SANE
Spin Asymmetries of the Nucleon Experiment
(TJNAF E07-003)

SANE Collaboration

U. Basel, C. Newport U., Florida International U., Hampton U.,
Los Alamos N.L., Mississippi S. U., U. of New Hampshire, Norfolk S. U.,
North Carolina A&T S. U., Ohio U., IHEP-Protvino, U. of Regina,
Rensselaer Polytechnic I., Rutgers U., Seoul National U.,
Temple U., TJNAF, U. of Virginia, C. of William & Mary,
U. of the Witwatersrand, Xavier U., Yerevan Physics I.

Spokespersons:
S. Choi (Seoul), M. Jones (TJNAF), Z-E. Meziani (Temple), O. A. Rondon (U. of Virginia)

Safety & Readiness Review
June 26, 2008
Jefferson Lab

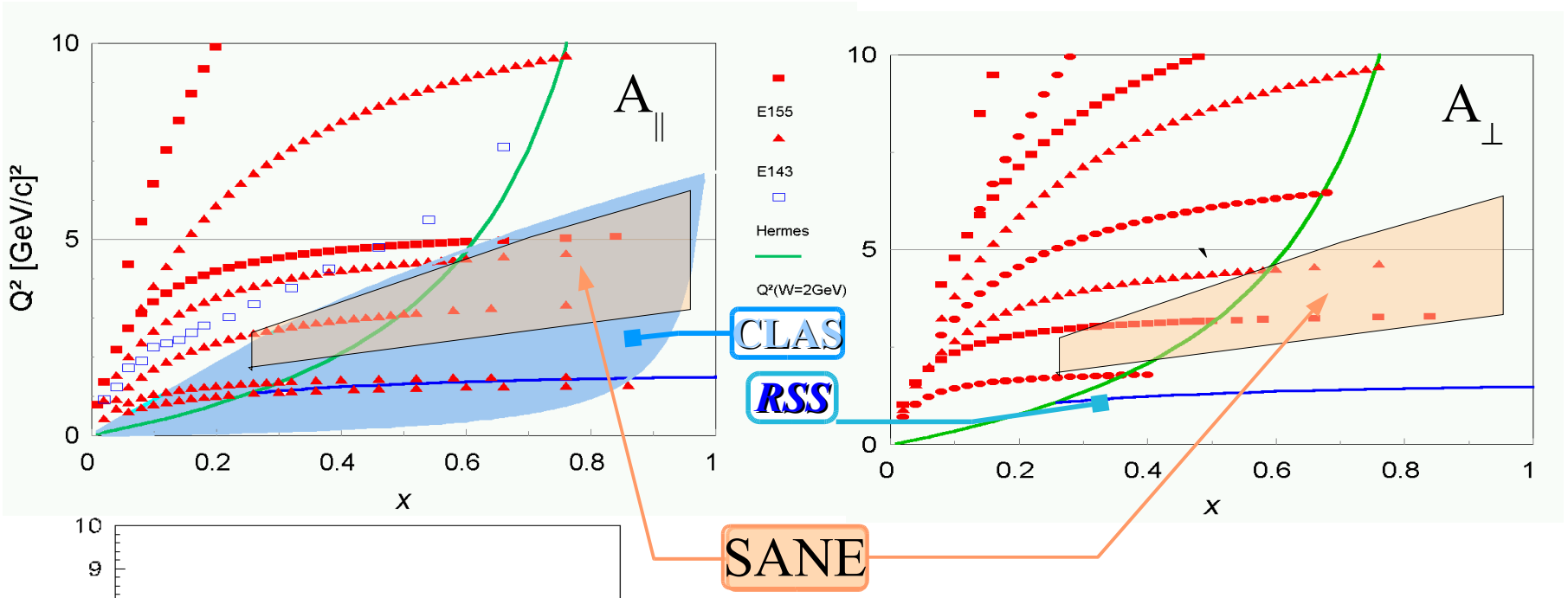
SANE Readiness Review

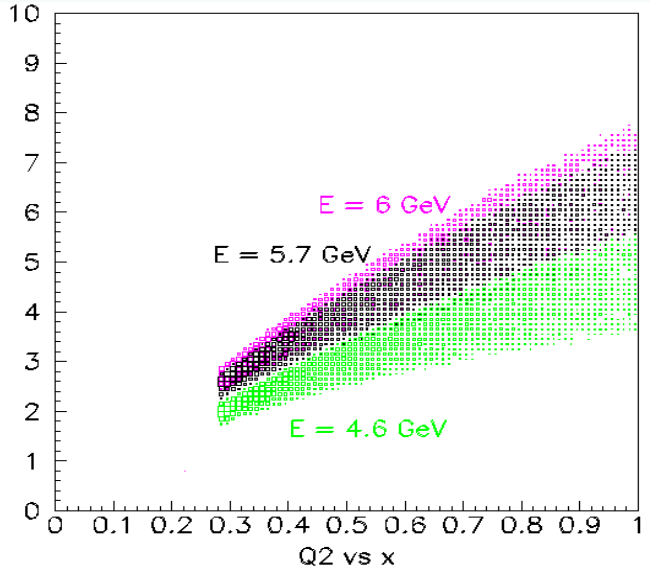
- Overview
- Status and Readiness Summary
- Response to 2007 Review report
- Manpower
- Safety documents: K. Slifer

SANE Physics

- Measure proton spin structure function $g_2(x, Q^2)$ and spin asymmetry $A_1(x, Q^2)$ at four-momentum transfer $2.5 \leq Q^2 \leq 6.5$ GeV² and Bjorken x $0.3 \leq x \leq 0.8$
  - **Meets or Exceeds DOE 2011 Milestone for Proton Spin Structure**
- Goal is to learn all about proton SSF's from inclusive double polarization measurements of parallel and near-perpendicular spin asymmetries
  - twist-3 effects from third moments of g_2 and g_1:
    - d_2 matrix element $= \int_0^1 x^2 (3 g_2 + 2 g_1)\, dx$
  - comparisons with Lattice QCD, QCD sum rules, bag models, chiral quarks
  - Study x dependence (test nucleon models) and Q^2 dependence (evolution)
  - Exploration of "high" x region: A_1's approach to $x = 1$
  - Test polarized local duality for final state mass $W > 1.4$ GeV
- Detect electrons with novel large solid angle electron telescope **BETA**

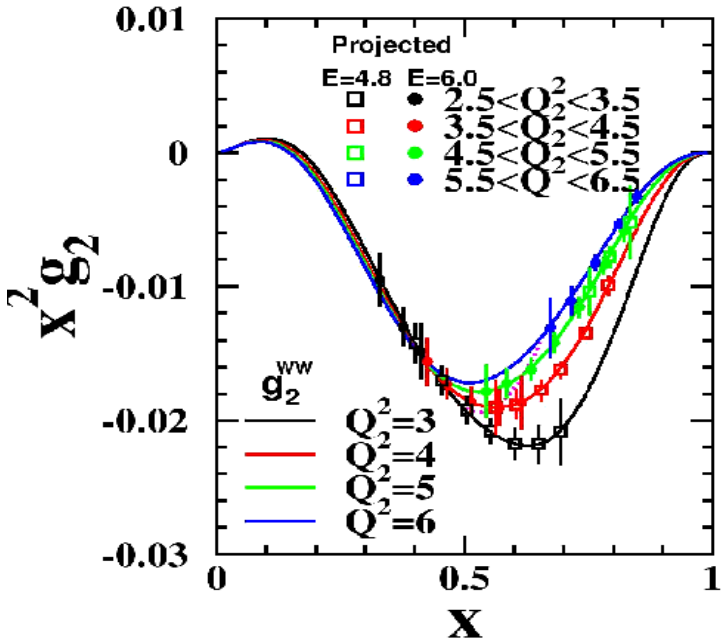
World data on $A_{||}$, $A_{\perp}$ and SANE kinematics

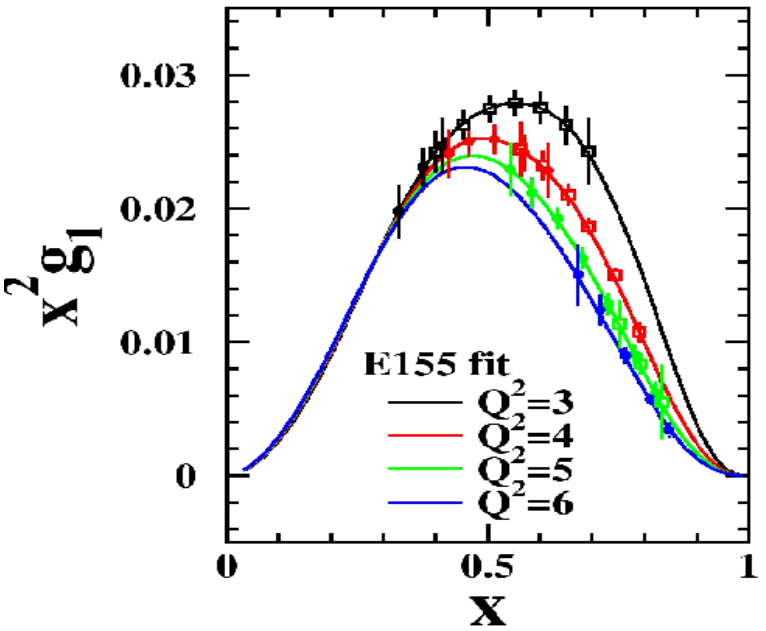




- Two beam energies: **5.9 GeV**, **4.7 GeV**
  - (small loss if **5.7 GeV**)
- Very good high ***x*** coverage with detector at 40° (plot from BETA's GEANT simulation)

