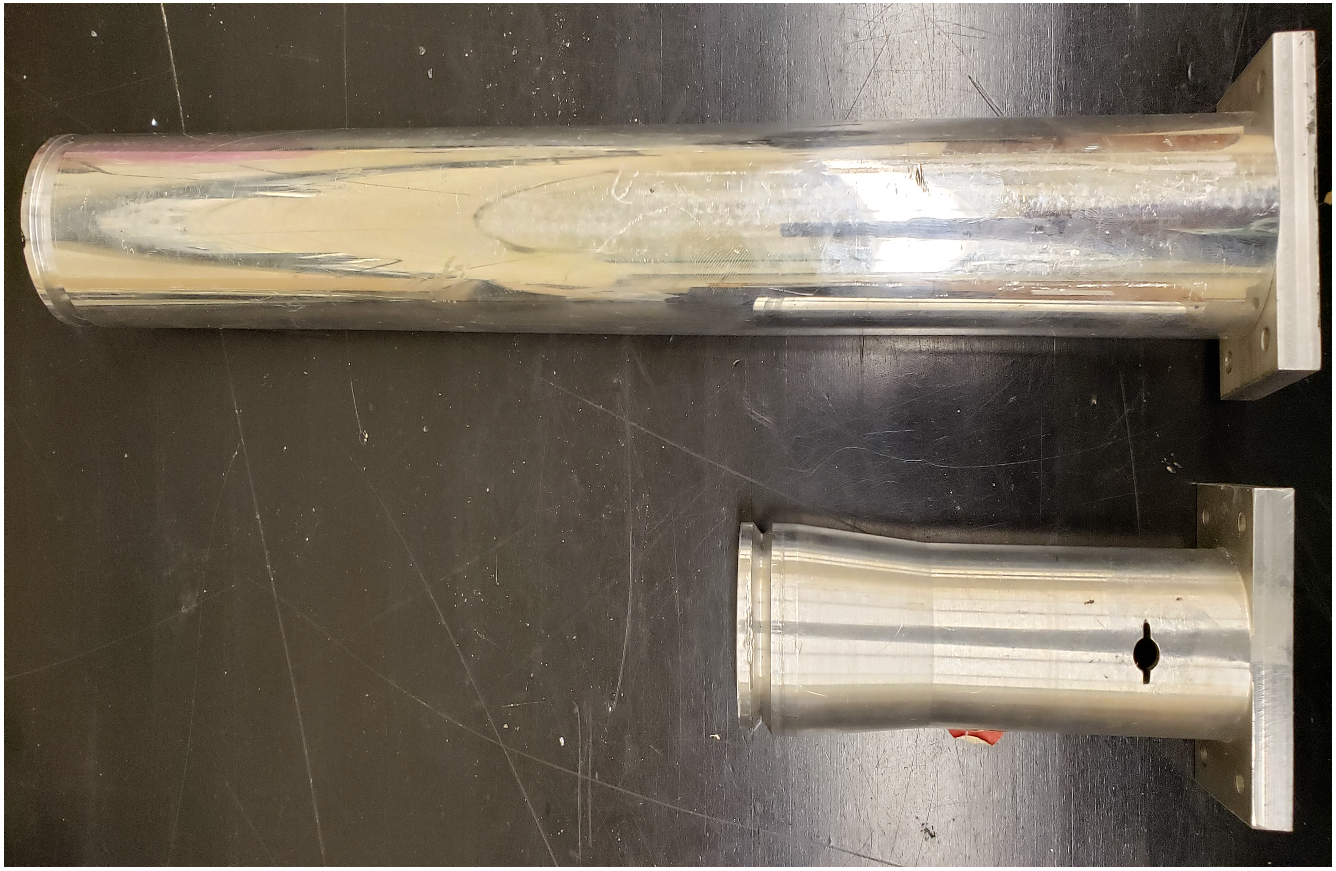








Reflections in the non-vertical Beam Pipe to primary mirror Connectors are close by. We present only data from Down Telescopes.



