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Video-based X-Ray Beam Position Monitoring at CHES

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Basic Types of XBPMs:

Intercepting

Most fluorescent
screens

barely intercepting

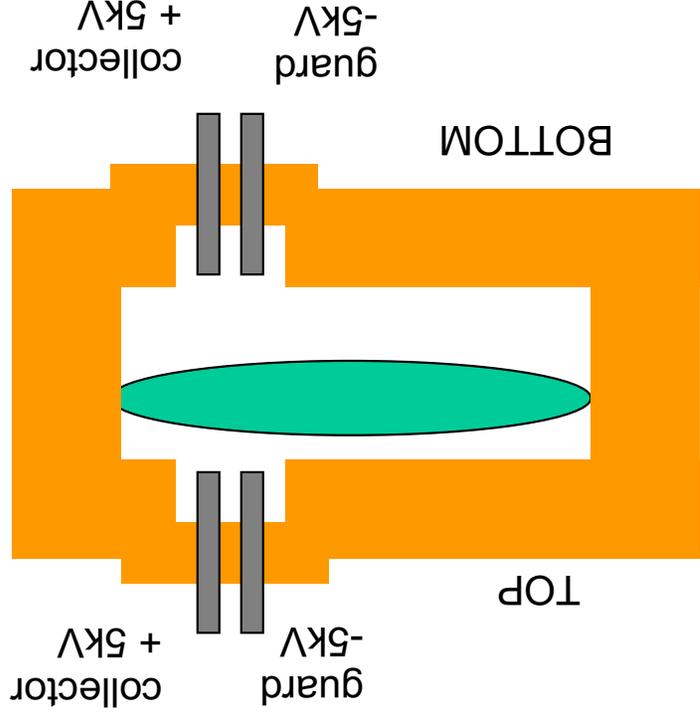
photo-electron types
wires
lateral photo-diodes

non-intercepting

Gas luminescence



Photo-Electron Beam Position Monitor for CHESS wiggler beam lines



- Disadvantage: Measures the fringes only. Hard bend contamination.
- Benefits: Fast, robust, reliable
- Possible problems: Linearity?

$$T = \alpha I_0 x + \beta,$$

$$B = \alpha' I_0 (1-x) + \beta'$$

For symmetrical and linear detector:

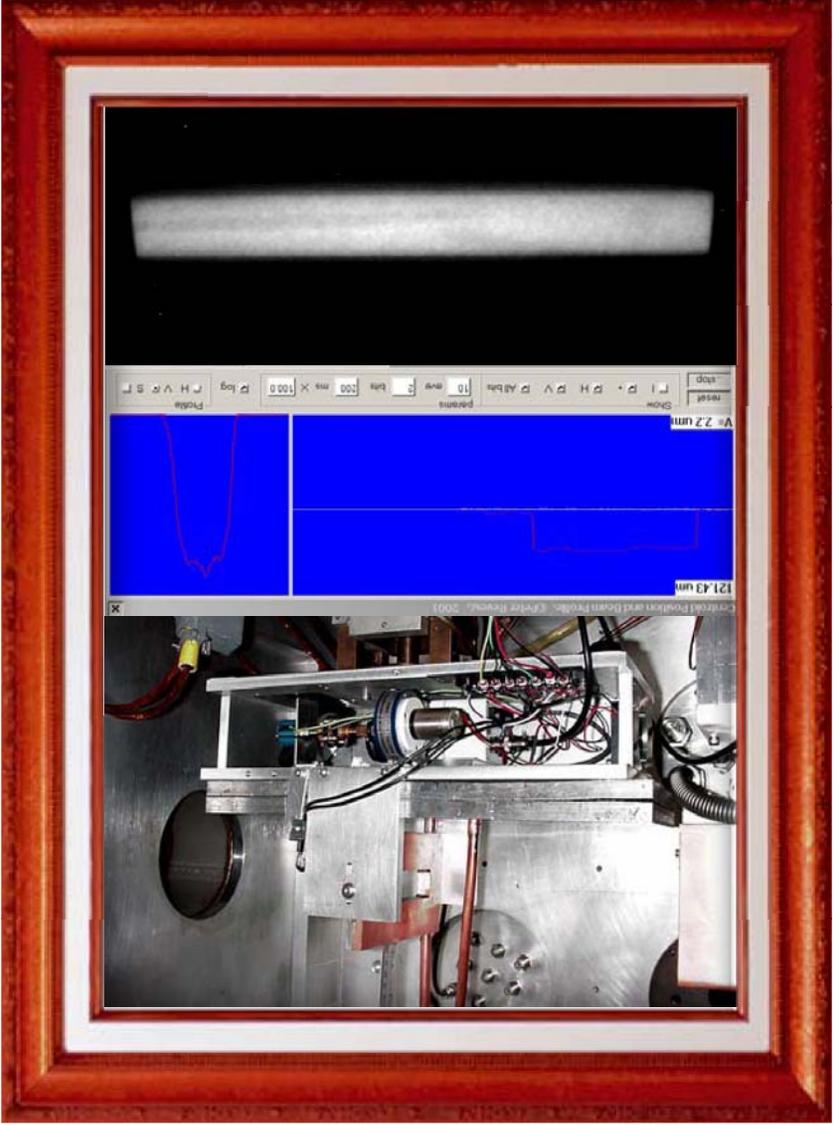
$$x \sim D/S = (T-B)/(T+B)$$



He gas luminescence



Diamond screen



The Classics form 2002
VBPM exhibition at G-line

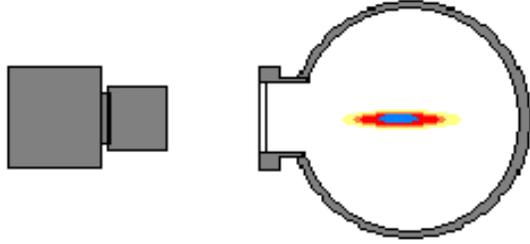
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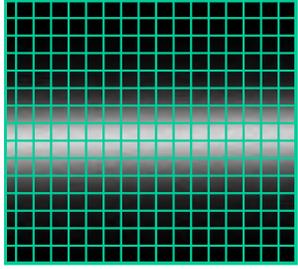