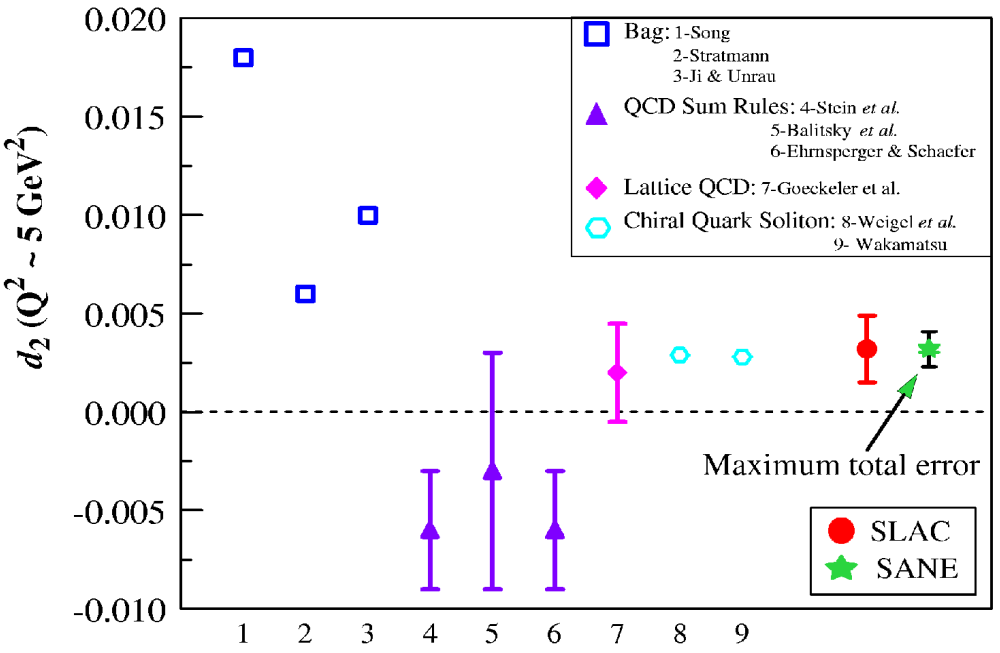
SANE Expected Results

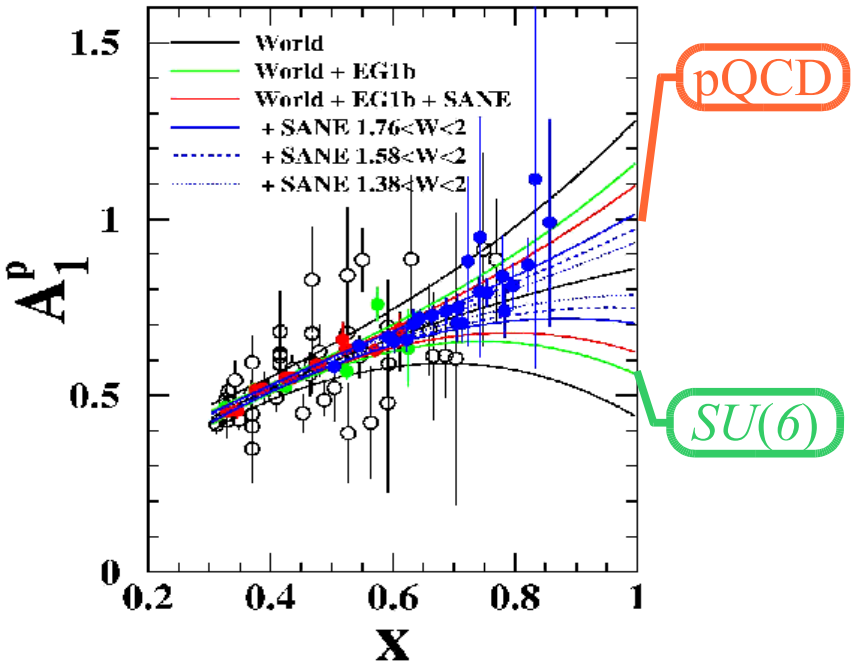




- x dependence at constant Q^2 and Q^2 dependence at fixed x (illustrative binning only)
- data are concentrated in the region most sensitive to $x^2 g_{2,1}$
  - (estimates based on 75% beam and target polarization, and 85 nA beam current)

SANE Expected Results (II)





- Improve total error on $d_2(Q^2 = 5\ \text{GeV}^2)$ by better than a factor of 2; systematics dominated
- Constrain extrapolations of A_1^p to $x = 1$ within +/- 0.1 (using duality)
- SANE's measured A_2 will improve world's A_1 data set

SANE Layout

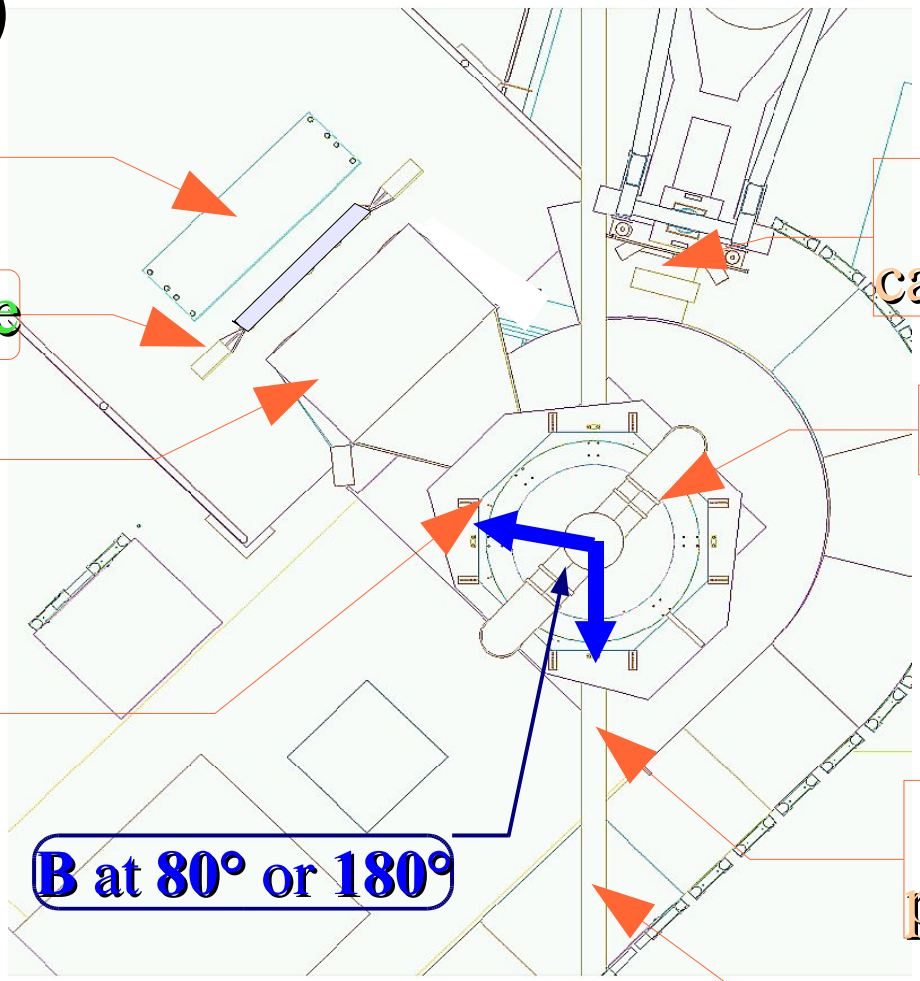
BETA (40°)

BigCal
w. Gain Monitor

Lucite Hodoscope

Gas Cherenkov

Forward
Hodoscope



HMS (14°- 48°)
calibrations, backgd.