Signal is still small

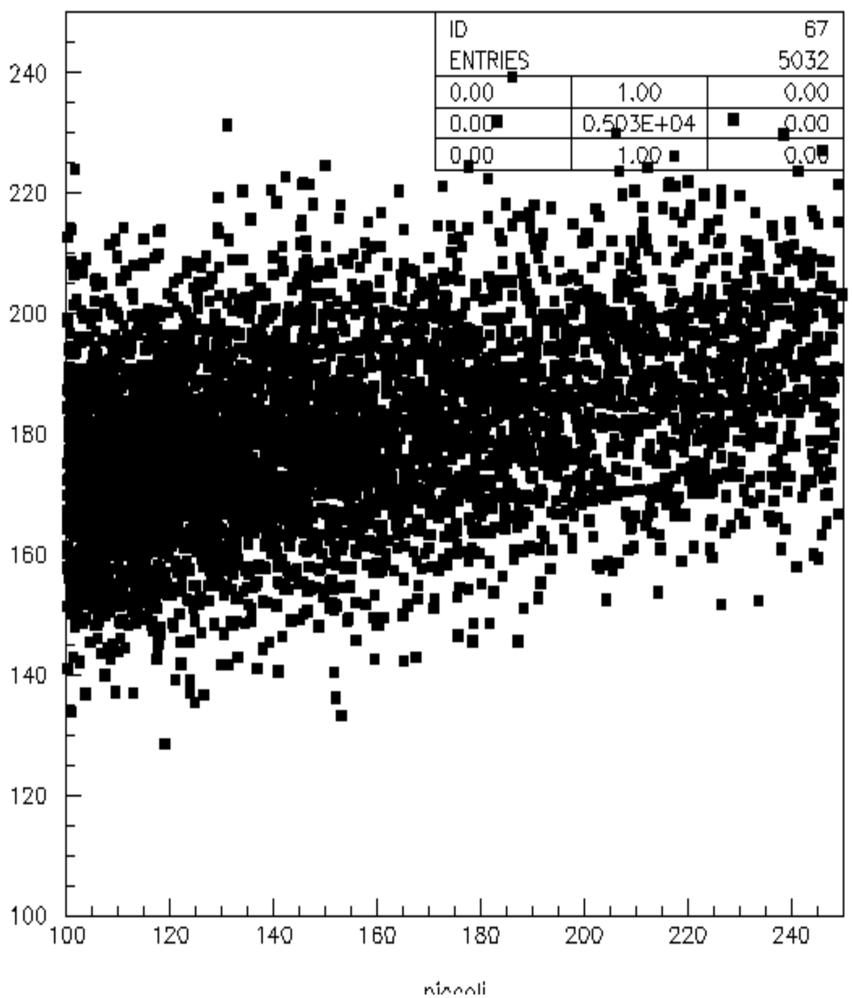
From 2015 talk, total LABM rates at nominal luminosity is 20-25 MHz.

$P_{-} \approx I_{-} I_{+}^{2} (2501)^{2} / (N_{b} \sigma_{x})^{2} \approx 100\text{-}300\text{Hz}$ per PMT with 1576 bunches in Phase II

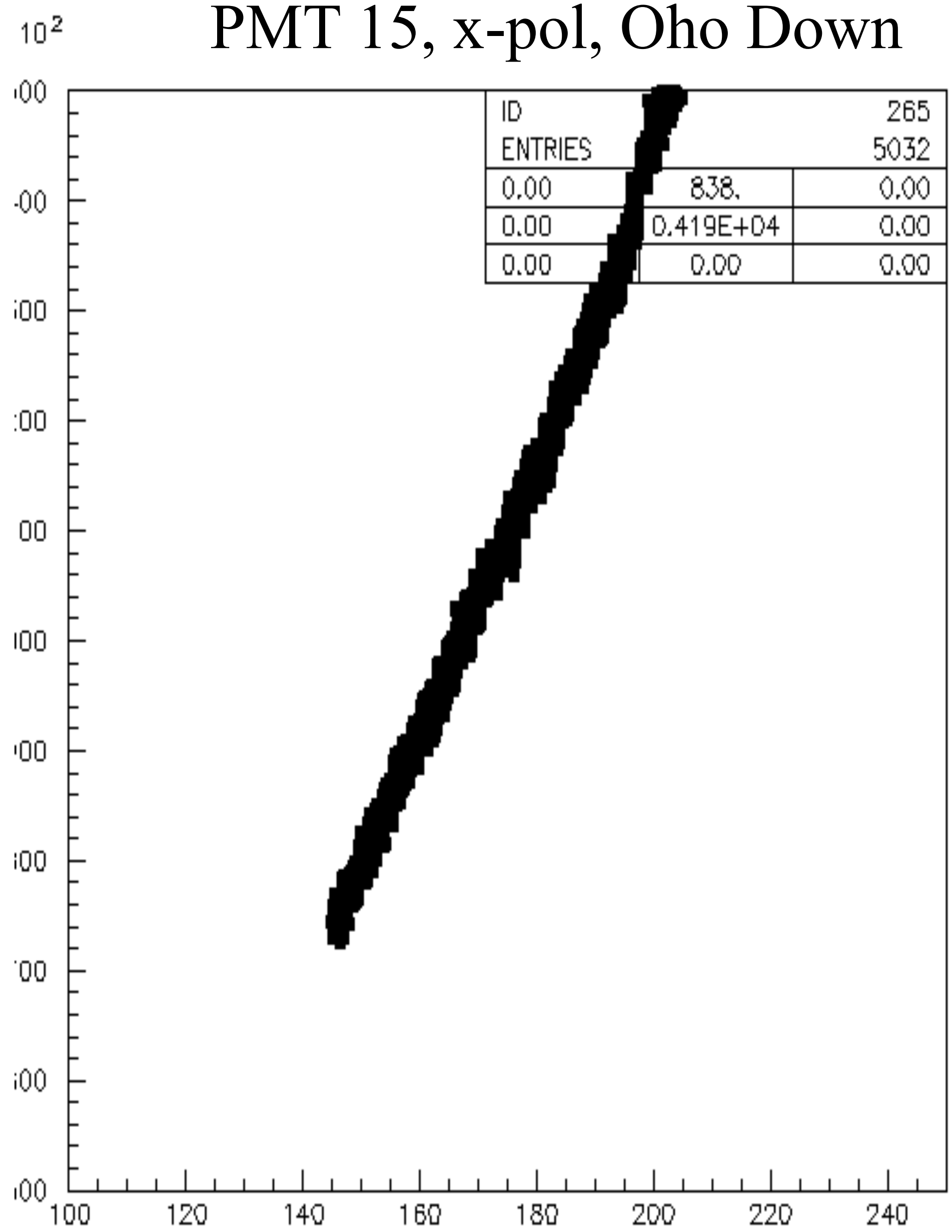
Extract information from data by looking at long fills. Needs strong linearity and well understood pedestals.