The Principle of VBPM

Camera setup



Captured image



Centroid position

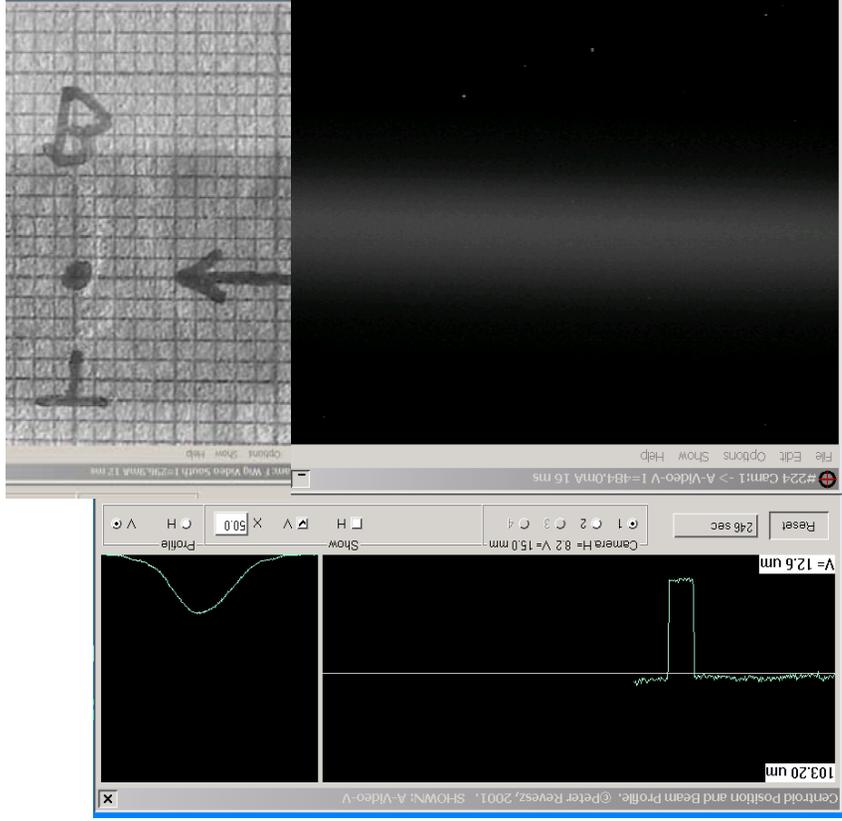
$$X_c := \frac{\sum_i G(i,j)}{\sum_j G(i,j)}$$

$$Y_c := \frac{\sum_j G(i,j)}{\sum_i G(i,j)}$$

Xc and Yc in pixels, but it is easy to cross-calibrate to microns by imaging a mm-grid.

No Z-jack is needed, the whole system can be mounted rigidly.

It is not just a “number” but visual information as well. Important also as a diagnostic tool.



Advantages and Disadvantages of VBPMs

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PRO

- Non-intercepting
- Visual information
- Position is basically what the user has
- Provides beam profile
- No Z-jack needed, easy calibration
- Beam size information
- Beam intensity information

CON

- More complicated H/W
- Requires special software
- Requires computer
- For analog cameras: noise creates artifact beam motion
- Non-vacuum
- Possible radiation degradation
- “Zingers”



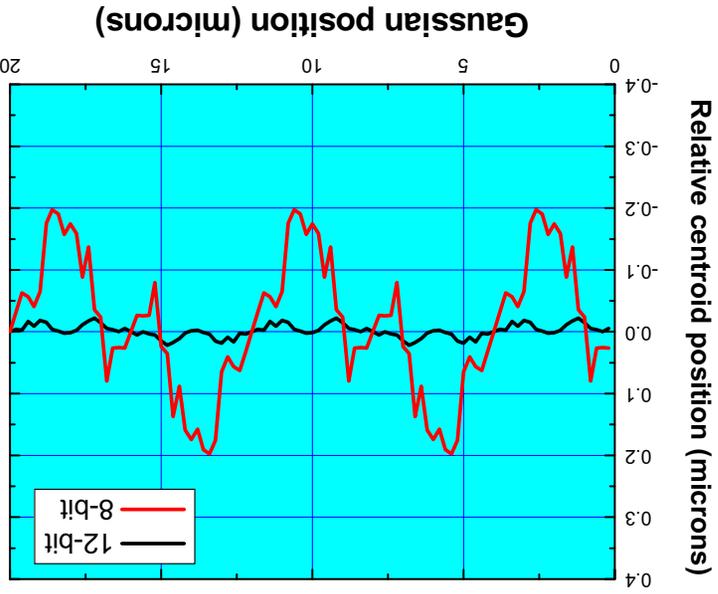
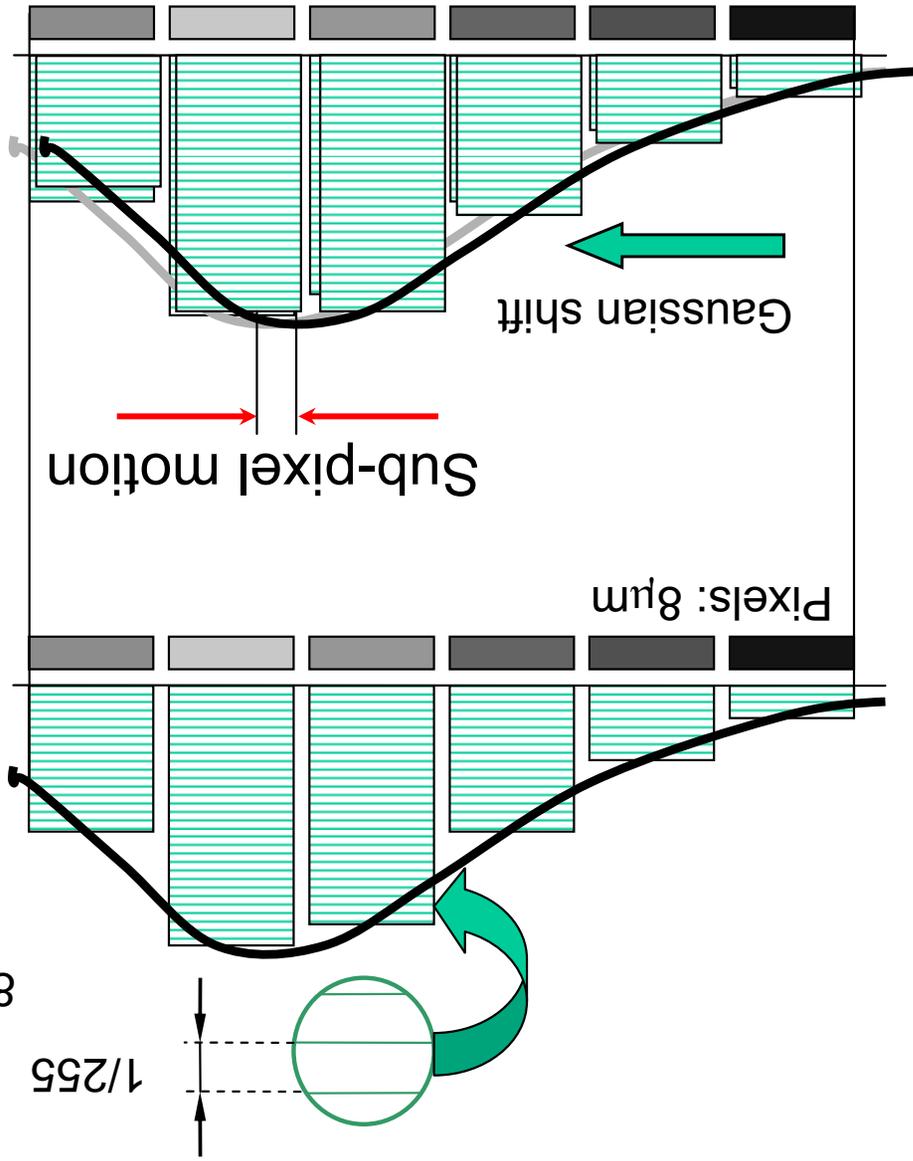
Cornell University
Cornell High Energy Synchrotron Source

How sensitive is the centroid measurement?