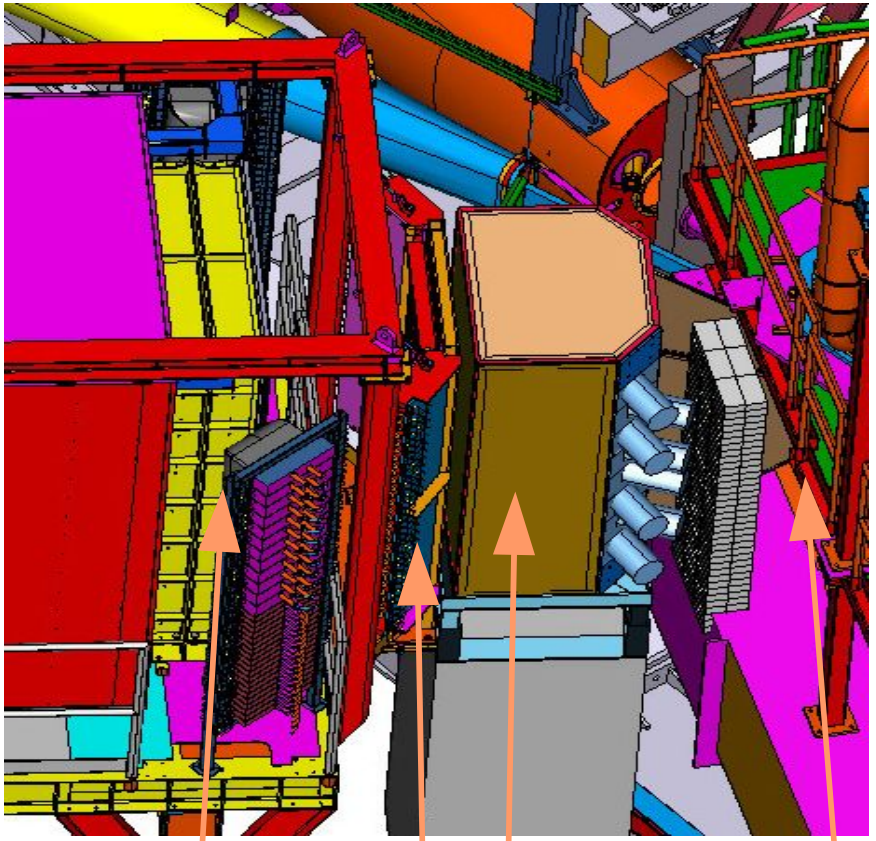
Polarized Target

Target Beam
position monitor

Beam Line

Big Electron Telescope Array - BETA

- **BigCal** lead glass calorimeter: main detector used in *GEp-III*.
- Tracking **Lucite hodoscope**
- **Gas Cherenkov:** pion rejection
- Tracking fiber-on-scintillator **forward hodoscope**
- BETA's characteristics
  - Effective solid angle = 0.194 sr
  - Energy resolution 5%/√ *E*(GeV)
  - 1000:1 pion rejection
  - vertex resolution ~ 5 mm
  - angular resolution ~ 1 mr
- Target field sweeps low *E* background
  - 180 MeV/c cutoff



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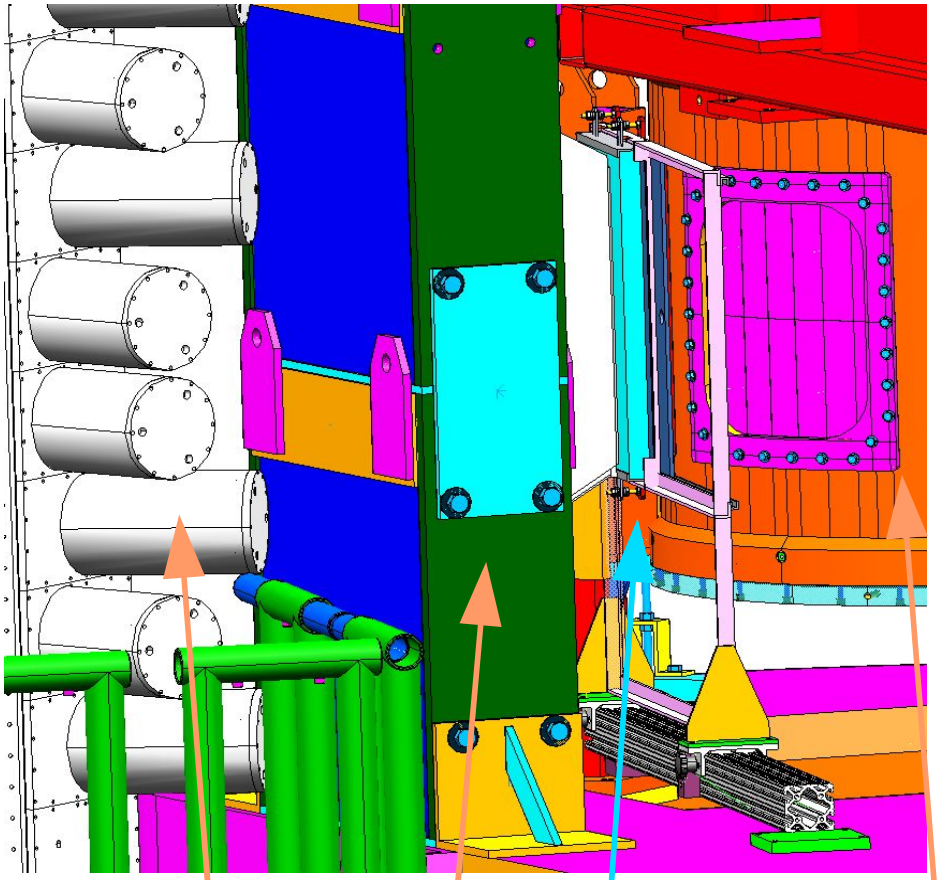
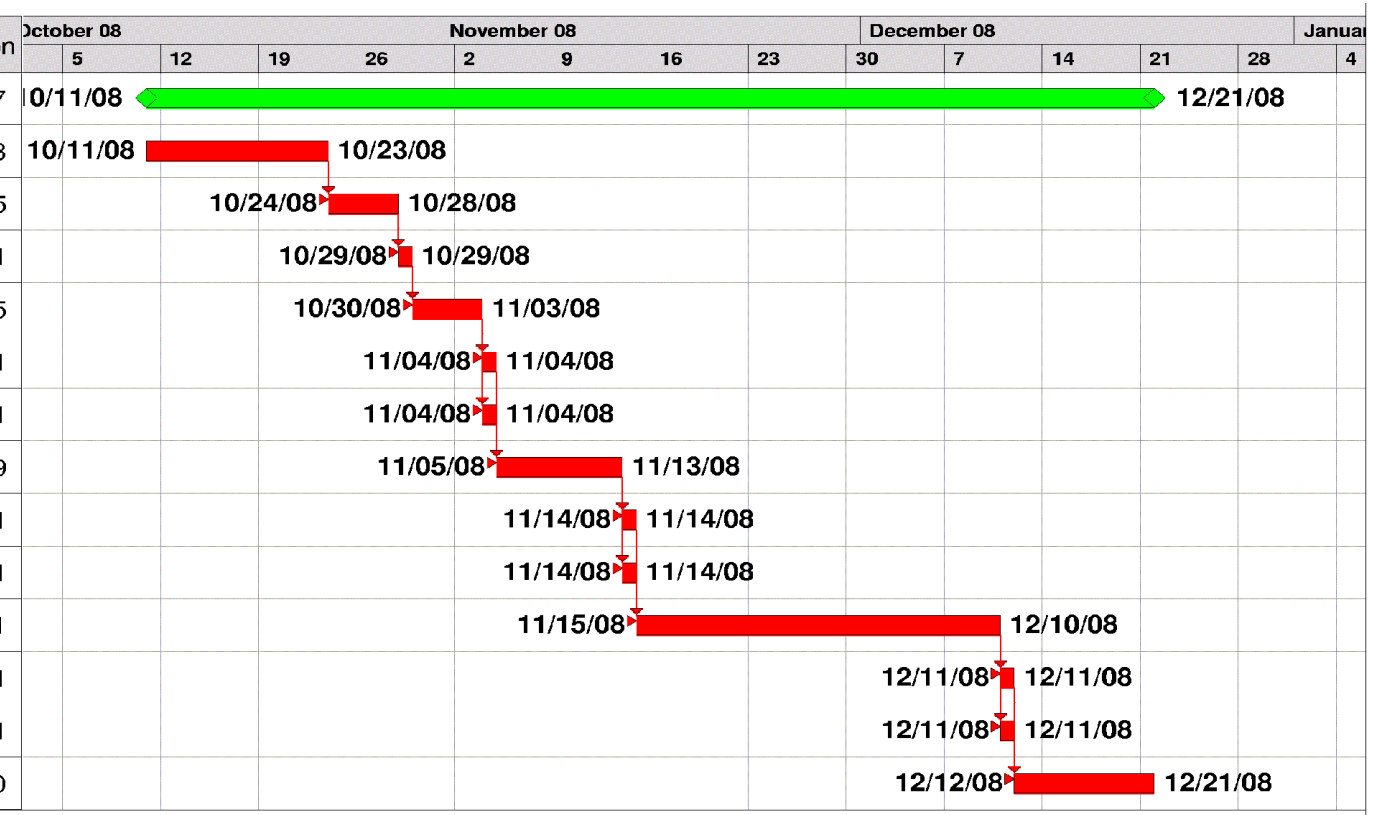


