Recent developments in crystal collimation at the Fermilab Tevatron (T-980)

FNAL, CERN, PNPI, IHEP, INFN

Dick Carrigan

UA9 Crystal Collimation Workshop, Rome, Italy

February, 2011

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a FNAL, Batavia, U.S.A. b IHEP, Protvino, Russia

c PNPI, Gatchina, Russia

T-980

Brief History of T-980

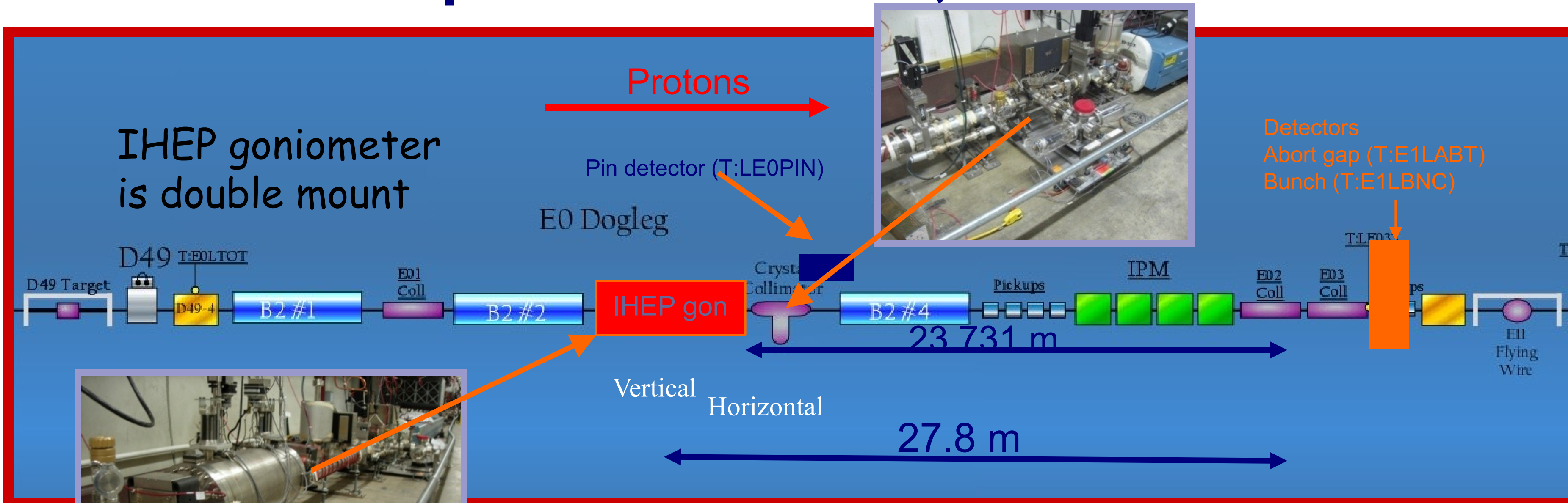
- 2005-2006 FNAL (T-980) used one crystal.
  - (O-shape O-BNL-02) with large miscut 1.6 mrad
- In 2005, Tevatron demonstrated channeling at 980Gev and found that proton halo loss at CDF IP could be reduced by factor of 2 as predicted.
- In 2009, crystal collimation was used during Tevatron collider stores
  - A successful automatic crystal insertion system was installed and operated.
  - A reduction of ring losses was reproducibly observed along with local loss effects on the collimator due to crystal channeling.
  - No adverse effects were found.
- In 2010 vertical collimation studies including multiple volume reflection (MVR) were underway
  - Pixel installation starts
  - Problems with QM, Ferrara 16 strip

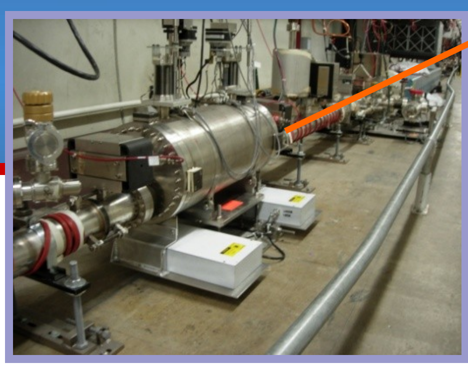
Some recent presentations

Shiltsev , IPAC 2010, Kyoto
http://accelconf.web.cern.ch/accelconf/IPAC10/talks/tuoamh03_talk.pdf

Still, Channeling 2010
http://www.lnf.infn.it/conference/channeling2010/presentations/101005/ch2010_still.pdf

T980 Setup in Tevatron E0, F17 circa 2011

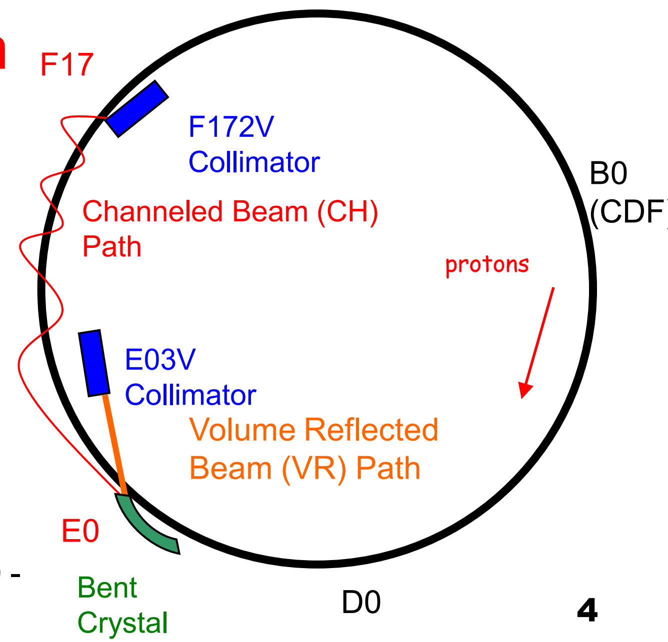




E0 expanded region

> 1 km separation

F17 expanded region



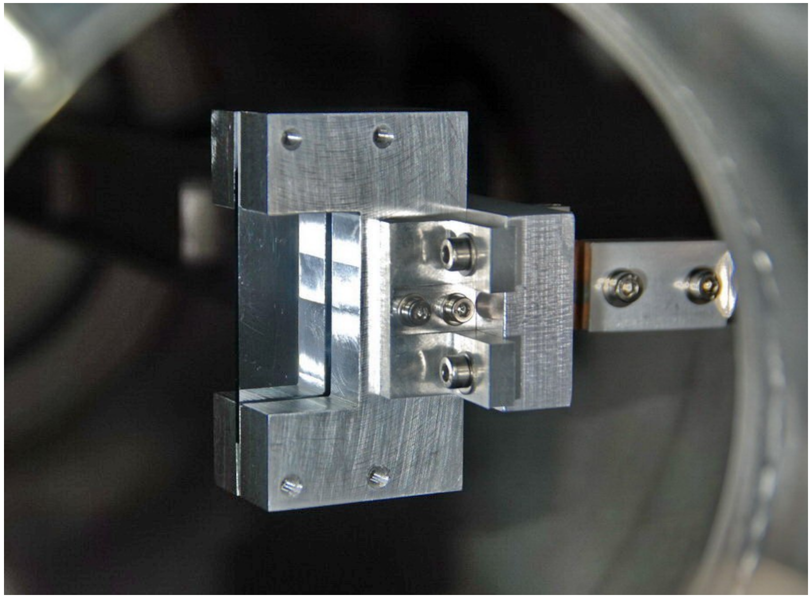
PNPI Quasi-Mosaic Crystal

Similar QM crystals used for UA9 measurements at SPS in 2009.
Feature: short bending length,
smaller nuclear interactions