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8-bit digitalization: 255 Grayscale steps



Computer simulation



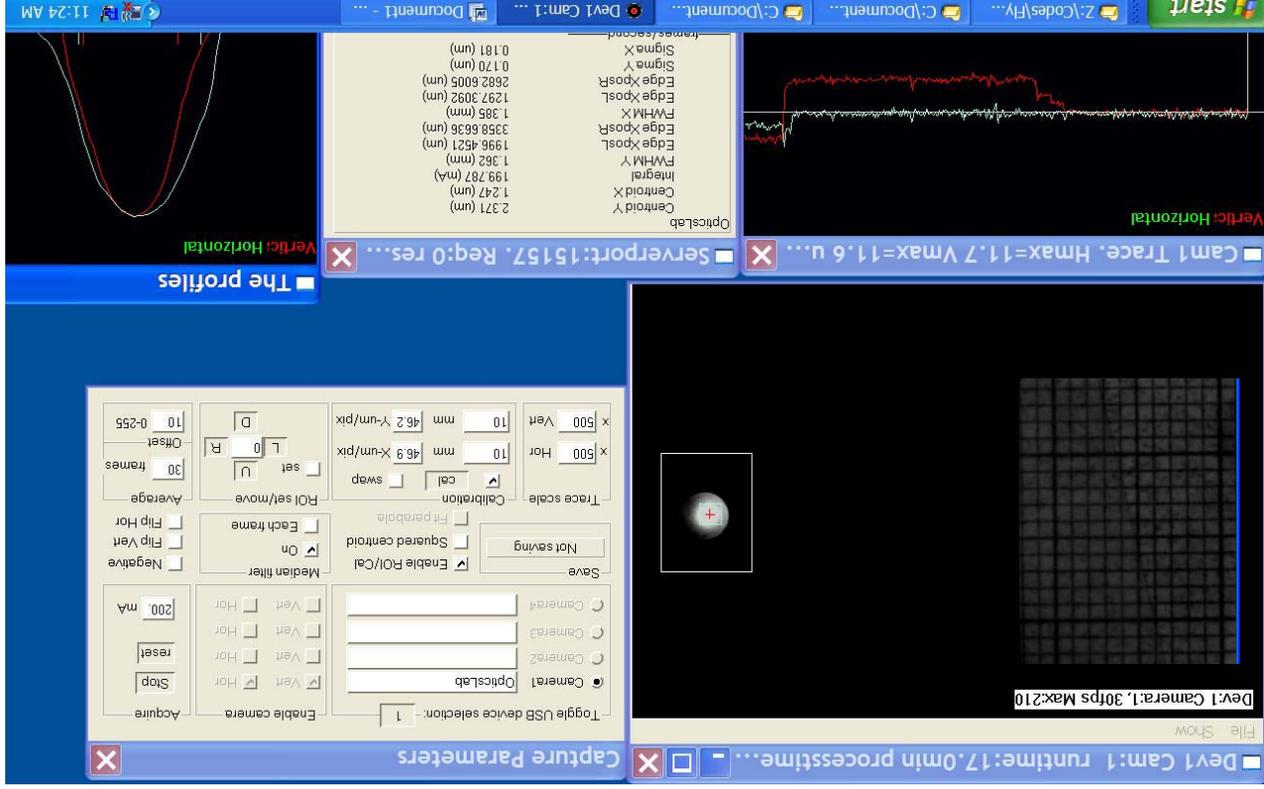
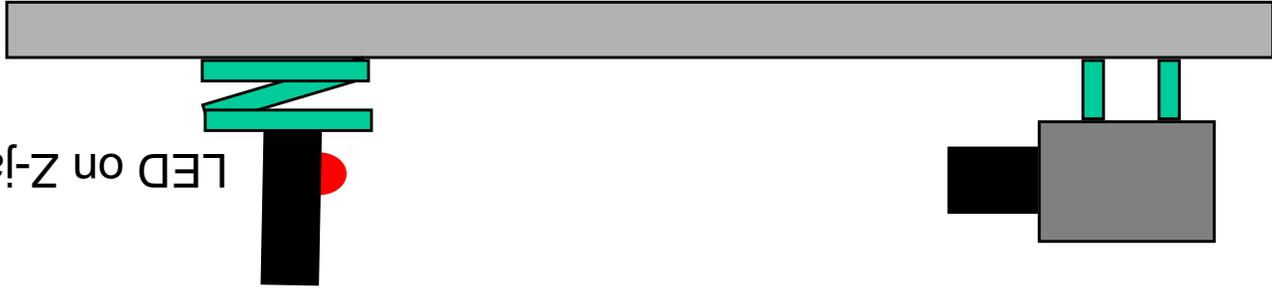
Bench test of centroid position sensitivity

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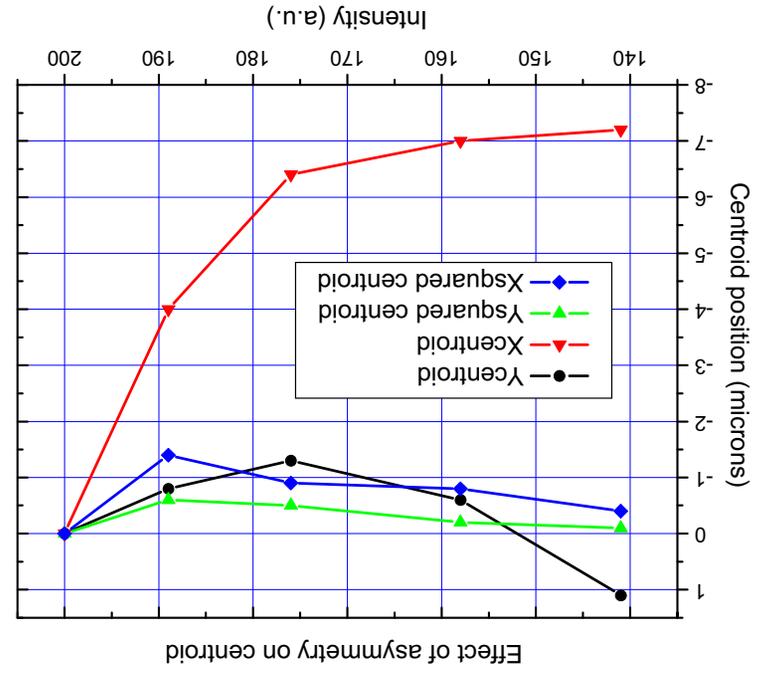


Optical bench

LED on Z-jack



Linearity and Offset



The use of squared centroid helps to reduce the artifact due to offset an asymmetry

$$\text{Squared centroid} : x_{sqc} = \frac{\sum x \cdot I_2(x, y)}{\sum I_2(x, y)}$$

-Helps to reduce the effect of offset for asymmetric profiles.