Run Plan and Beam Time

		Activity Name	Duration
1	—	***SANE Run***	67
2		Commission 5.9 - 2.4 GeV	13
3		Calibration 2.4 GeV	5
4		Energy change 2 => 4 pass	1
5		4.734 GeV parallel	5
6		Target rotation 180° - 80°	1
7		Chicane alignment	1
8		4.734 GeV 80 deg.	9
9		Energy change 4 pass => 5 pass	1
10		? Chicane alignment (if needed)	1
11		5.9 GeV 80 deg.	21
12		Target rotation 80° - 180°	1
13		Chicane alignment	1
14		5.9 GeV parallel	10



	Calibration			Data				Moller		C runs		Commiss.	
Energy - field angle	B OFF	0°	180°	4.7 ||	4.7 80°	5.9 80°	5.9 ||	180°	80°	180°	80°	5-p	2p
Run plan calendar days	**1**	**2**	**2**	**5**	**9**	**21**	**10**					**11**	**2**
Run plan PAC hours	12	24	24	60	108	252	120					132	24
Proposal hours	12	24	24	70	130	200	100	7	14	7	13	144	
Proposal data + systematics				76	141	216	108	4	8	4	8		
Efficiency (proposal+syst.)/run plan (relative to 50%)				1.26	1.30	0.86	0.90						

SANE Status

- After July 2007 Readiness Review:
  - series of 16 bi-weekly work meetings on target, beam line, detectors and software
  - Successful test run of partial BETA configuration in early April:
    - BigCal at 40°; ½ Cherenkov (bottom); 16 Lucite bars; 2 partial Y and all X Tracker planes
    - 83 runs at 5.7 and 3.5 GeV with 200 nA to 5 μA beam on 4 cm LH2 and thin C targets: comparable SANE luminosity; largest fast raster.
    - GEp-3 analyzer modified to include BETA detector for test run
  - Collaboration-wide meeting on 5/30/8 reviewed test run, safety docs. drafts
- Target cooldowns in EEL: ongoing work - status by K. Slifer
- Draft ESAD, Installation COO, expt. COO circulated among committee

SANE Status (II)

- Preparation for installation:
  - Define scope of work: collaboration meetings
  - Analyze hazards and develop controls:
    - HCList; safety document drafts; SANE safety review
- Installation started on 6/16 (W. Kellner): work within controls
  - BigCal reconditioning: June 17 through Aug. 30
  - HMS reconfiguration (remove FPP, reinstall base pkg.): June 17 to July 1st
    - Yerevan Phys. I. and Hall C
  - Cryotarget deinstallation: June 17 to June 30
  - Polarized target OVC and instrumentation platforms: July 8 to July 28
  - G0 magnet move: July 8 to Aug. 5
  - Install SEM: Aug. 11 to Aug. 15
  - Install BETA (Cherenkov, Tracker, Lucite): starting on Sept. 1st.
  - Install SANE beam line: Sept. 2 to Oct. 6

Readiness Summary - 2008

Subsystem	Parts		Construction - Assembly	Tests		Preparation for SANE	
	In hand	On order / procurement		Lab	In Hall	Conditioning	Other
BigCal	All		Ready	Completed	Done	UV Glass anneal	
Gain Monitor	All		Resady	Completed	Done	Visual inspection	
Cherenkov	All		July '08	Completed	Done		Alignment
Lucite tracker	All		Ready	Completed	Done		Alignment
Forward tracker	All		Aug. '08	Completed	Done		Alignment
Target	Magnet, refrigerator, OVC, microwaves, NMR, pumps, ammonia	Inserts		June '08	Sep. '08		Installation July '08
Target platform	GEn-01/RSS platforms		June '08			Refurbish	
Beam line	Upstream girder/chicane, rasters, BCM's, BPM's, SEM, Downstream extension, He Bag		Sep. '08	Slow raster: Summer 07; Check low current BPM's		Recommission: Slow raster SEM	Install low power dump after G0 magnet exit
Beam line shielding	All		Sep. '08				
HMS					July '08	Restore standard package	Cosmic tests
Trigger/DAQ	All modules						Set up Cherenkov*BigCal coincidence and pi0 triggers
Online reconstruction	Analyzer, BETA simulations	HMS, BETA target field tracking	Aug. '08		Done		

2007 Readiness Review Report

- Report indicates no serious issues
- Report identifies 12 areas for comments:
  1. Physics goals
  2. Beam Line: J. Dunne/P. Bosted
  3. Radiation shielding
  4. Target: D. Crabb
  5. BigCal: M. Jones
     - Triggers: H. Baghdasaryan
  6. Cherenkov: B. Sawtazky
  7. Hodoscopes:
     - Lucite: NC A&T/ H. Baghdasaryan
     - Tracker: C. Butuceanu
  8. Software
  9. Detector infrastructure
  10. Installation
  11. General Organization
  12. Manpower

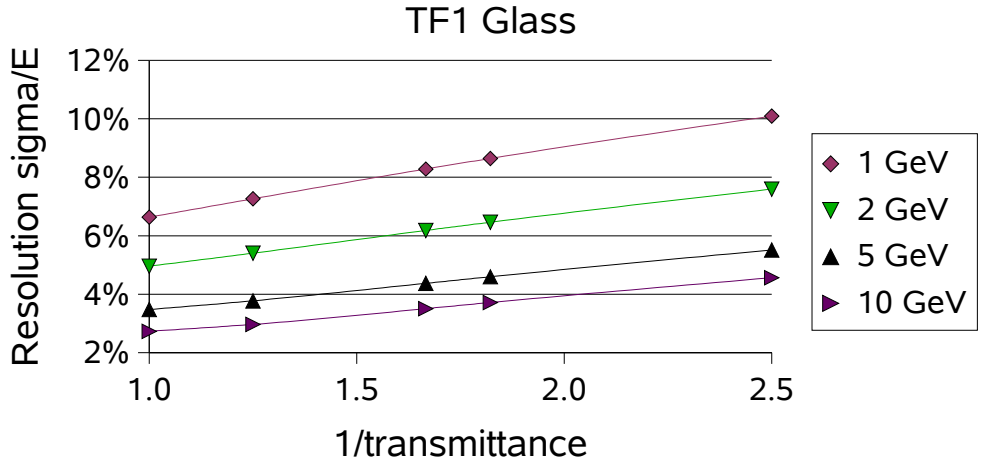
- <= Report's important comments
- <= Report's secondary comments
  - Responses

1. Physics goals

- BigCal resolution consistent with physics goals
  - Proposal based on 5% /√ E' resolution
  - BigCal glass darkened by radiation after GEp: worse resolution
  - Goals vs resolution:
    - clean inelastic data for d_2 integral: highest x bin free of elastic events (2σ)
      - acceptable loss of integration range up to 8% /√ E' resolution
    - $A_1(x \rightarrow 1)$: resolution not critical; elastic contribution OK
    - Spin local duality for $W > 1.4$ GeV: 8% /√ E' = 1 σ from Delta
  - Resolution vs glass transmittance shows 8%/√ E' resolution for ~ 0.65 transmittance
  - GEp March '08 UV curing shows ~80 days curing projected to restore 0.8 transmittance

1. Physics goals (Ia)

Q^2 range GeV^2	$\langle Q^2 \rangle$ GeV^2	Lowest W GeV	Resolution $\sigma\sqrt{(E')}$	High x	d2 error (stat)
2.5 - 3.5	3.107	1.100	5.0%	0.713	3.6%
	3.107	1.350	6.6%	0.713	3.6%
	3.107	1.480	8.0%	0.713	3.6%
3.5 - 4.5	4.069	1.100	5.0%	0.929	2.4%
	3.998	1.350	6.6%	0.825	2.5%
	3.951	1.480	8.0%	0.776	2.8%
4.5 - 5.5	4.890	1.100	5.0%	0.940	3.4%
	5.014	1.350	6.6%	0.842	3.6%
	5.000	1.480	8.0%	0.796	3.8%
5.5 - 6.5	5.912	1.100	5.0%	0.909	6.7%
	5.922	1.350	6.6%	0.879	7.6%
	5.928	1.480	8.0%	0.837	7.8%