Examples of fills
(rate vs current)

PMT 17, x-pol, Nikko Down



PMT 15, x-pol, Oho Down



Fitting functions and telescope used (initially)

a) Oho Down because its rates are highest (that turned out to be a mistake)

b) Beamstrahlung Rate= I_-*(B+S*I_+^2). Simple double combination of linear Background and quadratic signal. For presentation, B an d S are given as Hz, when two beams of 300 mA collide.

c) Beam-beams hypothesis Rate= I_-*(B+S*I_+). Non-linear effects Are due to off-axis particles shining into the detector.

d) Touschek. Rate= I_-*(B+S*I_-). Non-linear effects are also due to Off-axis particles.

Scan selection

a) $(I_+, I_-)_{max} > 70$ mA

b) $\Delta(I_\pm) > 70$ mA

c) $\chi 2 <$ cut

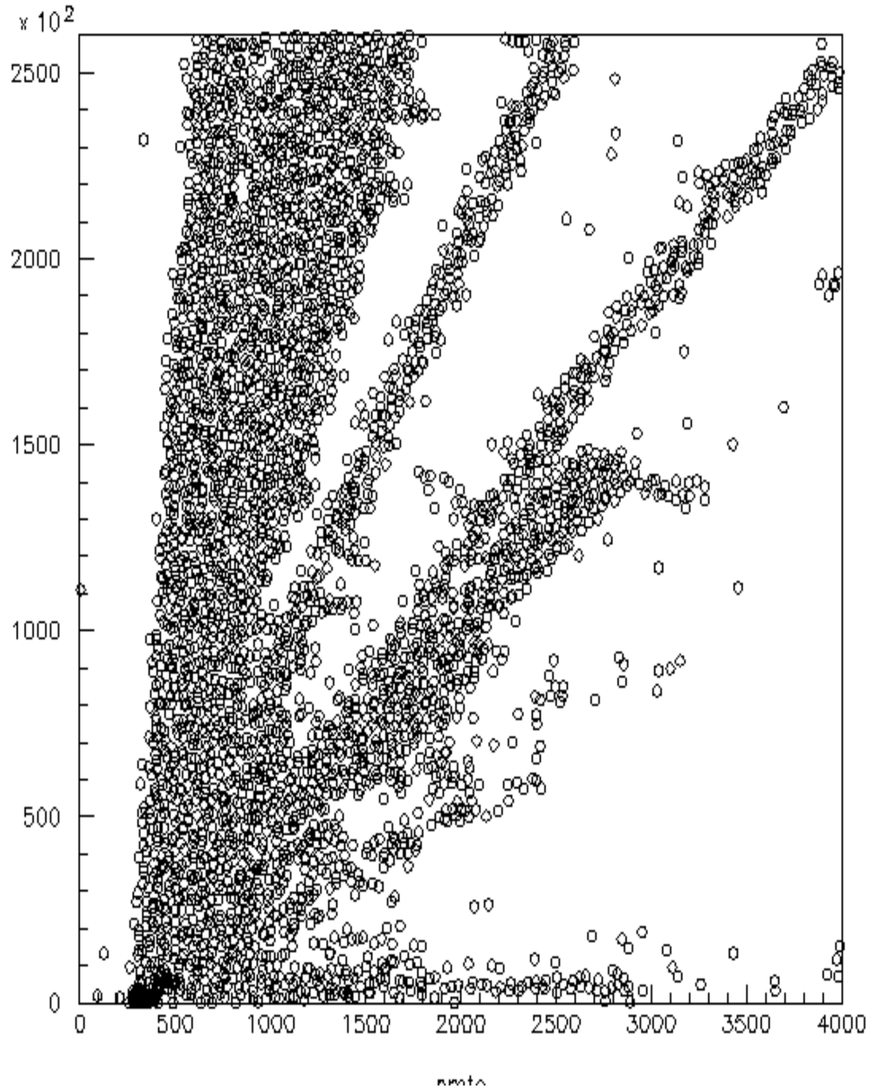
d) $\chi 2$ of exponential fit to current vs time< cut