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VBPM program and architecture

Beam lines Analog cameras, Sensoray 4 input USB 2.0 frame capture devices



<p>Communicate:</p> <ul style="list-style-type: none"> • Accept UDP connection from server • Accept and respond to: SENDALL LISTALL and SENDBYNAME • Send data 	<p>Frame Capture:</p> <ul style="list-style-type: none"> • Get pixel data in ROI • Adjustments: median, rotation, flip • Calculate: centroids, intensity, FWHMs, edges • Display: standard deviations • Image, centroids, trace, profiles 	<p>Camera/image control</p> <ul style="list-style-type: none"> • For multiple cameras: Enable/Disable cameras • Set ROIs • Adjustments: Brightness, gain, offset, averaging • Calculate: centroids, intensity, FWHMs, edges • Display: Image, centroids, trace, profiles • Calibrate: Pixel-to-micron Intensity-to-mA
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VBPM Centroid program user interface



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Allows to control 12 cameras,

Allows operator to visually inspect all camera images to optimize settings,

Transmits positions, width, intensity to signal collector program,

Saves data,

Saves/retrieves system configuration

FW_PM_V		FH_PM_V	
Centroid Y (um)	16336.386	Centroid Y (um)	5.643
Integral (mA)	0.000	Integral (mA)	196.444
FWHM Y (mm)	0.001	FWHM Y (mm)	8.590
Edge Xpost(um)	82.6000	Edge Xpost(um)	8985.1429
Sigma Y(um)	0.0000	Sigma Y(um)	17575.6025
-----frames/second-----			
Dev1	13	14	11
Dev2	26	23	
Dev3	14	14	20
-----Average:16.9 FPS -----			

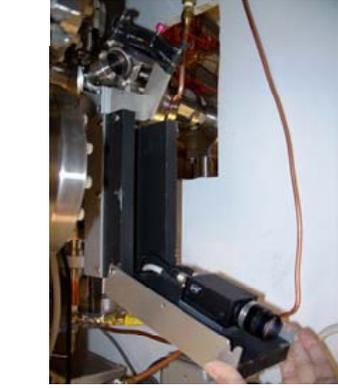


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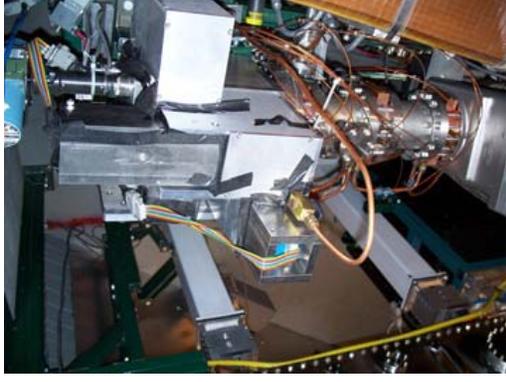
D-line diamond
VBPMs in tunnel
And cave