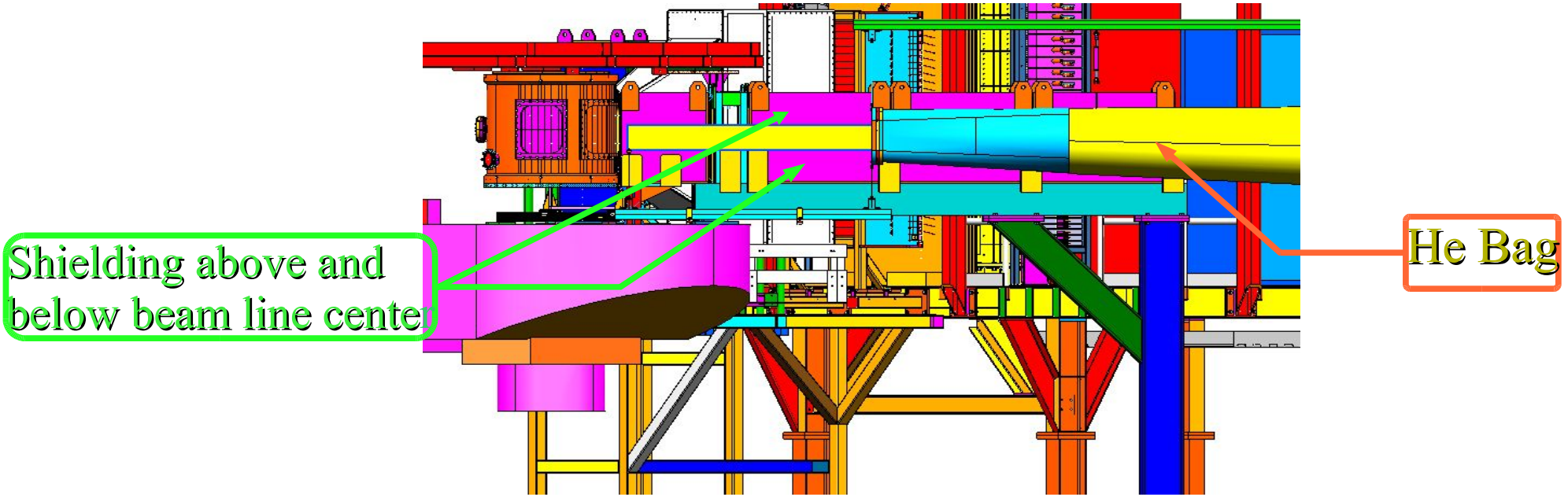


1. Physics goals (II)

- BigCal calibration consistent with goals
  - Amplitude distributions for *ep* elastic signals show
    - < ~1% error of means
    - 10-20 MeV accuracy for *E*' 1 to 2 GeV (HMS offset included)
  - π^0 mass reconstruction
    - April test run data show reconstruction works

3. Radiation Shielding

- Shield lead bricks must be in cassettes
- Special shield support platforms need to be designed with attention to interference and strength
- Platform dimensions and locations need to be provided to Hall designers timely
  - Detector shielding should be optimized before BigCal's calibration
    - All done



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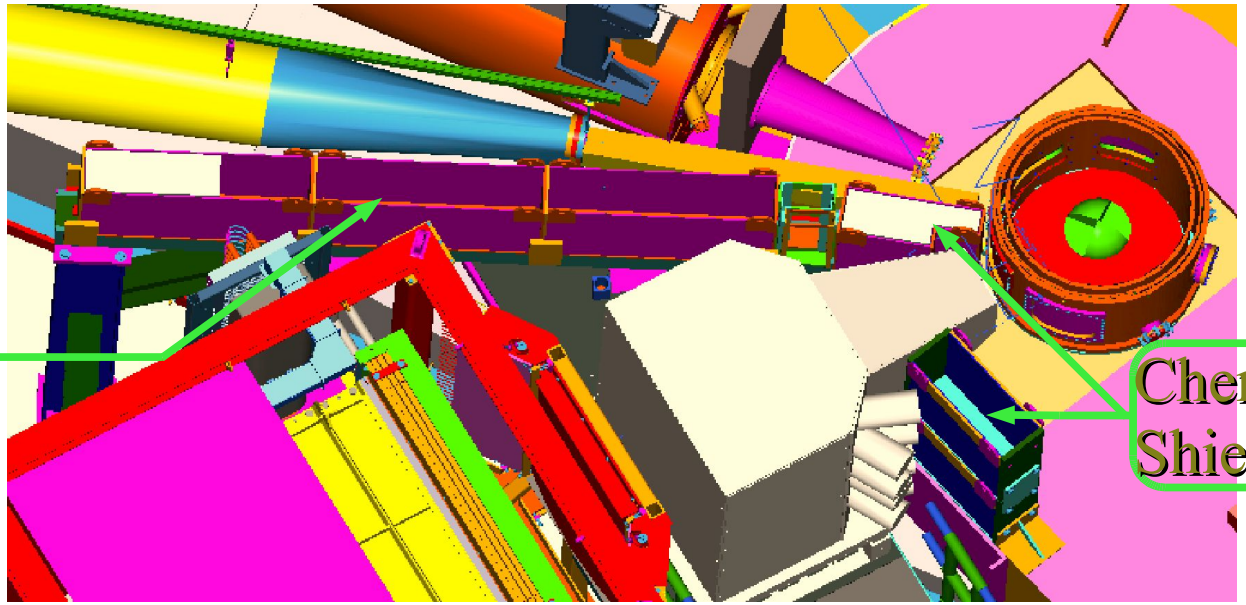


8. Software

- Crucial to have working code for BigCal $e^{-}p$ and π^0 calibrations before the experiment starts
  - Elastic $e^{-}p$ Calibration (U. Regina)
    - Modification of *GEp* code to include tracking in target field in progress; Run plan in preparation; detailed simulations done
  - π^0 calibrations (H. Baghdasaryan -UVA)
    - basic code (BETA single arm) tested in April; integration with HMS and target field in progress
  - Software group meets weekly
    - coordinator: S. Choi (Seoul)
    - On-line code: H. Baghdasaryan (UVA), C. Butuceanu (Regina), M. Jones, P. Bosted (JLab), F. Wesselmann (Xavier)
    - Simulations (BETA, Backgrounds): Thesis students H. Kang (Seoul), J. Maxwell, J. Mulholland (UVA), grad. student W. Armstrong (Temple) - kibitzer: O. Rondon

9. Installation & 10. Detector infrastructure

- 9. Installation: Detailed installation plan needs to be developed
  - done (W. Kellner - Hall C Work Coordinator - M. Jones - P. Manager)
    - Schedule at http://hallcweb.jlab.org/doc-public/ShowDocument?docid=152
- 10. Detector Infrastructure: Proper timing of detector elements and ADC gate needs to be demonstrated
  - tested in April

11. General organization and 12. Manpower

- 11. Physics liaison recommended
  - PDL: P. Bosted; Project Manager: M. Jones; Proj. Coordinator: H. Areti
- 12. Increased participation of post-doctoral research associates
  - Online software; triggers
    - **H. Baghdasaryan** (UVa)
  - Elastic *ep* calibrations; forward tracker
    - **C. Butuceanu** (Regina)
  - Cherenkov
    - **B. Sawatzky** (Temple)
  - Safety - Polarized target
    - **K. Slifer** (UVa)

SANE Manpower: Subsystems

Subsystem	Component	Manager	Experts	Institution
BigCal				
	Operation	M. Jones		Hall C
			L. Pentchev	William & Mary
			Protvino	Protvino
			Yerevan	Yerevan P. I.
	Trigger	H. Baghdasaryan		UVA
			R. Gilman	Rutgers U.
			P. Bosted	Hall C
	Calibration	G. Huber		U. Regina
			C. Butuceanu	U. Regina
Gas Cherenkov		Z-E. Meziani		Temple U.
			B. Sawatzky	Temple U.
			O. Lukhanin	Temple U.
Forward Tracking Hodoscope		M. Khandaker		Norfolk S.U.
			P. Bosted	Hall C
			C. Butuceanu	U. Regina
Lucite Hodoscope		A. Ahmidouch		North Carolina A&T S.U.
			S. Danagoulian	North Carolina A&T S.U.
Polarized Target		D.G. Crabb		UVA
			D.B. Day	UVA
			K. Slifer	UVA
			M. Seely	JLab
			C. Keith	JLab
			G. Smith	Hall C
Beam Line		J. Dunne		Mississippi State U.
	Raster		Chen Yan	Hall C
	BCM		D. Mack	Hall C
	Target BPM -SEM	F. Wesselmann		Xavier
			M. Steinacher	Basel
Shielding design		S. Choi		Seoul National U.
			H-Y.Kang	Seoul National U.
HMS		H. Mkrtchyan		Yerevan P. I.
			Yerevan	Yerevan P. I.
			Hall C	Hall C
			C. Keppel	Hampton
Moller		D. Gaskell		Hall C
			T. Horn	Hall C
Online Software		H. Baghdasaryan		UVA
			J. Maxwell	UVA

Shift and Run Coordinator Staffing

- Run duration: 67 beam days
  - 3 staff/shift
  - 603 workers-shifts
- Confirmed 67 of 86 collaborators to be shift workers (6 experts only, 15 students)
  - standard 10 shifts load
    - 460 worker-shifts
  - students 10 shifts/ea. minimum
    - 150 additional shifts
- M. Khandaker (NSU) is shift czar
- Shift load assigned per institution
  - each institution distributes shifts
- Run coordinators (RC):
  - Rotation: once/week
  - 10 weeks run
- 10 confirmed or likely RCs identified
  - senior staff or associates with polarized target training
- Target operators (TO):
  - need 201 TO shifts
  - 14 confirmed TOs - 3 likely ones
    - 3(4) UVA students
  - need to sign up 3 additional operators