e) May and June fills only

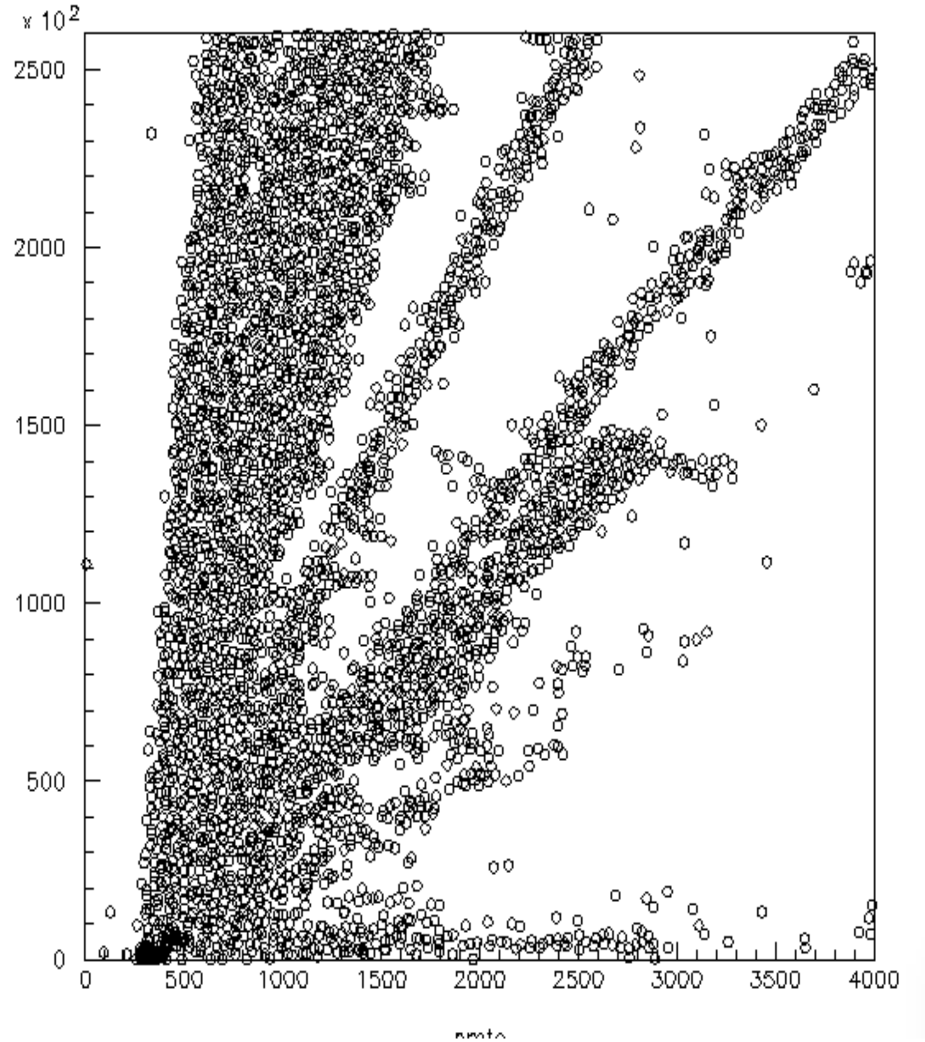
f) At least 3000 seconds.

There is a very large polarization in the El. background (Px/Py≈100)