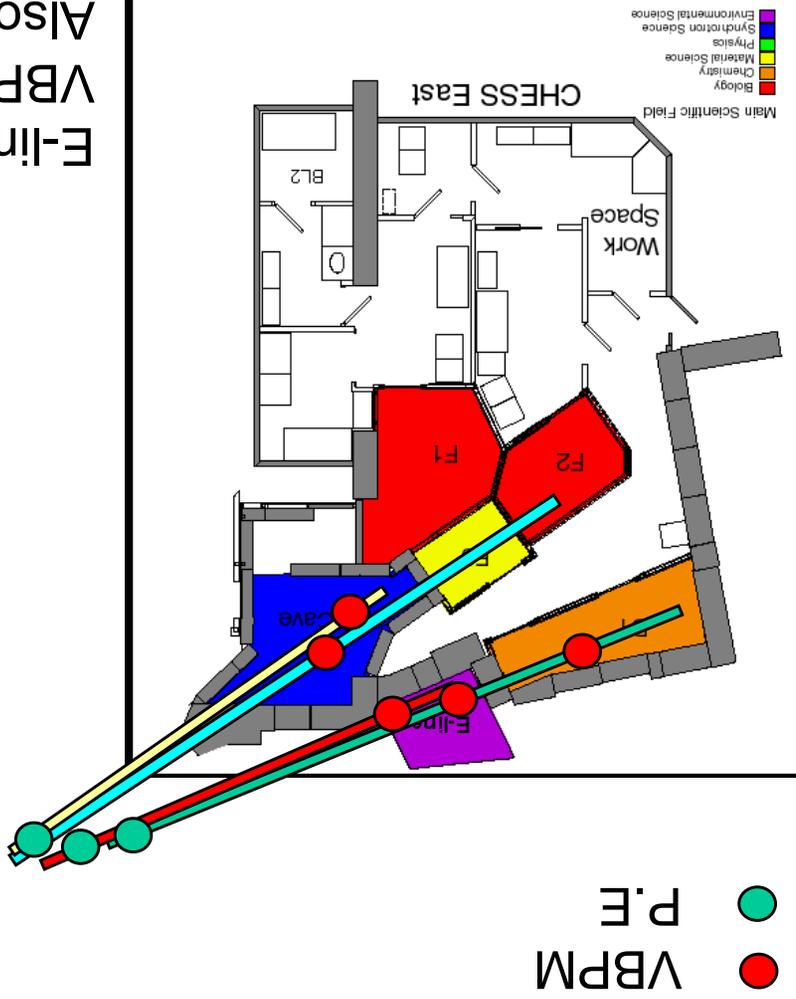
F1-F3-line
He VBPMs
in cave

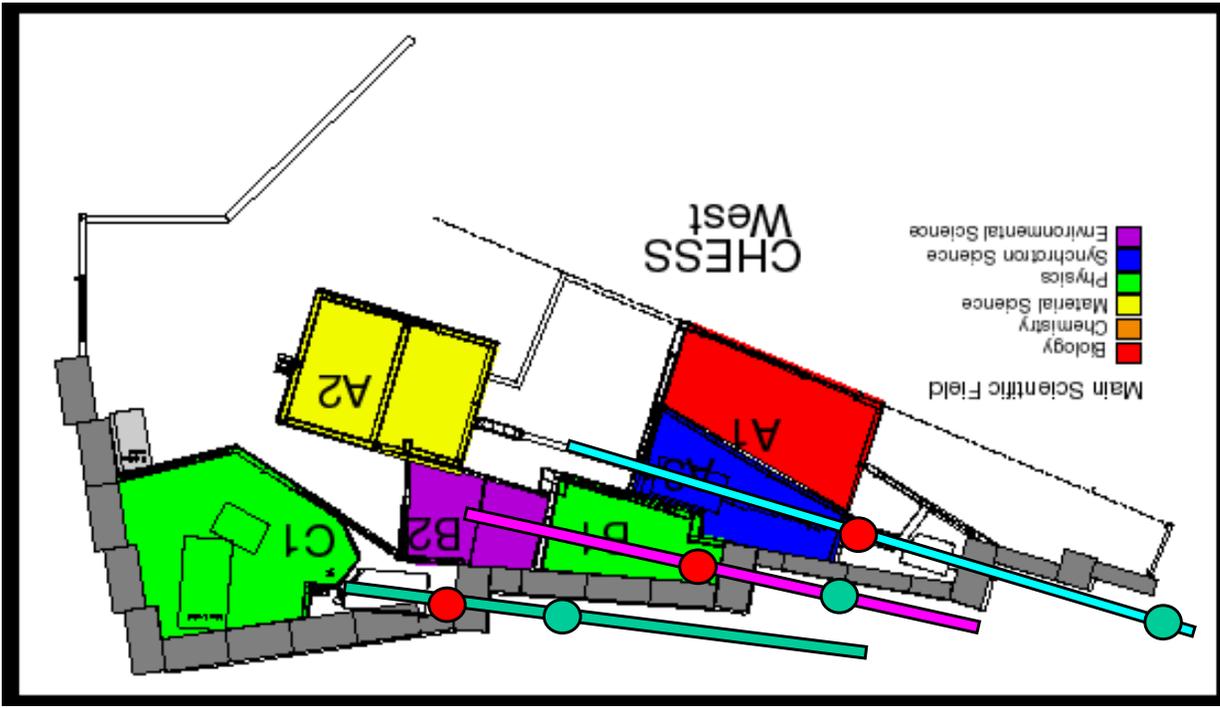


E-line He
VBPM in tunnel
Also source size
measurement

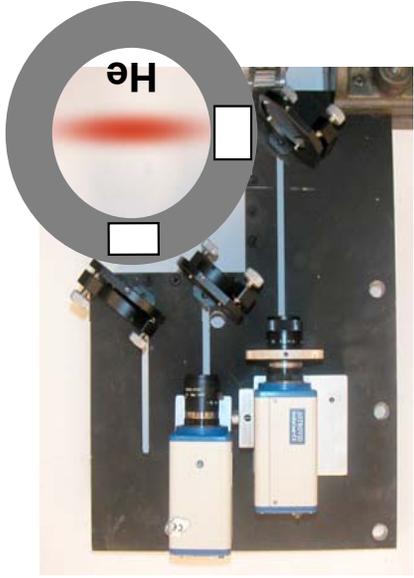
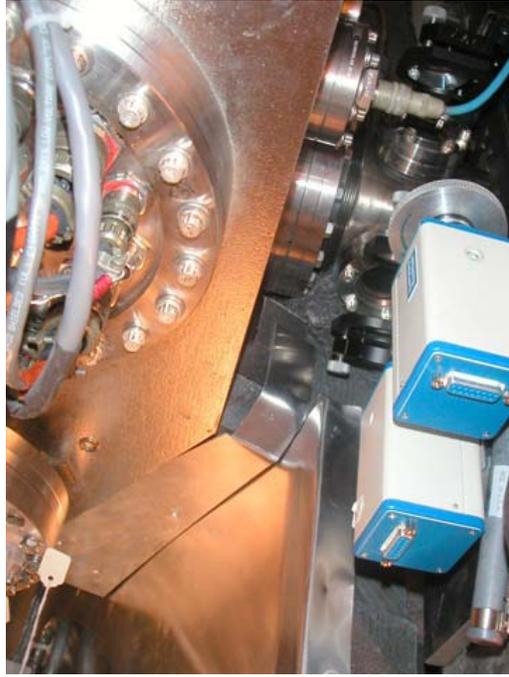


CHES-East Position monitors





● P.E
● VBPM



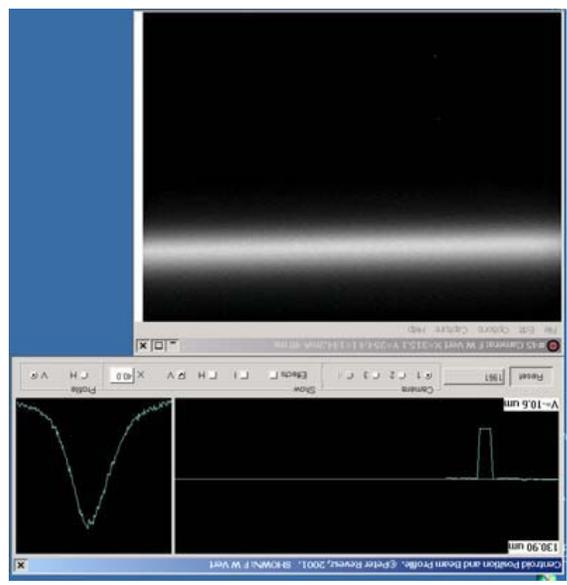
CHESS-West Position monitors

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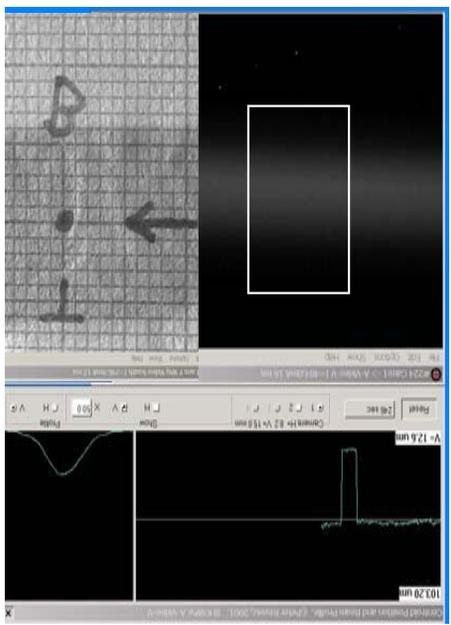




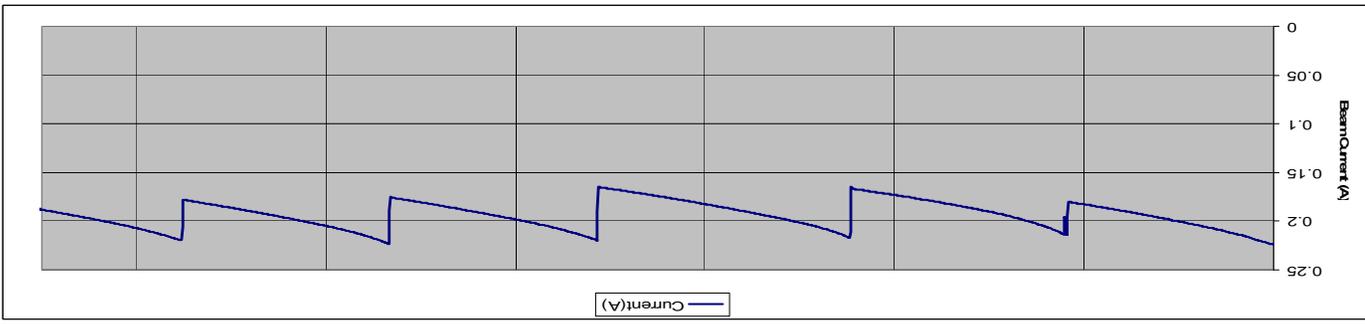
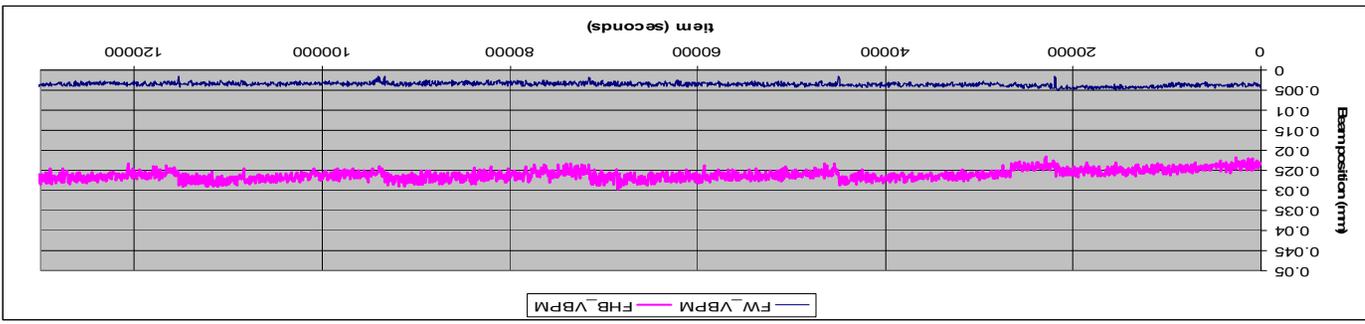
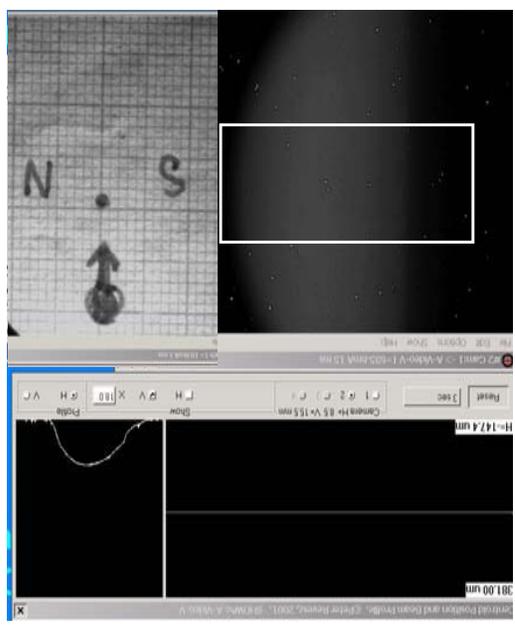
F-W_VBPM