2. Beam line

- Low current diagnostics to track beam from target to dump:
  - ion chambers at He bag exit windows
- SEM output on EPICS for MCC
  - in the works
- Additional FSD protection for total beam *I*, chicane, rasters and downstream:
  - Hall probe of target field interlocked to FSD; ion chamber interlocks
- TOSP for hall access including the Hodoscope and target platform
  - ESAD and COO for run; COO and TOSP for installation period
- Check of SEM in "noisy" hall to add cable shielding if needed: planned
- Maximum energy in range 5.6 to 6.0 GeV. Collaboration should provide optimal points for maximizing polarization in all Halls
  - Scheduled energy 5.9 GeV corresponds to 0.8 longitudinal spin at target for Halls A and C

4. Target

- Target operator training of 9 additional operators needs to identify operators and training plan
  - 13 confirmed + 4 likely TOs; 3 more needed to sign up
- Target cups easy to replace, made of hydrogen-free plastics (e.g. no Torlon)
  - done

5. BigCal

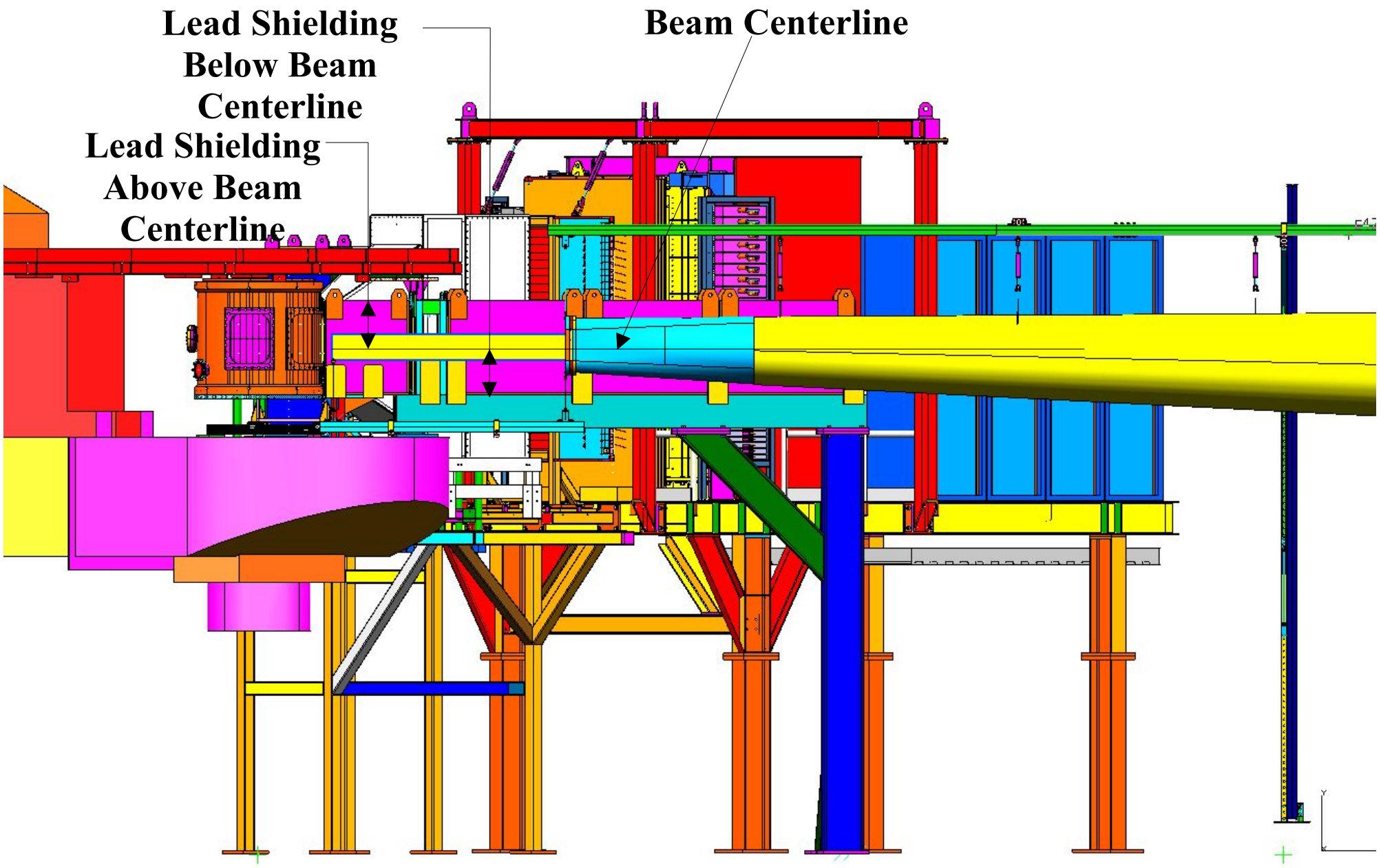
- Quantitative justification of glass anneal
  - if needed, manpower requirements must be determined
    - not needed
  - less intrusive anneal (no PMT removal) should be investigated
    - done: UV curing based on GEp-III procedure
- Magnetic shielding needs careful calculation
- Detector response needs to be measured for range of residual fields, field orientations
  - existing BigCal PMT shielding measured tested, found acceptable for expected fields
- Calibration with π^0 mass reconstruction turn-around time (from data collection to analysis to results) needs to be estimated; special trigger should be configured if needed.
  - π^0 trigger will be configured - H. Baghdasaryan report