Opening in bending device 2x10 mm^2

2-mm thick, 120-μrad bending, miscut angle 50 μrad

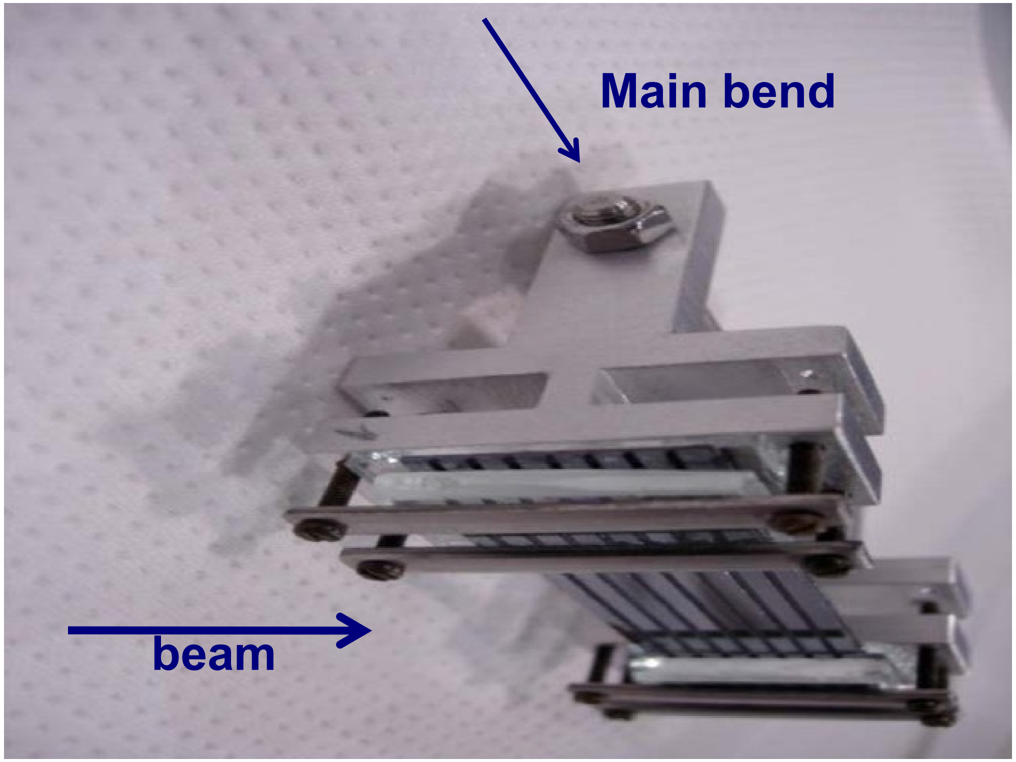
Characterized, tested and installed in the vertical IHEP goniometer.



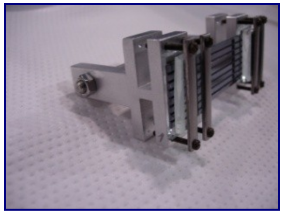
Problem – no clean evidence of CH or VR in five dedicated End-of-Store (EOS) sessions over last three months!
Ivanov asks if in later turn it hits aluminum holder?
Pin counter nearer horizontal? Maybe a 2nd pin?
BLMs out of time? Now being checked

IHEP MS-08-09 eight crystal "strips" separated by "groves", major face is (111)

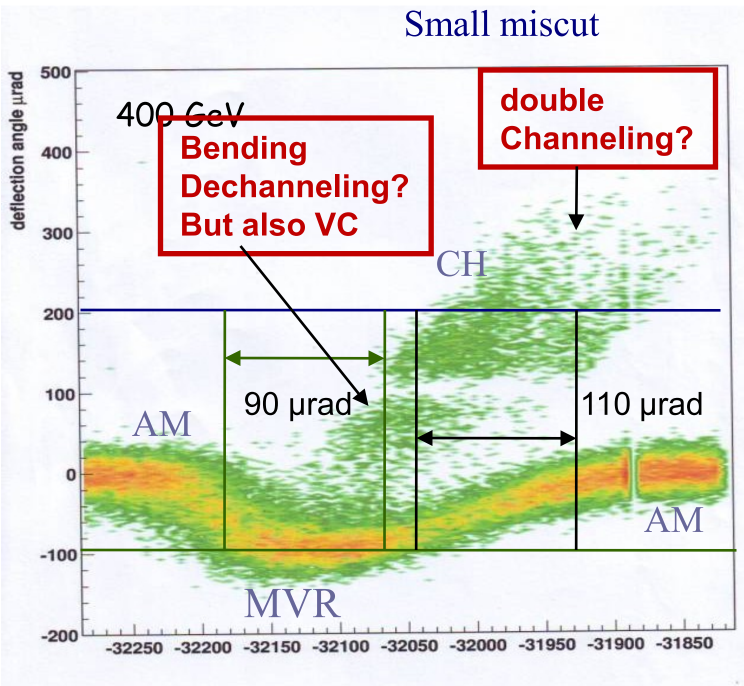
- interesting example of volume reflection
- well studied earlier at H8 and in simulations
- may also indicate a few challenges