PMT15 vs PMT10

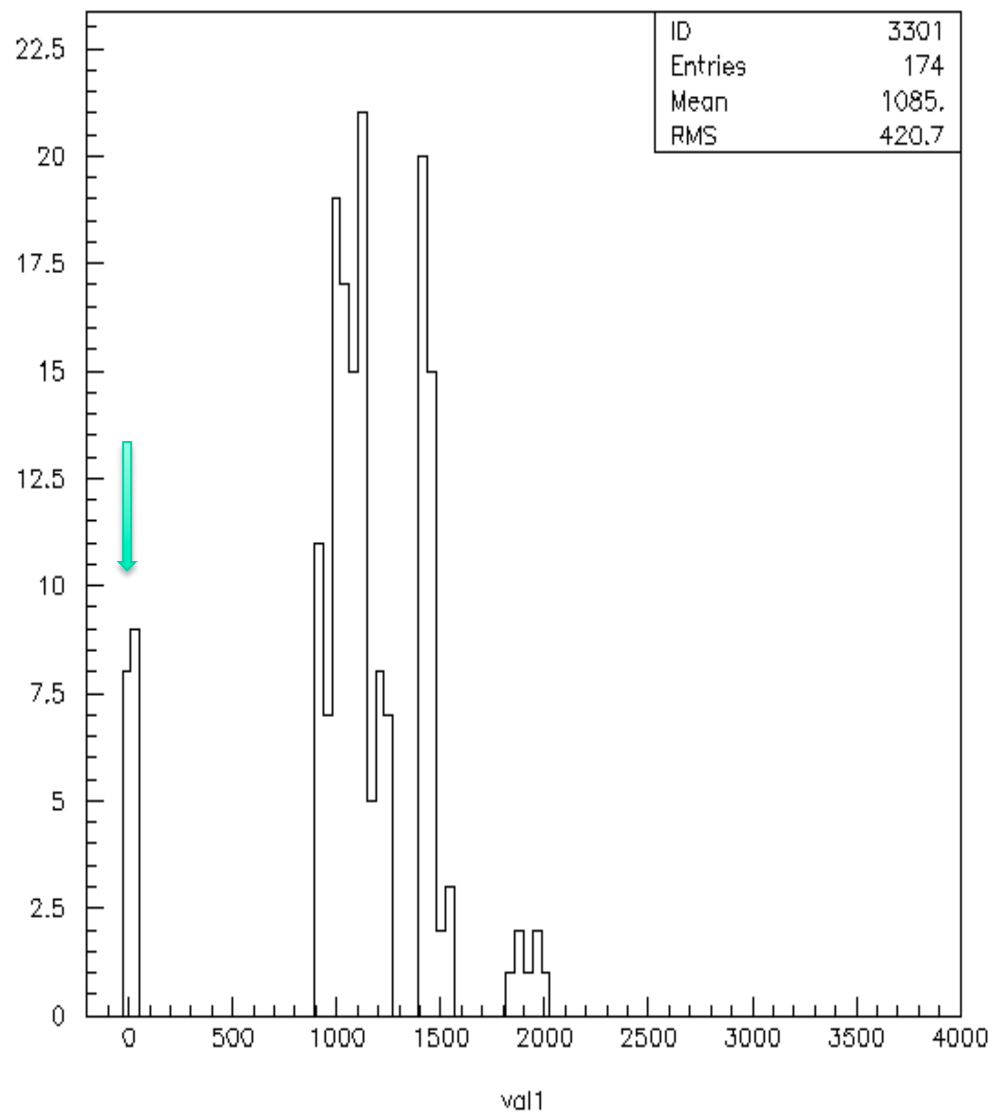


PMT14 vs PMT 11

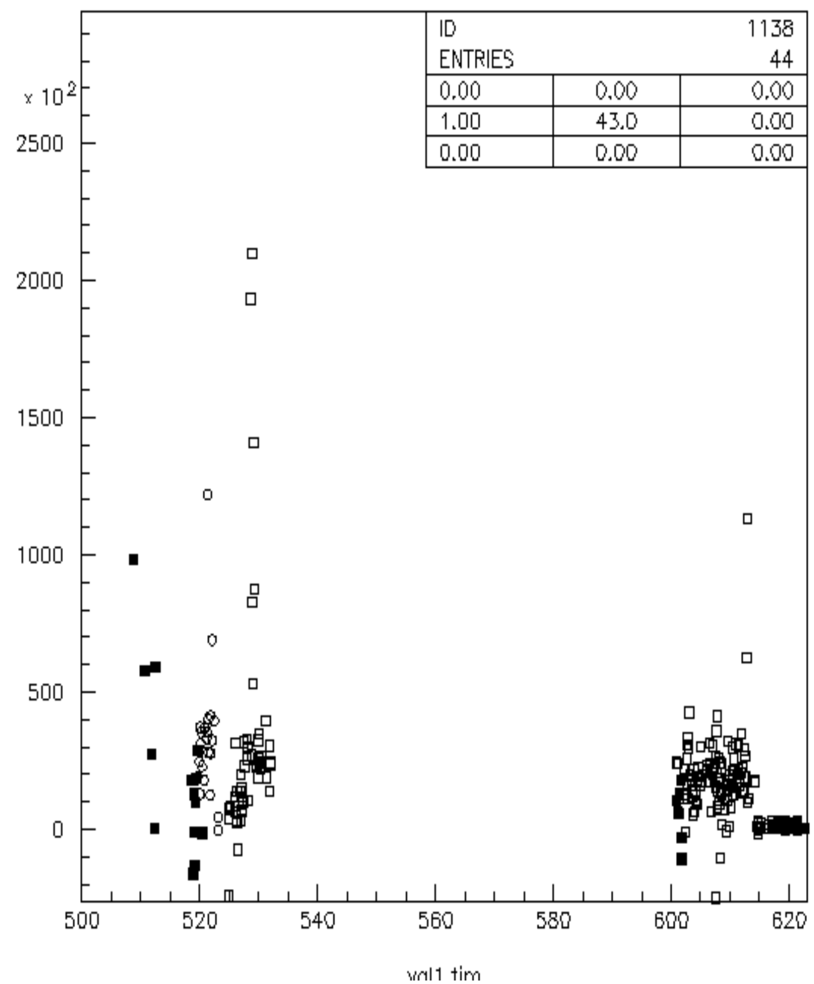


And the linearity constant largely depends on time. Low Backgrounds first seen June 15!