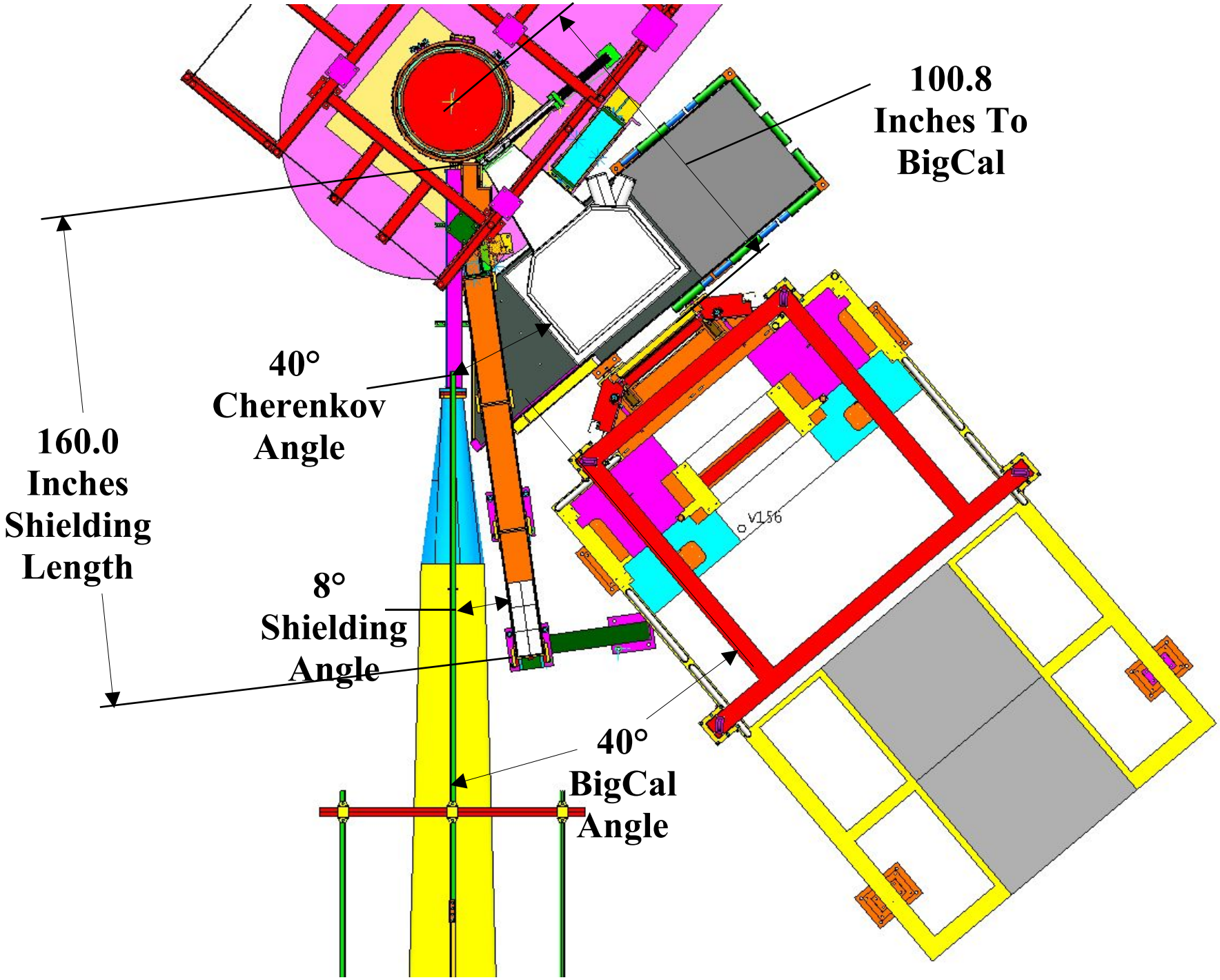
6. Cherenkov & 7. Hodoscopes

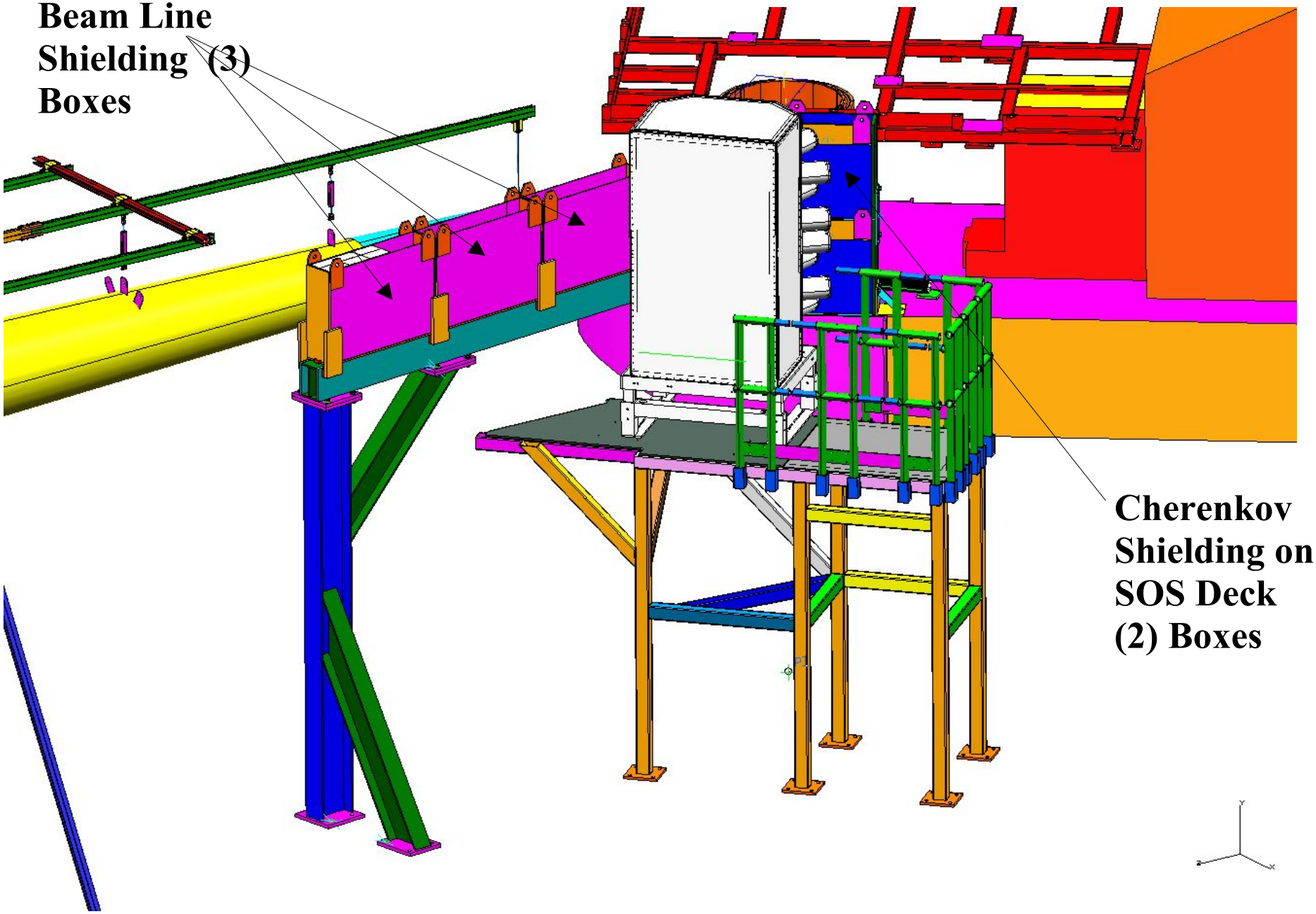
- 6. Cherenkov: Fall '07 tests need improved coordination with GEp-III collaboration
  - Successful tests done in April; report by Temple
- 7. Hodoscopes: Effectiveness of magnetic shields need to be demonstrated with calculations or measurements
  - done:
    - Forward tracker PMTs will be in 6 mm soft iron box
    - Lucite hodoscope will be in 12.7 mm soft iron boxes
    - all PMTS will have mu-metal sleeves extending 1 diameter beyond photocatode

SANE Safety Documents

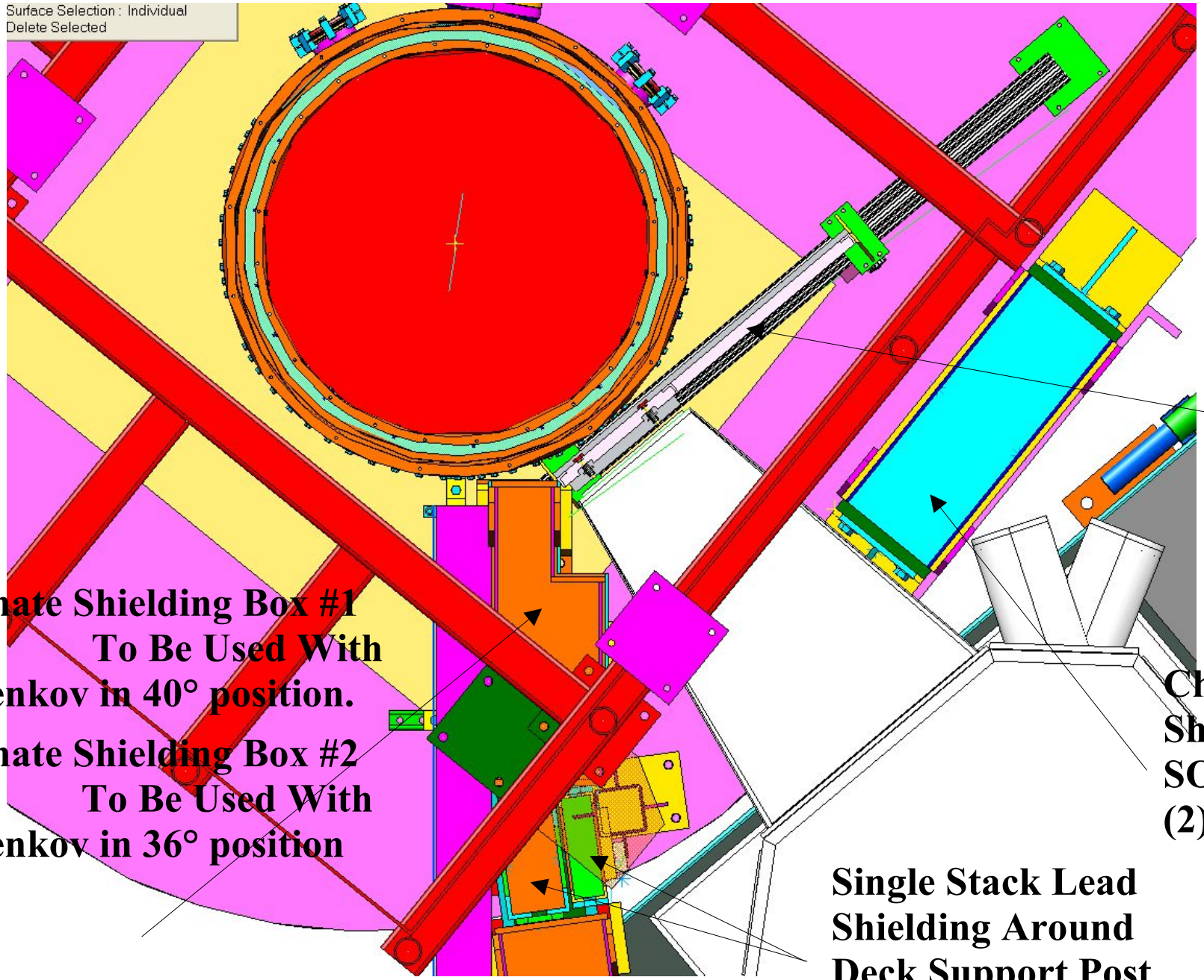
- Existing polarized target COO and ESAD for ***RSS*** (E-01-006) and ***GEn*-01** (E93-026) updated for SANE
  - using current version of Hall C base equipment material
  - added safety assessment for BETA detector components:
    - BigCal, Cherenkov, Lucite Hodoscope and Forward tracker
  - update polarized target access for new platform configuration
- Used ***GEp*-III** (E04-109) as model for Installation COO
- Existing RSAD document for ***RSS*** is base for SANE RSAD
  - almost identical beam energy, luminosity, beam deflections, beam line
  - updated radiation budget submitted with Beam Request (9/14/2006)
- Additional shift directives, run coordinator duties, manuals being updated from ***RSS*** documents