IHEP MS-08-09 characterizations at CERN North Area RD22 H8, 400 GeV/C protons

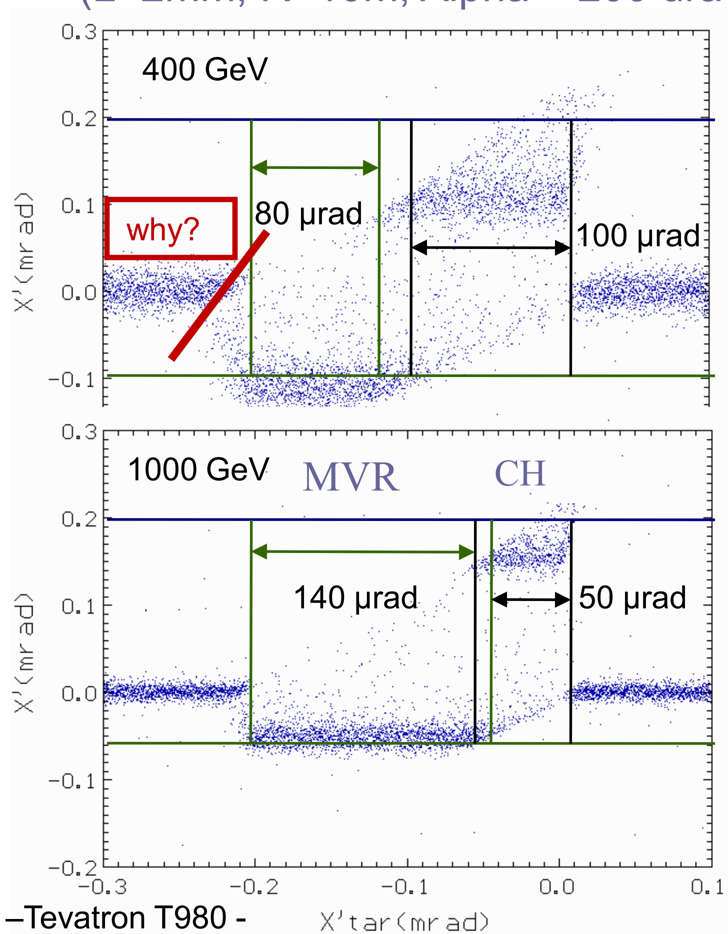


Name: MS-08-09
Bend: 63urad (VR)
Bend: nominal
200urad (CH)
8 strips
Small miscut

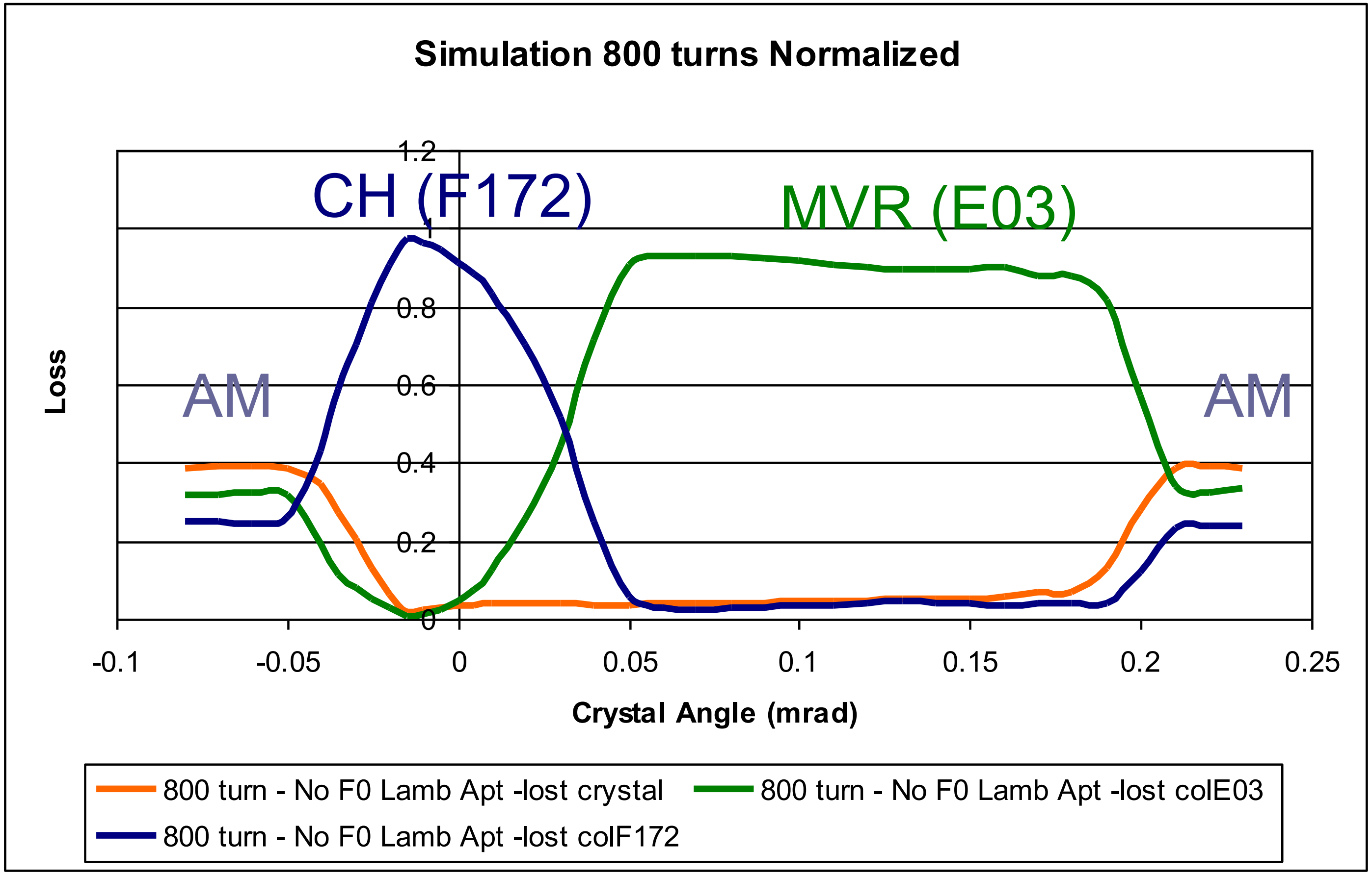


Crystal angle

Yazynin simulation
8 Ideal strip crystals Si(111) "array"
(L=2mm, R=10m, Alpha = 200 urad)