PMT13 B distribution

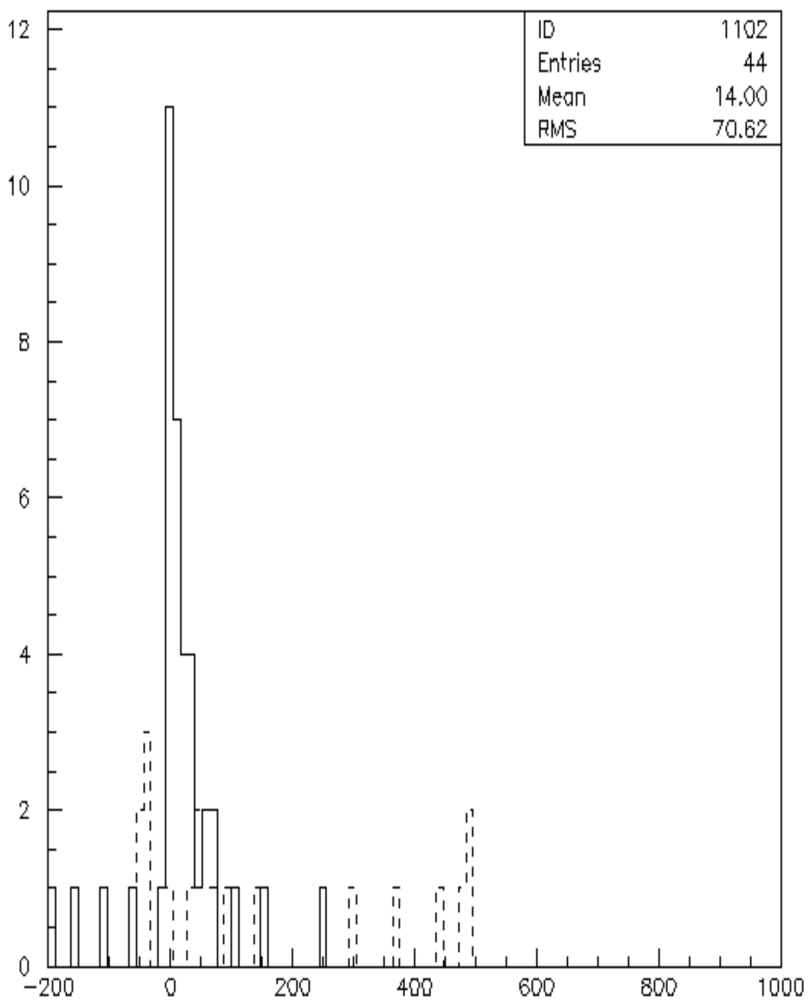


PMT linearity vs time. circles 789, triangles 601,boxes 1576

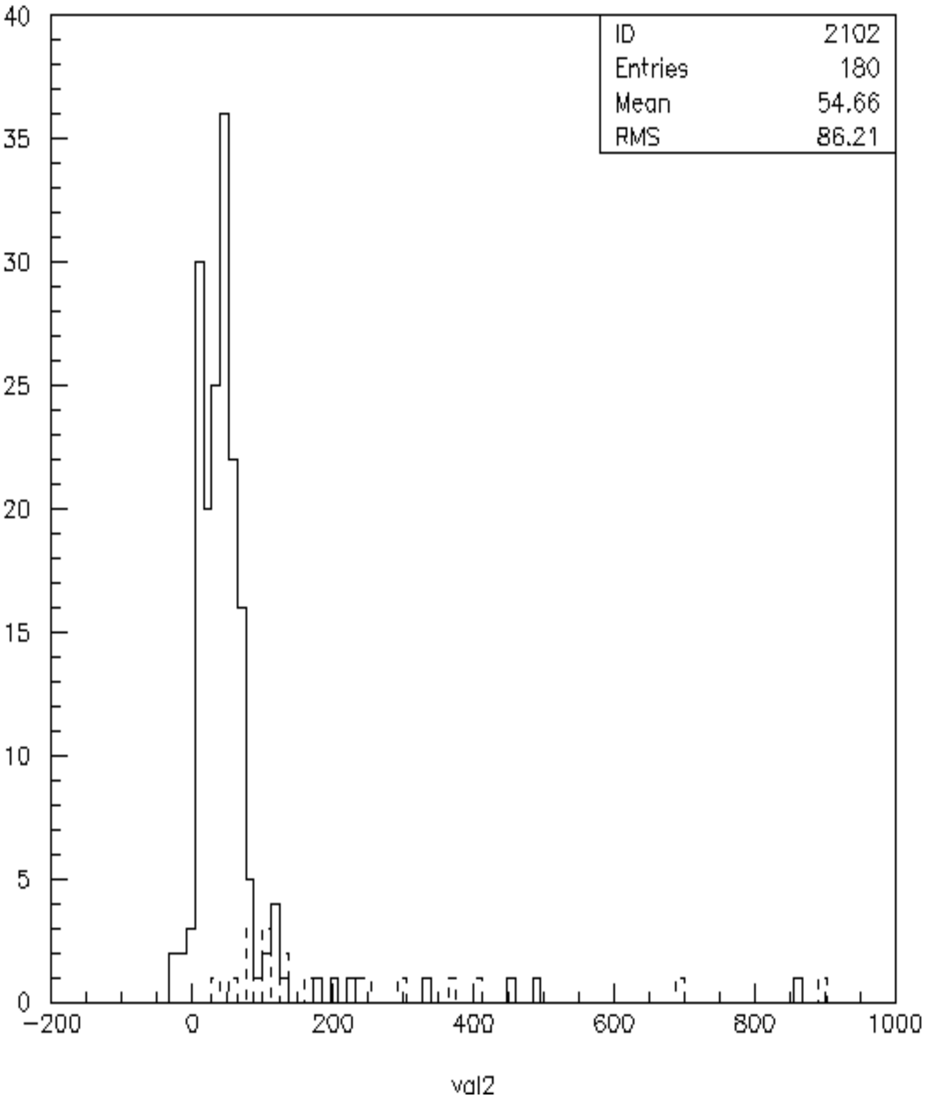


Signal parameter in Oho Down(11 vs 14, Nbunch=1576 and 789). 11=Blue PMT-y (solid), 14=Blue PMT-x(dashed).