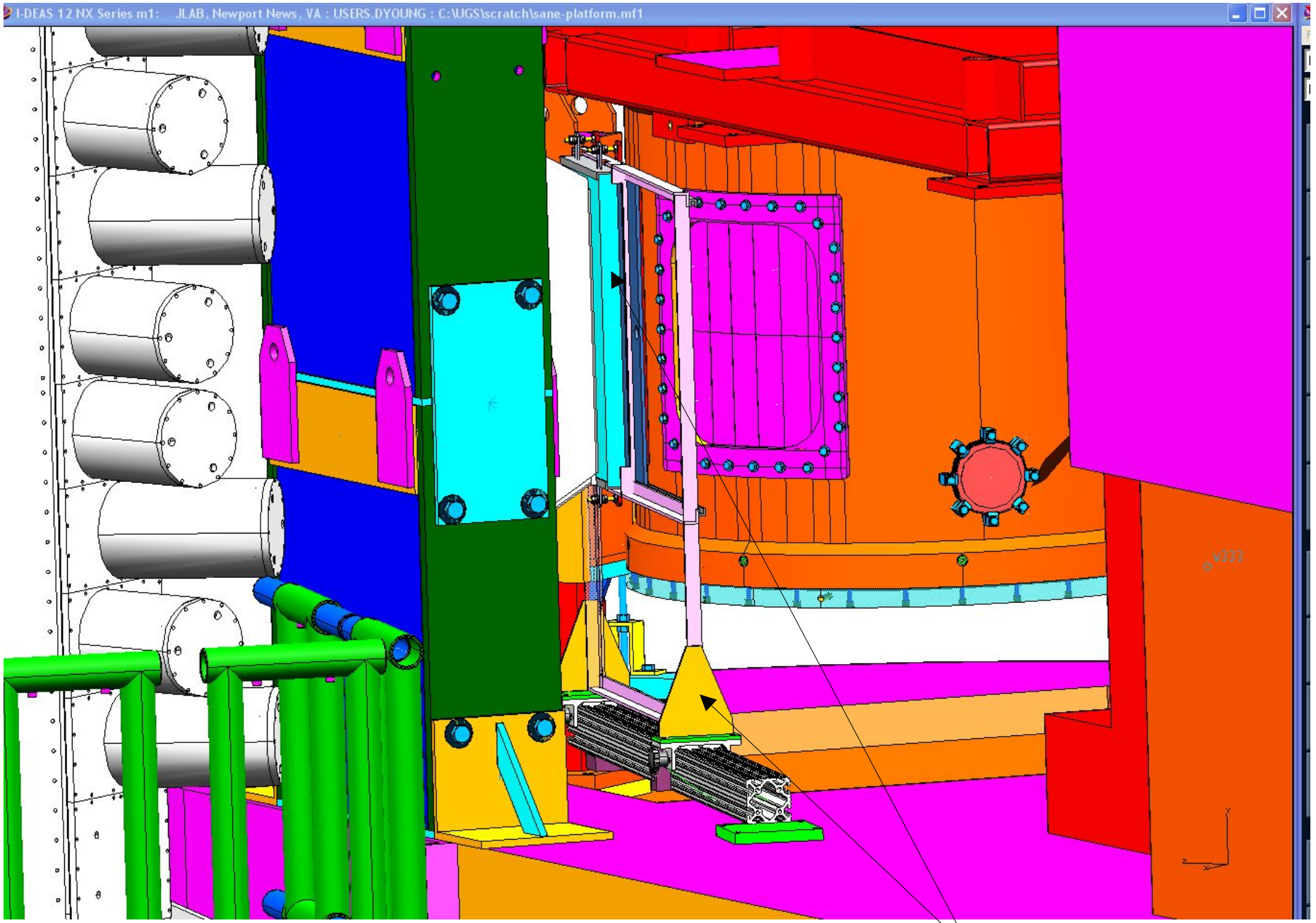

Lead Shielding
Below Beam
Centerline
Lead Shielding
Above Beam
Centerline
Beam Centerline


100.8
Inches To
BigCal
40°
Cherenkov
Angle
160.0
Inches
Shielding
Length
8°
Shielding
Angle
40°
BigCal
Angle



BigCal Removed For Clarity

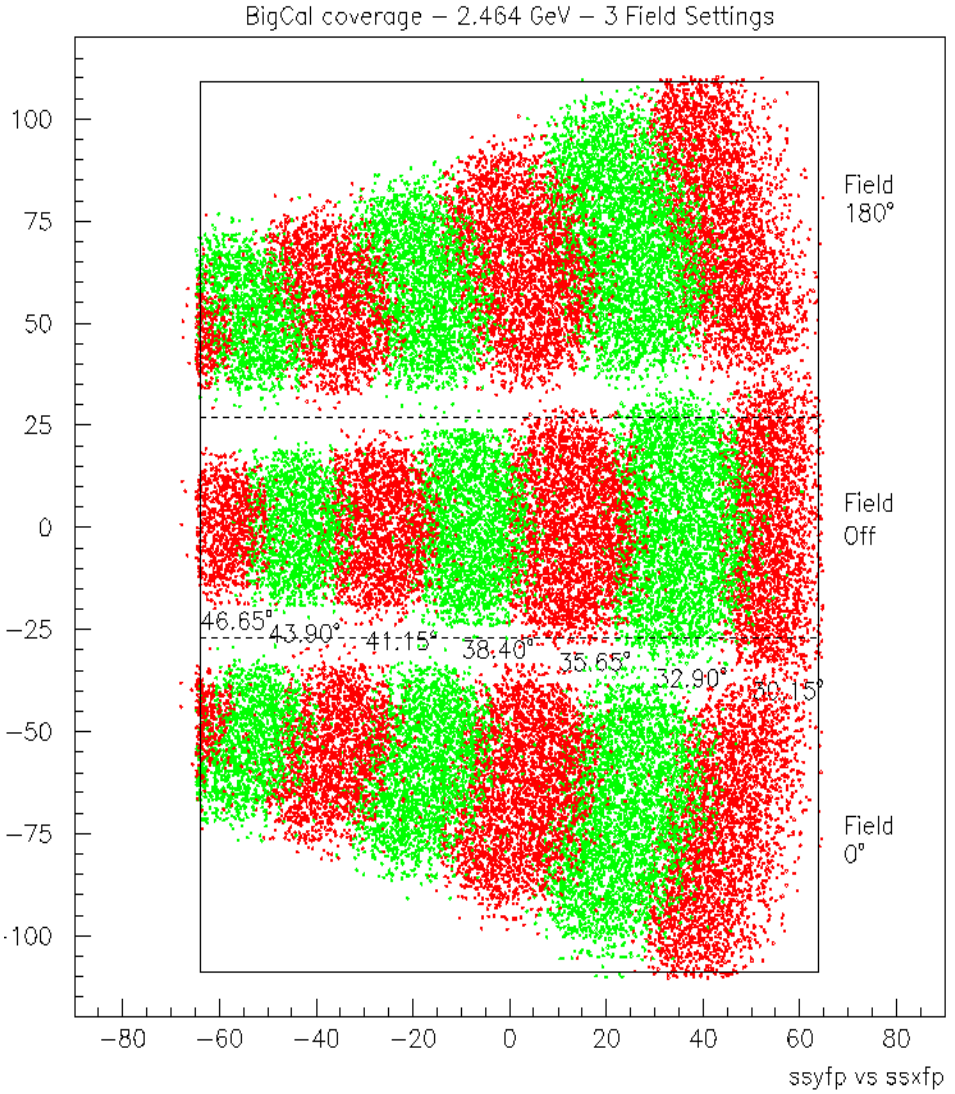

Surface Selection : Individual
Delete Selected
Tracker Detector
Alternate Shielding Box #1 To Be Used With Cherenkov in 40° position.
Alternate Shielding Box #2 To Be Used With Cherenkov in 36° position
Cherenkov Shielding on SOS Deck (2) Boxes
Single Stack Lead Shielding Around Deck Support Post



Tracker Detector on Slide Between Cherenkov and Target Chamber

Elastic Calibration (ii)

- BigCal Energy Calibration:
  - $e+p$ elastic coincidences with p detected in HMS, NH_3 target, 1 μA
  - one pass with target field off
  - two passes with full field on, pointing in opposite directions along beam, two passes with ½ field on
  - 2-pass, 2.46 GeV beam; no deflection
  - 90% coverage of BigCal (5 passes; 75% with 3 passes)
    - 60 h (5 passes, 100% efficiency)
      36 h (3 passes); ≤ 5% statistics
- Continuous π^0 mass reconstruction



Elastic Calibration (iv)

- BigCal Energy Calibration:
  - e+p elastic coincidences with p detected in HMS, NH_3 target, 1 μA
  - one pass with target field off
  - two passes with full field on, pointing in opposite directions along beam, two passes with ½ field on
  - 2-pass, 2.46 GeV beam; no deflection
  - 90% coverage of BigCal (5 passes; 75% with 3 passes)
    - 60 h (5 passes, 100% efficiency)
      36 h (3 passes); ≤ 5% statistics
- Continuous π^0 mass reconstruction