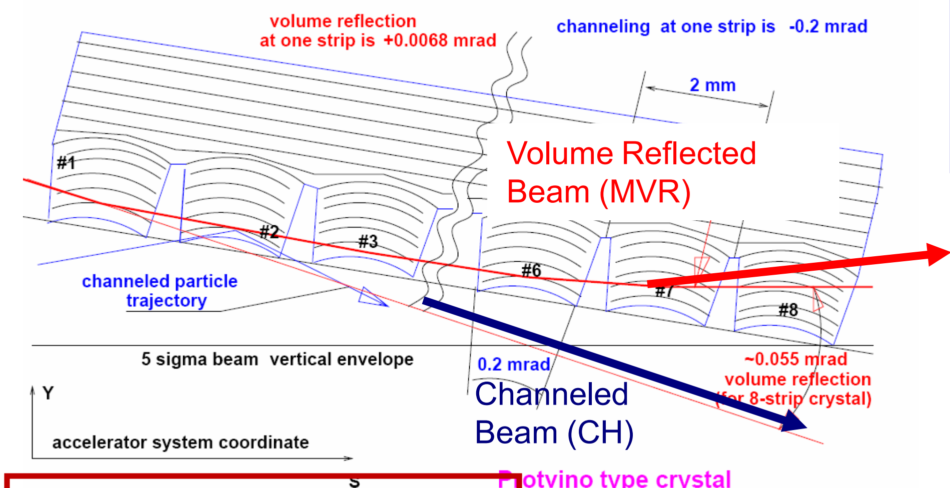


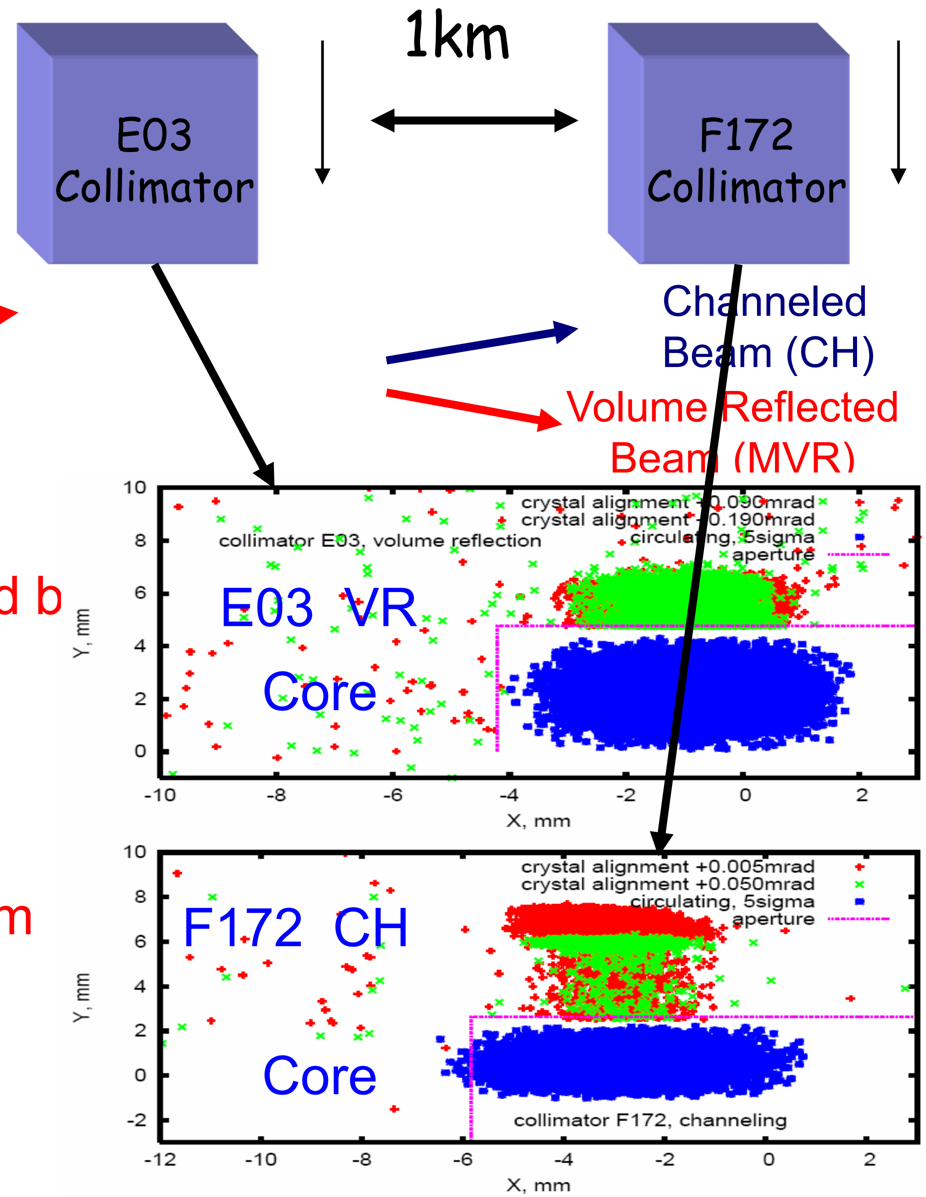
Simulations for IHEP 8 strip at 1 TeV



Simulations by:
S. Drozhdin with imbedded code from I. Yazynin

Vertical Multi-Strip Orientation





Watch out!
Si wafer may not be flat

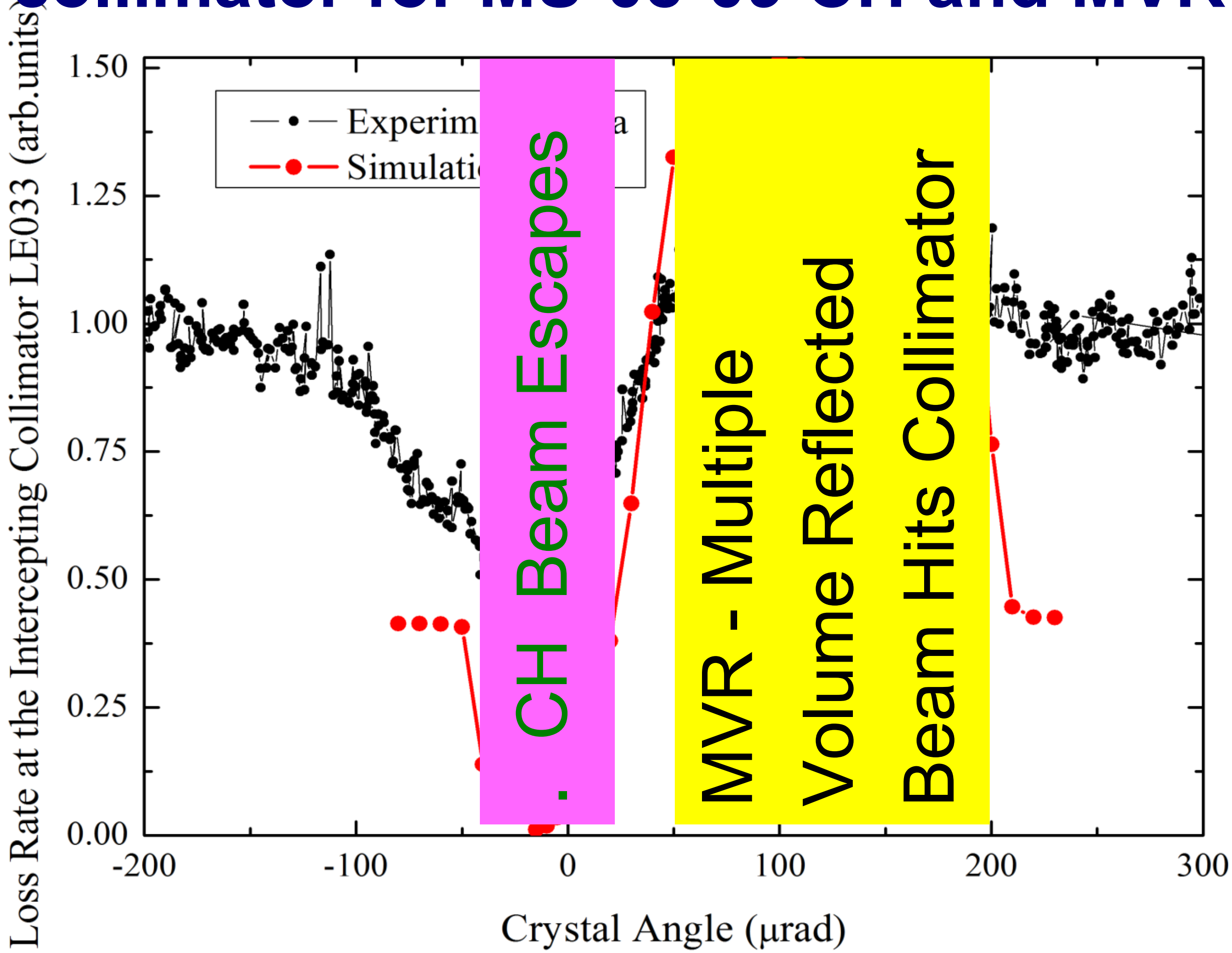
Volume Reflected b (MVR) at E03 Collimator