A-Ver_VBPM



A-Hor_VBPM



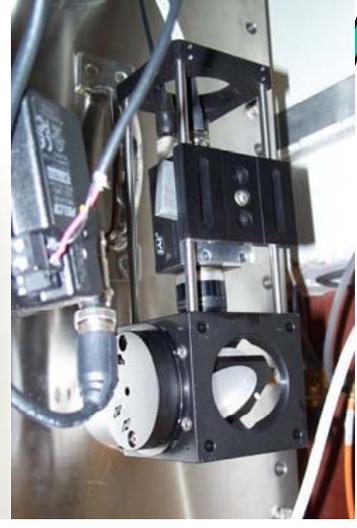
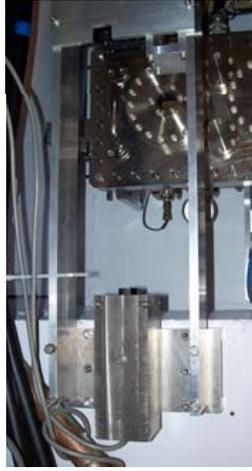
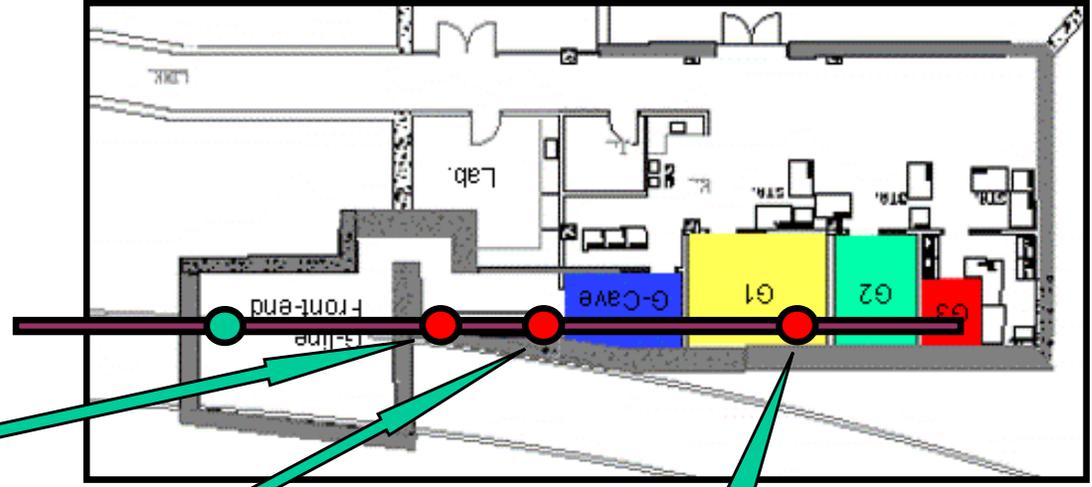


CHES-G-line Position monitors

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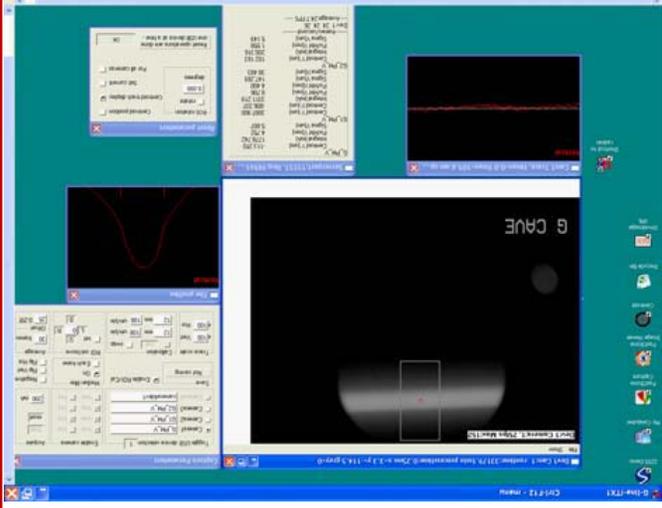
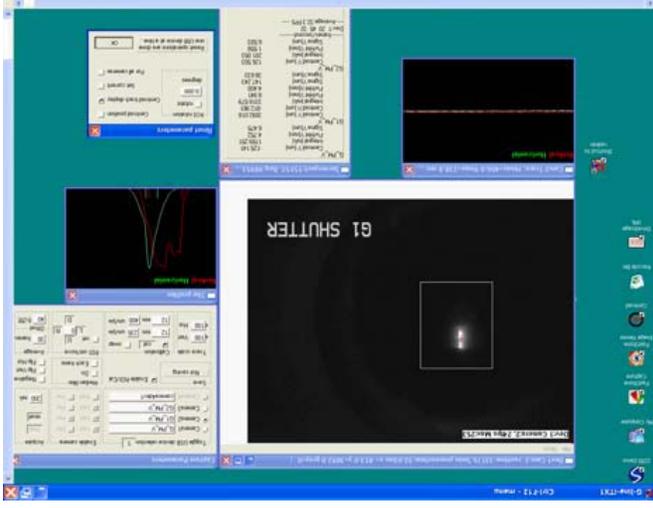
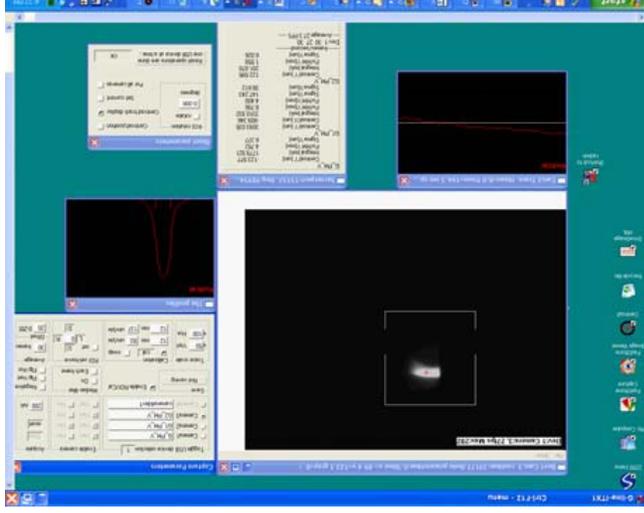
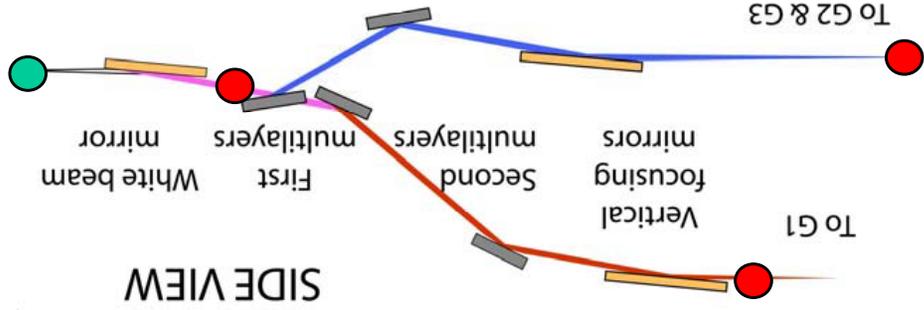
● VBPM
● P.E