1576

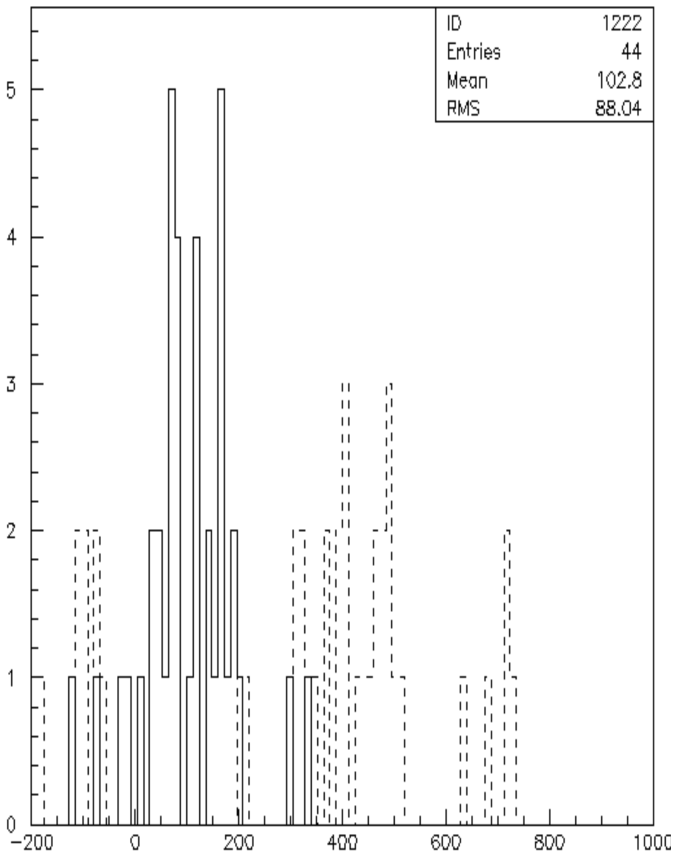


789

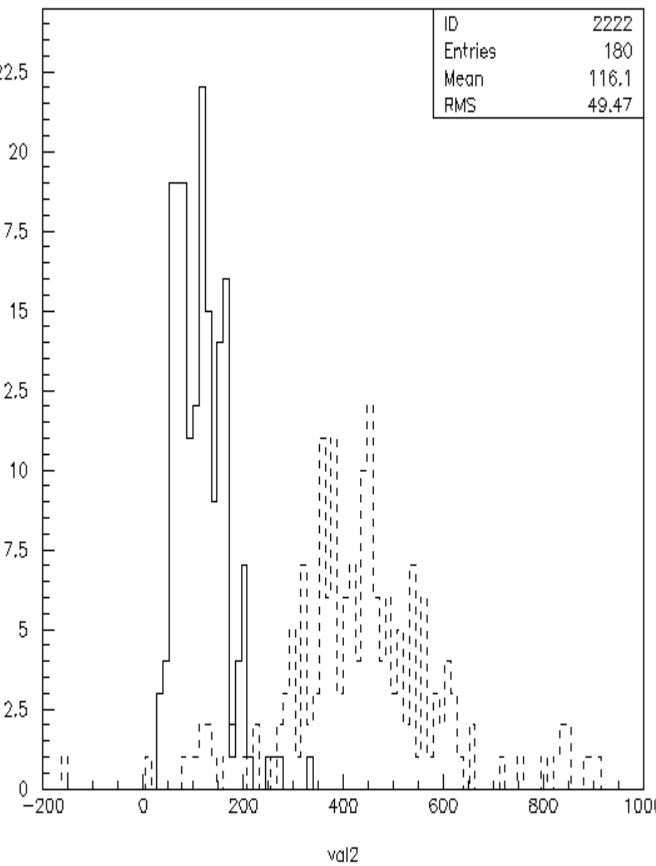


Signal in Nikko Down not very polarized, produces meaningful histograms, and increases with decreasing number of bunches. Blue PMTs. X=dashed, y=solid).

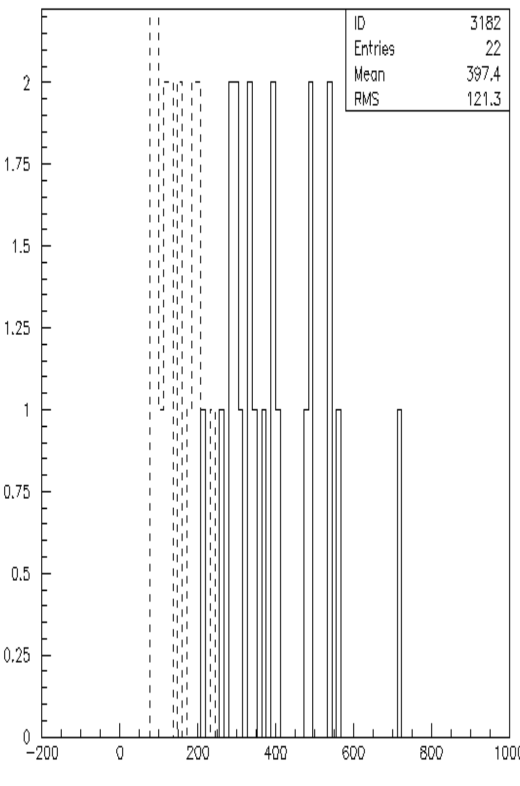
1576



789



601



LABM Yields summary (300mA beams, Phase II, S/B>0.1)

Rate (Hz)/ PMT	Nb=1576	Nb=789	Nb=601
Tot. el. y	326+-20	651+-20	-
Tot. el. x	724+-50	1050+-50	-
Tot. pos. y	421+-10	806+-7	1201+-150
Tot. pos. x	844+-10	1910+-8	2020+-180

Cross check	Expected	Precision
Yield e+	1 kHz	16%
Ratio e+/e-	1.0	25%
Polarization	2.0-4.0	OK
Nbunch dep.	1/Nb	Seen

BPM background Correlation studies

The CSS archive was used to see if backgrounds could be Characterized based on beam orbit. This is necessary for at least the electron Down telescope (even at nominal condition, for Precision measurements). Only QC2 BPMs were available After May 25 on either side of the IP.
Linear backgrounds for our 330 fills (with good chi 2) were correlated to BPM Locations and linear combinations. Modest success but we will build a better event record next year.

PMT	Max. correl.	Variable
El. Pol y	65%	QC2 LE x
El. Pol. x	27%	QC2LE x
Pos. Pol. y	47%	QC2RP x
Pos. pol. x	21%	QC2RP x

Status and summary

LABM not as impactful in Phase II as it was hoped for. Two big Problems:

1) Up telescopes give reflections and rates 10-40 times Lower than Down telescopes. Solution: BP connectors and Primary mirrors being rebuilt with 75% larger mirrors and Non-reflective wider walls.

2) Backgrounds could not be characterized due to un-detailed event Record. Solution: bring internet (EPICS) into our Control Room Through an internet antenna.

3) A candidate signal is clearly seen in 3 out of 4 polarizations (4^{th} One only for low background fills) for most fills, satisfying yields, Nbunch and polarization expectations.

Can this method be used at CEPC?

Almost certainly yes. The method provides information (through polarization) that hard beamstrahlung does not provide. Large angle rates scale like $1/\gamma^2$ so rates will be lower.

However, the CEPC currents are much lower and SUPERKEKB sensors show no significant mirror heating. Larger mirrors (such as the CESR ones, 8X8 mm2) could be used to gain a factor 16. The current telescopes efficiency can be improved by a factor of 3 (a factor of 2 TBD next Fall). CEPC beams are shorter by a factor of 2. PMTs are 4 times less efficient than other photodetectors. So a factor of 100-400 could be obtained back.

The observation of dark zones in the BP was somewhat unexpected. Well planned design can easily make possible reflection spots, directly opposite the viewports, completely dark.