Drozhdin simulation

Channeled Beam (CH) at F172 Collimator

T-980

Experimental and simulated losses at E03 collimator for MS-08-09 CH and MVR beam



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I. Yazynin

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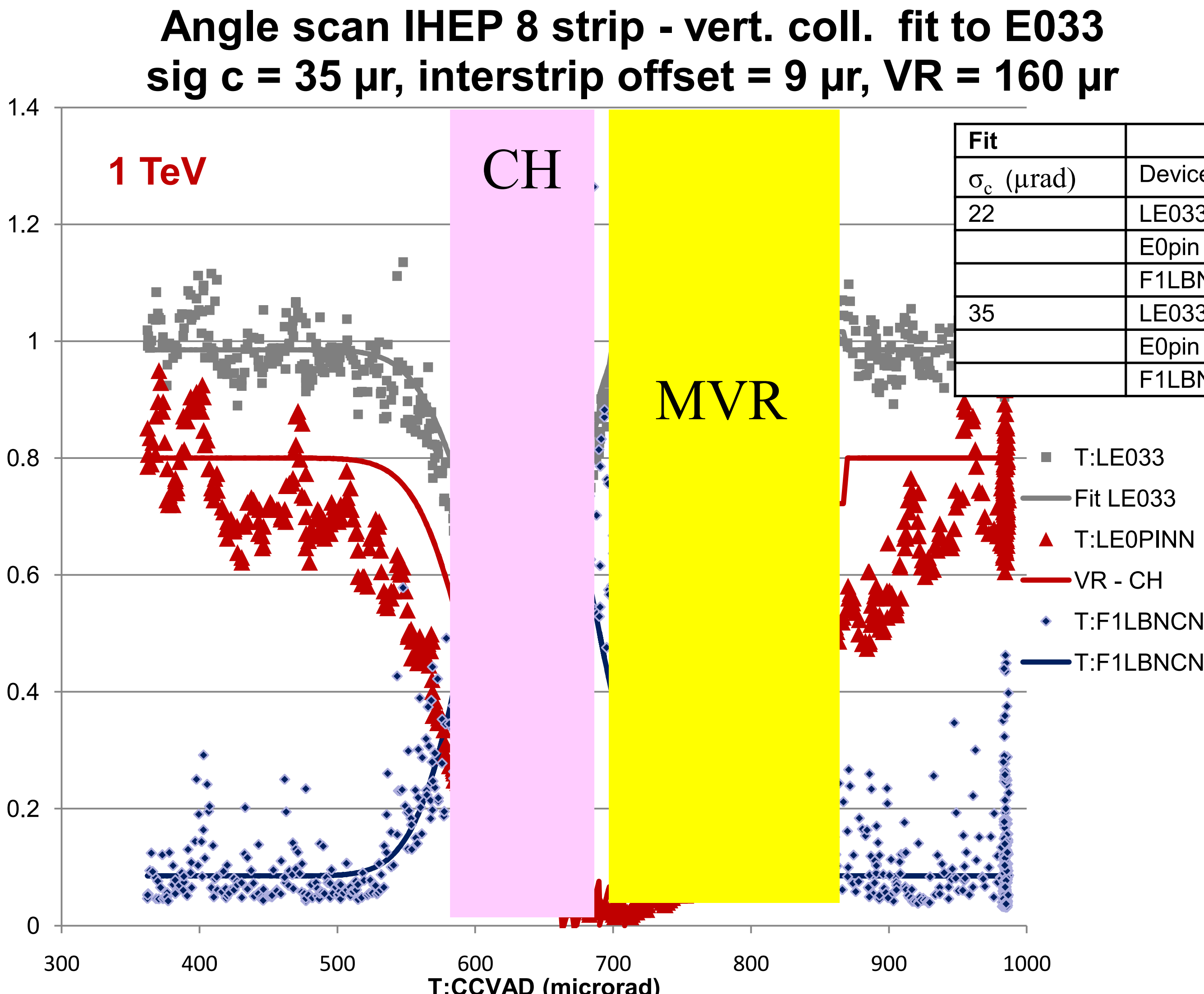
8 strip (MS-08-09) ala S. Hasan – Insubria for UA9



Fit			2/4/2011	
σ_c (μrad)	Device	A_{CH}	A_{VR}	Chi sq
22	LE033	0.86	0.21	0.084
	E0pin	0.875	0.665	0.154
	F1LBNCN	1.16		0.242
35	LE033	0.62	0.25	0.056
	E0pin	0.77	0.625	0.11
	F1LBNCN	0.92		0.205

Angular broadening factors

VR spread
(Maisheev simulation)

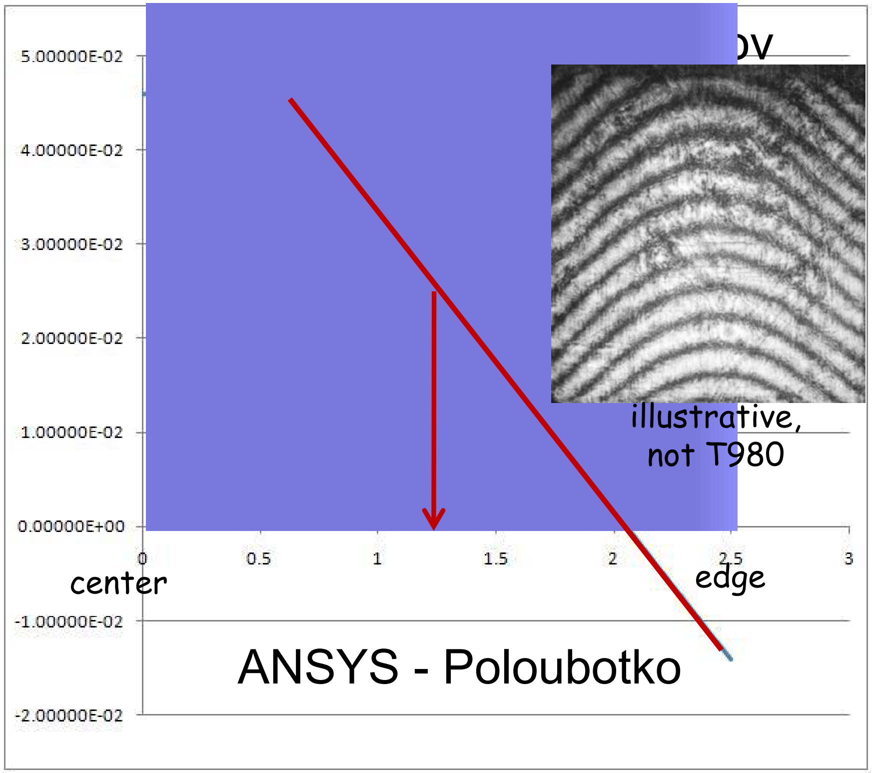
Beam halo dispersion
(seen in E853)