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CHES-G-line Position monitors



The Video BPM image of He-luminescence at G-cave. Here beam reflected from the mirror upstream is shown.

Diamond Video BPM image at G1 shutter location (passed multilayers and focusing). Spill-over is seen.

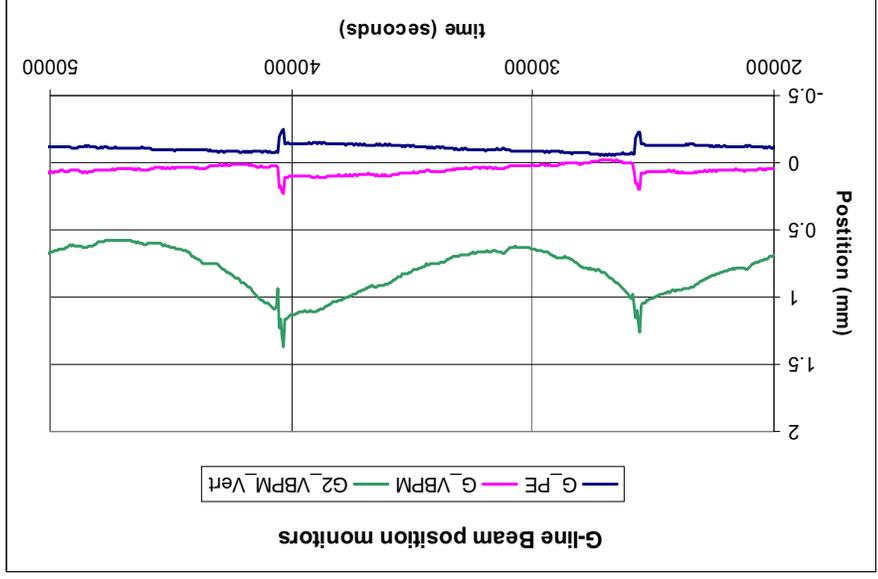
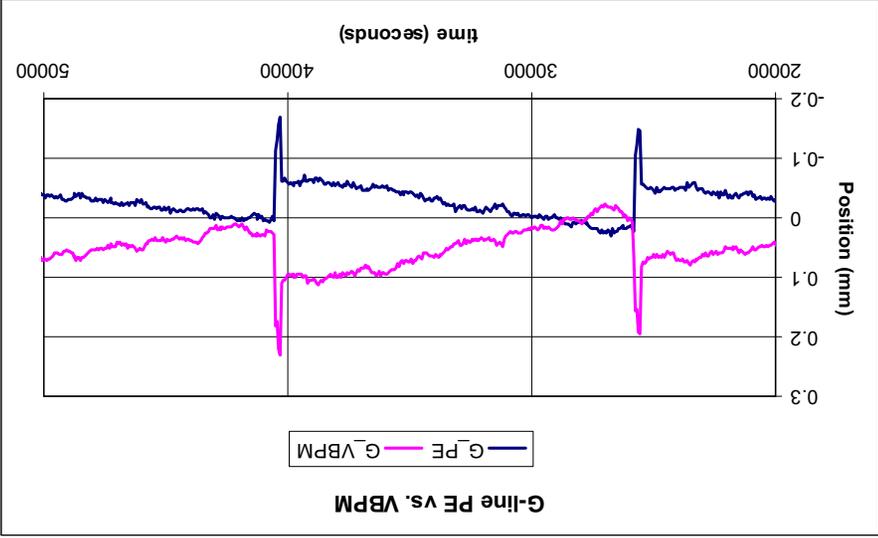
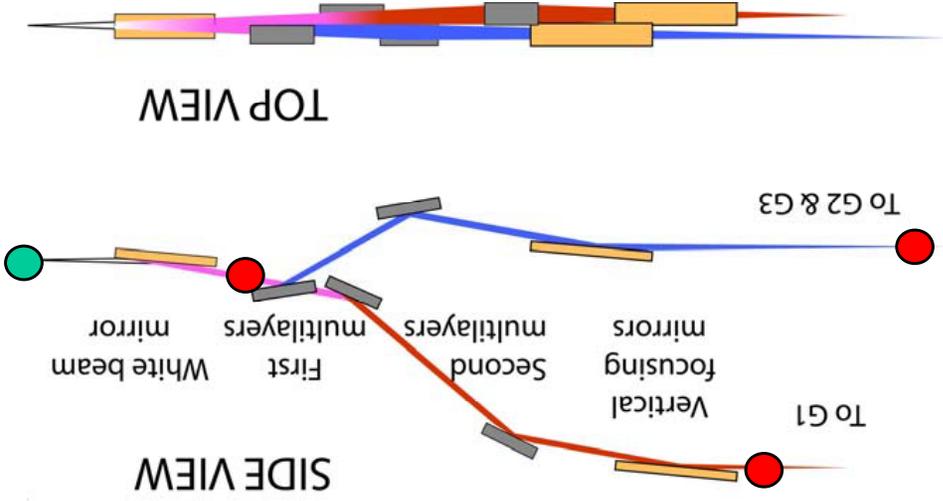
Diamond VBPM image at G2 beam passed at multilayers and focusing mirrors