Multiple turn effects
(Drozhdin)

Crystal distortions

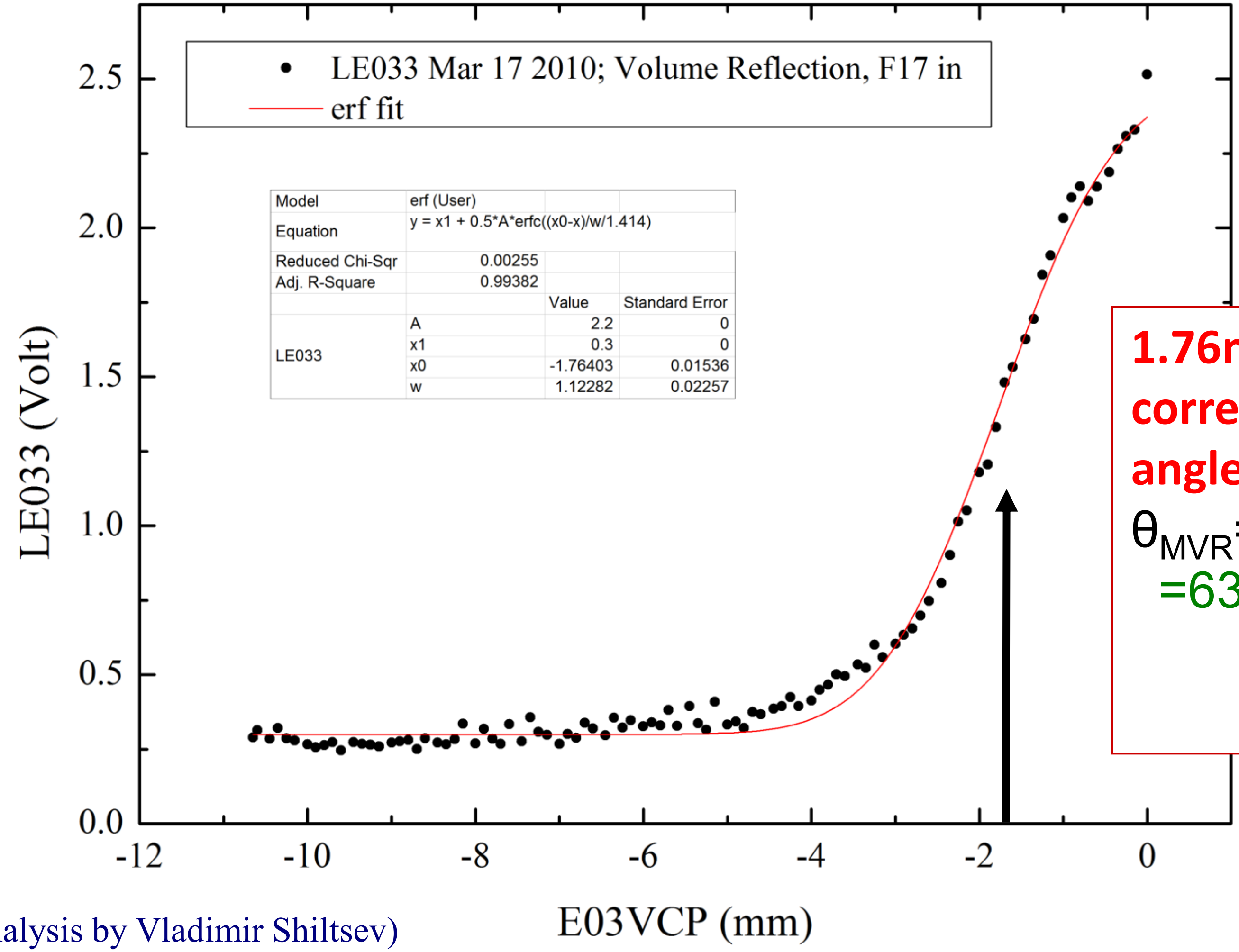
fringe – O(micron distortion)
skew effects

Crystal distortions (O-shaped)



E03V Collimator Scan with Crystal at VR angle

(MS-08-09)



Model	erf (User)		
Equation	y = x1 + 0.5*A*erfc((x0-x)/w/1.414)		
Reduced Chi-Sqr		0.00255	
Adj. R-Square		0.99382	
		Value	Standard Error
LE033	A	2.2	0
	x1	0.3	0
	x0	-1.76403	0.01536
	w	1.12282	0.02257

1.76mm displacement corresponds to VR angle:

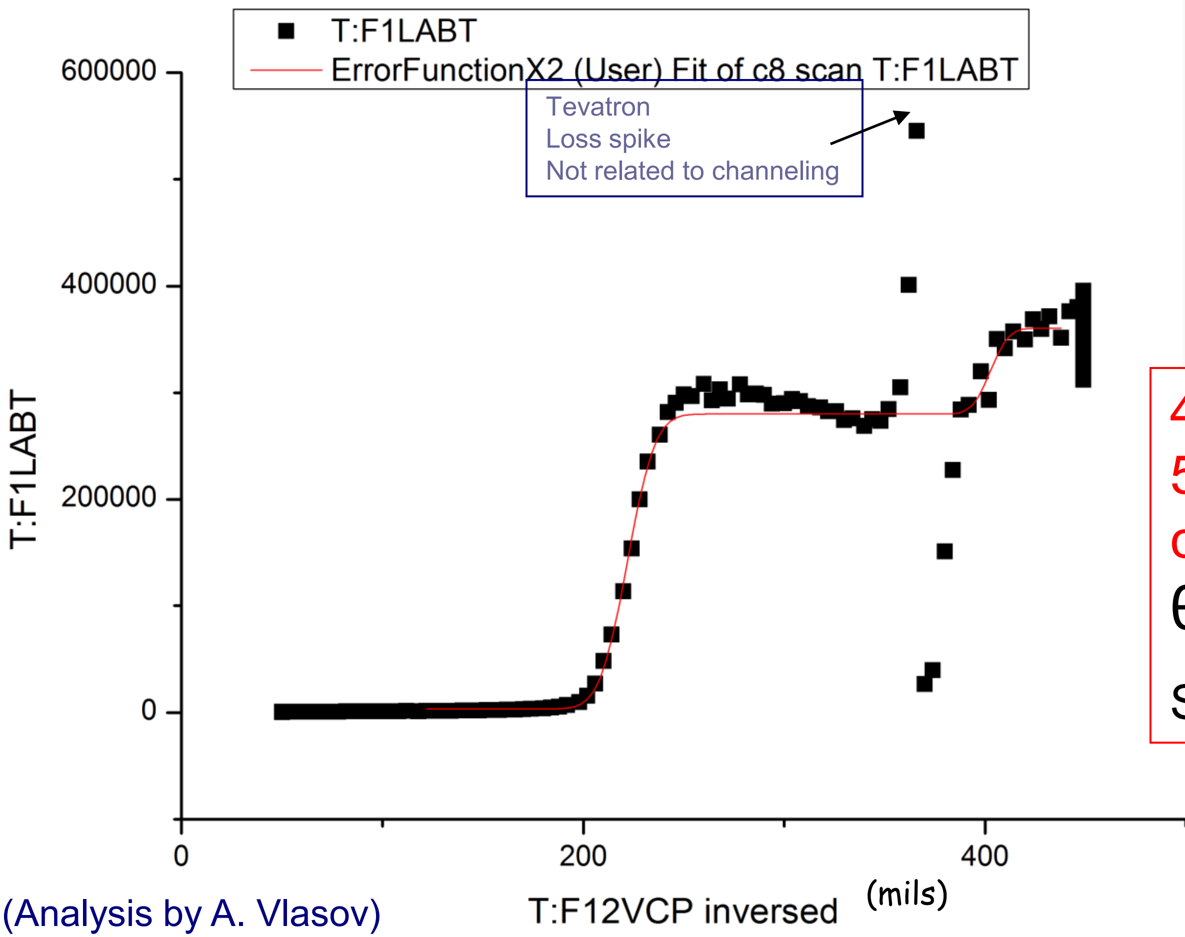
θ_{MVR}=1.76mm/28m

=63 urad

(Analysis by Vladimir Shiltsev)

T-980

F172V Collimator Scan with Crystal at CH angle (MS-08-09)



	A	B	C	D
1	Model	ErrorFunctionX 2 (User)		
2	Equation	y = y0 + A1/2*(erf((x-xc1)/w1/sqrt(2)) + 1) + A2/2*(erf((x-xc2)/w2/sqrt(2)) + 1)		
3	Reduced Chi-Sqr	3,60576E9		
4	Adj. R-Square	0,82812		
5			Value	Standard Error
6	T:F1LABT	A1	276612,9424	17837,62466
7		A2	80400,97533	29262,62564
8		y0	3445,40217	14135,20006
9		xc1	221,94543	3,10533
10		xc2	402,677	8,94663
11		w1	10,84337	4,29996
12		w2	7,1561	12,59536

449-222mils/40mils/mm = 5.7 mm displacement from core for Channeled beam.

θ_{CH}= 186 urad

Specified θ_{CH} =200urad

(Analysis by A. Vlasov)

Comparison crystal MVR parameters for Multi-strip crystal MS-08-09 (Zvoda)

Specified VR angle = 64 urad (8 strips X 8urad/strip) Note: This is not a strictly defined angle

	MVR angle (by collimator scan) (μrad)	MVR width (μrad)	MVR displaced at E03V collimator (mm)	MVR efficiency (%)	Bend angle (by angle scan) (μrad)	MVR peak (μrad)
Measured	74.6 (+/- 7.5 stat) (+/- 1.6 instr)	36 (+/- 10 stat) (+/- 2.5 instr)	1.7 (+/- .6 (stat)) (+/- 1.6 instr)	83.5% (+/- 4 instr)	255 (+/- 28.3 stat) (+/- 6 inst)	767 (+/- 12.72 stat) (+/- 3 inst)
Simulated	64	43.3 (+/- 1.9)	1.61	-	-	758 (+/- 2.9)
SPS H8 Run Result	60* *scaled by 1/sqrt(E)	28.6* *scaled by sqrt(E)	-	-	300 (+/- 50)	-
Measured /Expected	SPS 1.24 Simulated 1.17	SPS 1.25 Simulated 0.83	Simulated 1.05	-	SPS 0.85	Simulated 1.01

T-980

Comparison crystal CH parameters for Multi-strip crystal MS-08-09 (Zvoda)

Specified CH angle = 200 urad   Note: This is not a strictly defined angle

	CH angle (by collimator scan) (μrad)	CH width (μrad)	CH displaced at F172 collimator	CH efficiency (%)	Bend angle (by angle scan) (μrad)	CH peak (μrad)
Measured	186 (+/- 3 instr)	59 (+/- 12.2stat) (+/- 3.2 instr)	5.6 (+/- 3 instr)	87.5 (+/- 13.6)	255 (+/- 28.3 (stat) (+/- 6 inst)	655.7 (+/- 10.0 stat) (+/- 3.3 inst)
Simulated	200	26 (+/- 5.7 stat) (+/- 1 inst)	6.1	-	192.8 (+/- 20)	658.5 (+/- 2.1 stat) (+/- 1.25 inst)
Measured /Expected	0.93	2.26	0.92	-	1.32	0.99

SUMMARY

- First results obtained in 2010 for vertical plane eight strip crystal have been encouraging with consistent values for VR angle and width compared to SPS H8 run and simulations.
- Also results for new horizontal plane 360 urad bend O-05-09 crystal have been obtained with CH angle less at 0.44 of expected. This result is more consistent with the previous O-shape O-BNL-02 and appears not to be related to miscut angle. Collimator scans were also conducted with different impact parameters - small (nm) and large (10 micron) with no difference in displacement.
- Problem with quasi mosaic crystal. New sixteen strip Ferrara unit arrived Feb. 17 to replace flawed old Ferrara one.
- The first attempt at 2 plane crystal collimation had limited success. Main problems stemmed from wrong initial angular set point for the horizontal crystal.
- Pixel telescoping detectors are being commissioned (see below).
- Intensive End of store work until the end of Run II, possible 2-week studies after.

Future plans - visitors

Planned visits in 2011

Andrea Mazzolari – Ferrara (10 days late March)
Yuri Chesnokov - IHEP (possibly May - June)
Yuri Ivanov - PNPI (possibly May - June)
Yuri Gavrikov – PNPI (possibly May – June)
other UA9 personnel (May-October)

Near Future Plans

Uncertain when TeV will stop running (March to Oct – US fiscal problems). Plan to get as much time as possible.