G-line position signals

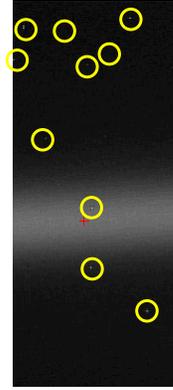


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Some VBPM pitfalls

- Offset effect on position
- Noise and ground-loops
- “Zingers”
- Intensity saturation
- Contamination, humidity

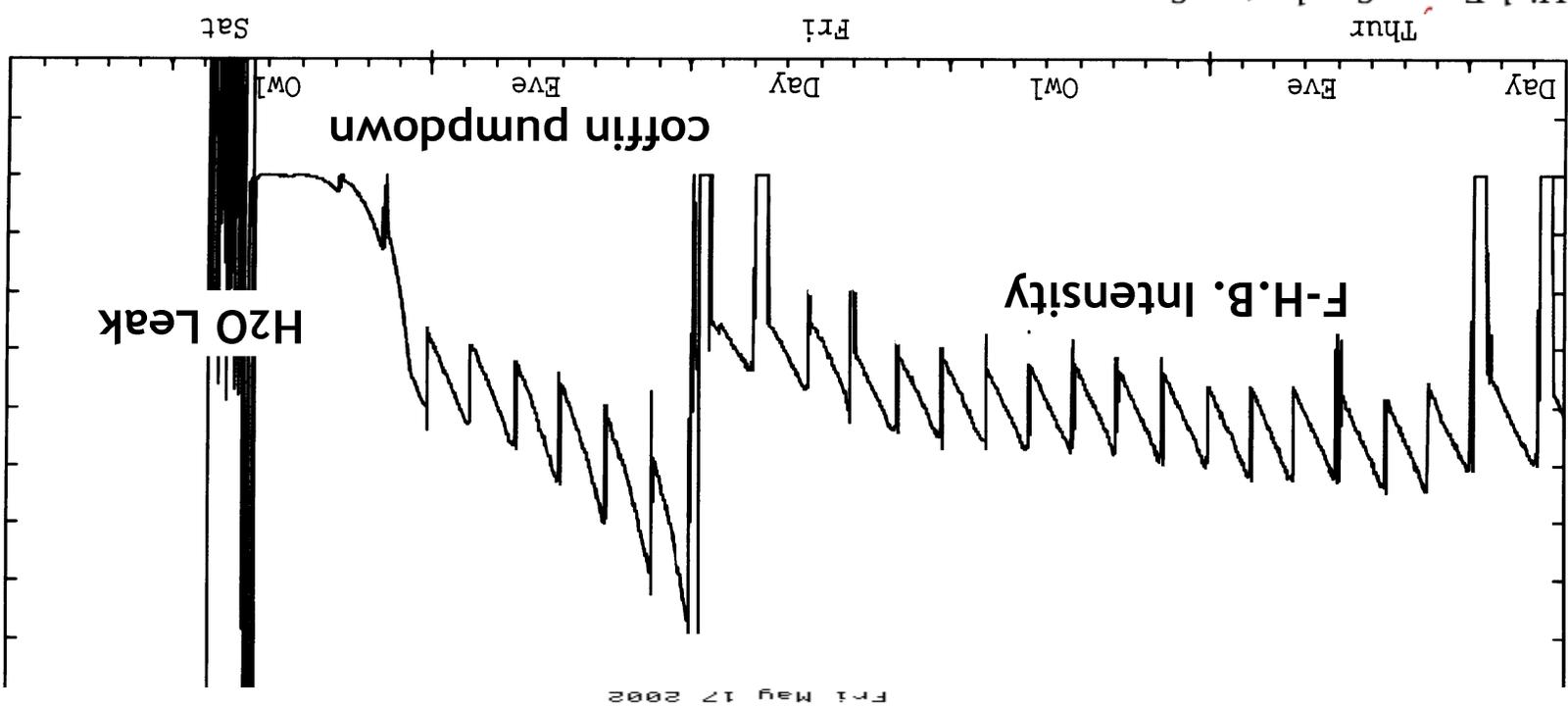
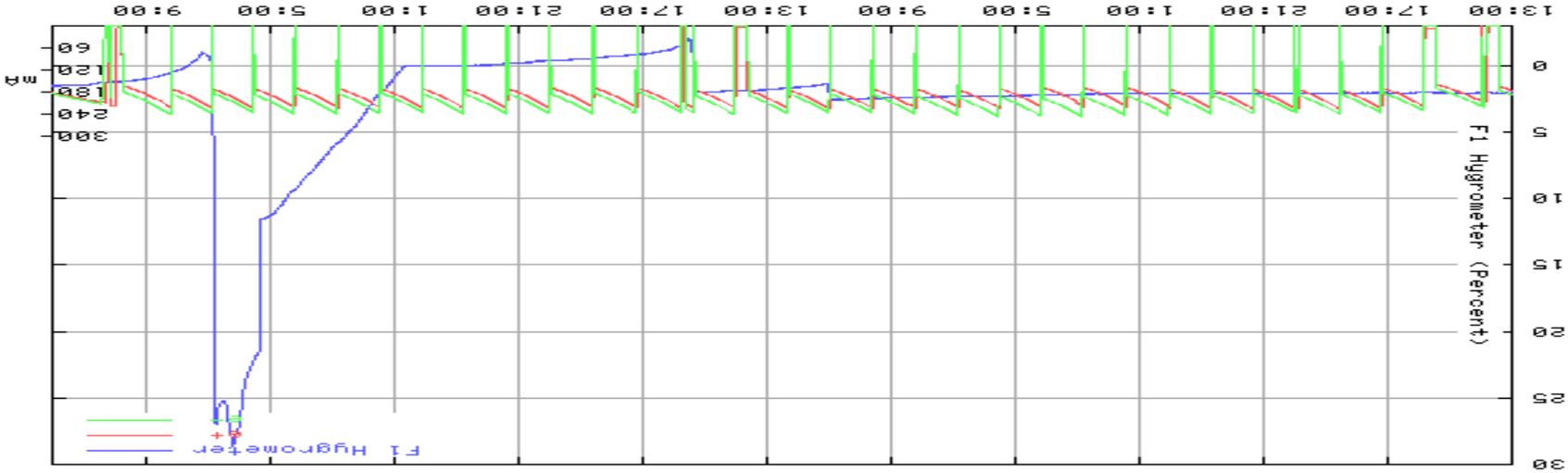


To minimize these effects:

- Eliminate background light, adjust offset
- Short video cables, filters and video amplifiers, ultimately use digital camera
- Image filtering i.e. median, shilding
- Optimize optics, shutter time.

Humidity effects He luminescence !

21 FPP



Conclusion and Summary

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Video BPMs give multitude of important operational information about X-ray beam conditions.

The future:

Application of intelligent cameras, where the frame processing is inside the camera with built-in FPGA and DSP. This will reduce noise, the network data traffic volume and make possible faster frame capture.

references

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CP705, Synchrotron Radiation Instrumentation: Eighth International Conference
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Cornell University
Cornell High Energy Synchrotron Source