1. Shutdown 2nd week of March (reinstall vertical goniometer and improved pixel telescopes)
2. New 16-strip Ferrara crystal and (probably) QM replaced with IHEP 8-strip in vertical goniometer, O-shaped in horizontal.
3. Schedule to be based on machine up time and visitors, priorities.
4. Exploit E0 pixel telescope and install pixel at F17 to get profiles of channeled and VR beams on intercepting collimators.
5. Demonstrate 2 plane crystal collimation.

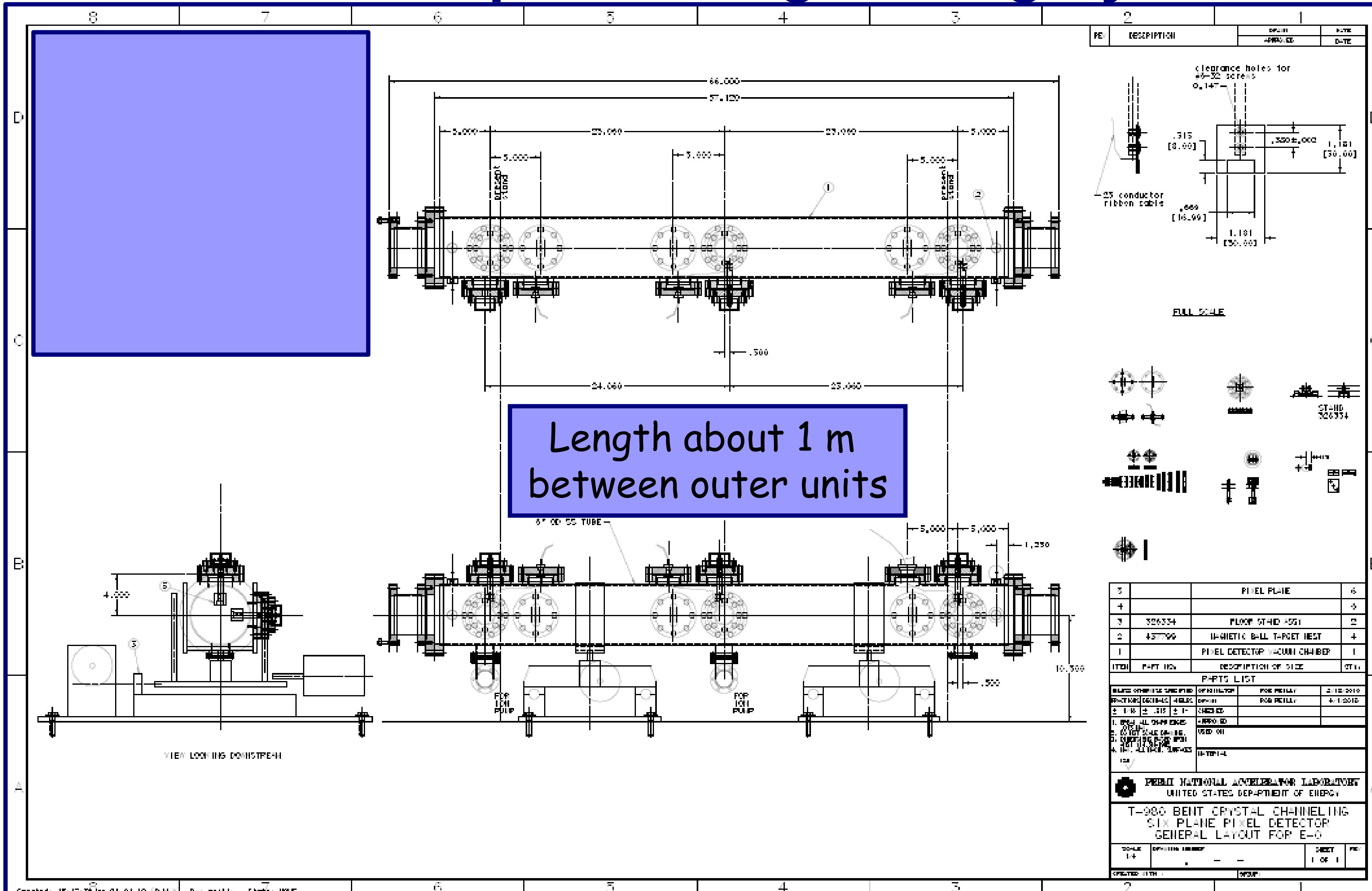
Post-Run II studies

1. Three to four dedicated collider collimation stores. May be some proton only, spread over two weeks (optimistic).
2. Focus on two-plane collimation measuring channeled and VR beam profiles with two pixel telescopes.
3. Possible synergy with hollow electron beam. Dedicated collimation and hollow beam studies, maybe some proton only.

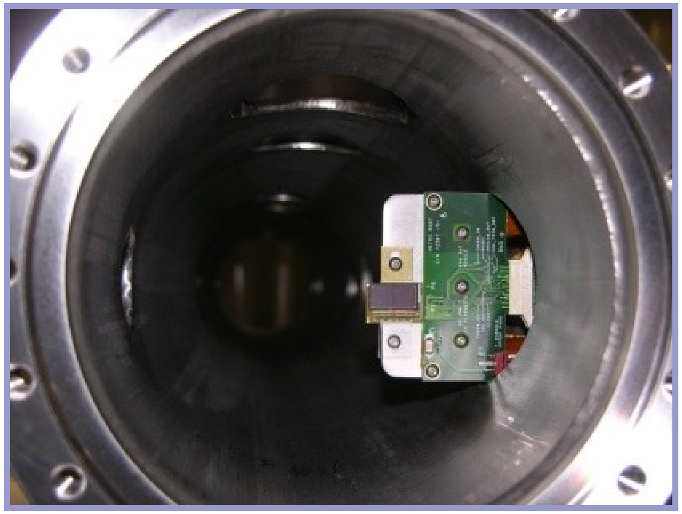
speaking personally -

1. Far out - an anticlastic single strip less than 2 mm along beam to test Scandale – Guidi point re nuclear interations?
2. Even further out: E0 for antiproton beam-only studies.
3. Maybe some secondary beam work later, e.g. muons

Pixel Telescope Housing/Moving System



Pixel Telescope Detector



- Multi-chip modules are of CMS forward pixel production.
- 1x2 cm^2 with a sensitive area 0.8x1.6 cm^2.
- Pixel size 100x150 μm^2, resolution 7-8 μm.

- commissioning 2 detectors
    - 1 installed in front of E03collimator (6 modules, x, y)
    - 1 ready to install in front of F172 collimator (4 modules, x, y)
- consists of 3 telescoping pixels per plane.
- overcame problems vacuum certifying pixel boards due to baking temperatures.
- E0 installed December 2010
- **Mid February –beam inducing noise in E03 pixel – some ideas**
- May not install F17 but use for practice

Questions?