Storage Ring Vacuum Systems and Front Ends

NSLS-II ASAC Review

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and

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Outline

Vacuum Requirement, Storage Ring Cell Layout

Chamber Design, Fabrication and Cross Sections

Ray Tracing Effort and Absorbers

Pumping and Pressure Simulation

ID and Front End Layout

Work Plan, Review Recommendations

Summary

Vacuum Requirement

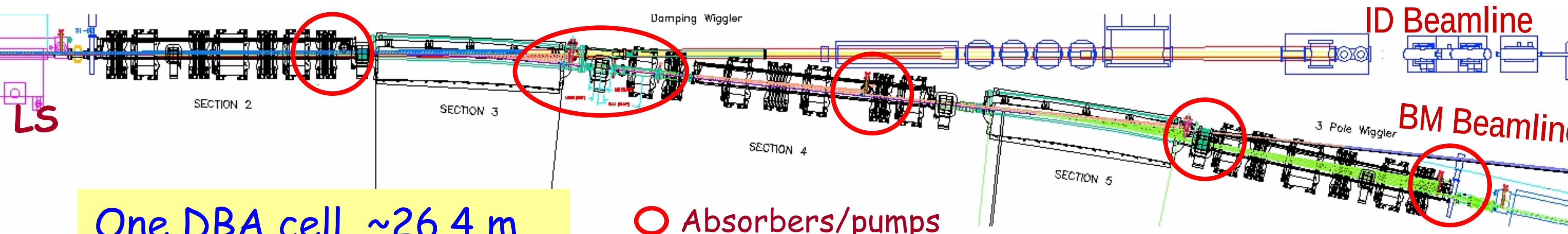
Vacuum Chambers - Adequate Apertures and Low Impedance

- Beam aperture – 25 mm (V) x 76 mm (H)
- Chamber straightness - < 1 mm / 5 m
- Smooth cross section changes: 9:1 ratio
- Minimum steps or cavities < 1 mm
- Mechanical stability: 1 fixed & 2 flexible Invar supports near BPMs

P(avg) < 1 nTorr (> 50% H_2, < 50% CO, CH_4, …),

- τ (beam-gas) > 40 hr (inelastic scattering)
- Local pressure bumps ⇨ bremsstrahlung radiation
- Intercept BM photons at discrete absorbers
  - To protect un-cooled flanges and bellows
  - Ion pump and TSP at absorbers
- Two NEG strips in ante-chambers

Vacuum Cell Layouts



One DBA cell, ~26.4 m

○ Absorbers/pumps

Extruded **Al 6063-T5**

60 dipole chambers - 6°, 3 m

90 multipole chambers - ≤ 5 m

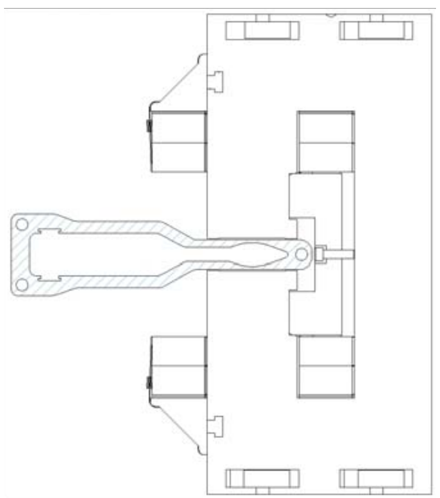
>30 ID chambers, 3–5 m

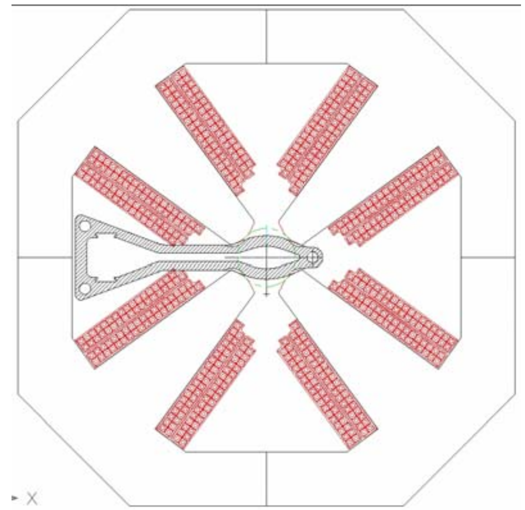
Sources*	L (m)	No.	P(kW)	Σ P(kW)	H (± mrad)
Dipole	2.6	60	2.4	144	52
DW	7	8	**65**	**520**	**2.6**
EPU	4	5	16.4	82	< 0.1
3PW	0.3	15	0.4	6	1
Others				~200	< 0.1

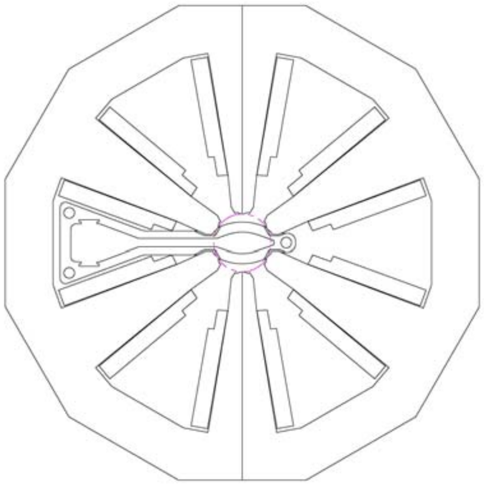
*E = 3 GeV, I = 500 mA

- Bending magnet fans intercepted by discrete absorbers
  - 2 crotch absorbers, ~ 7 stick/flange absorbers per cell
- < 30 % DW fan clipped by wiggler absorber before entering FE
- Other insertion device fans (≪ ± 1 mrad) are handled in FE

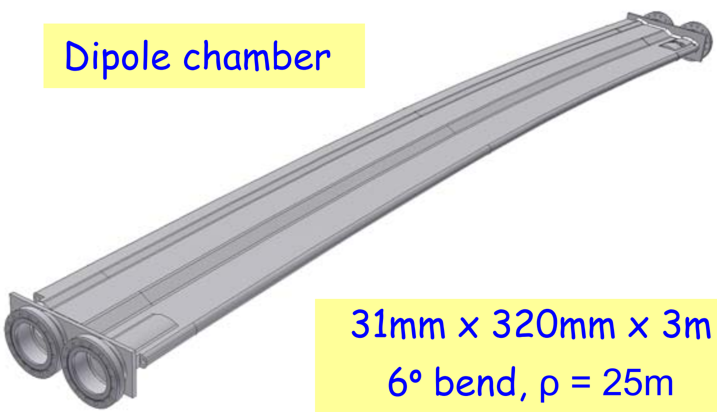
Cell Chambers and Magnets







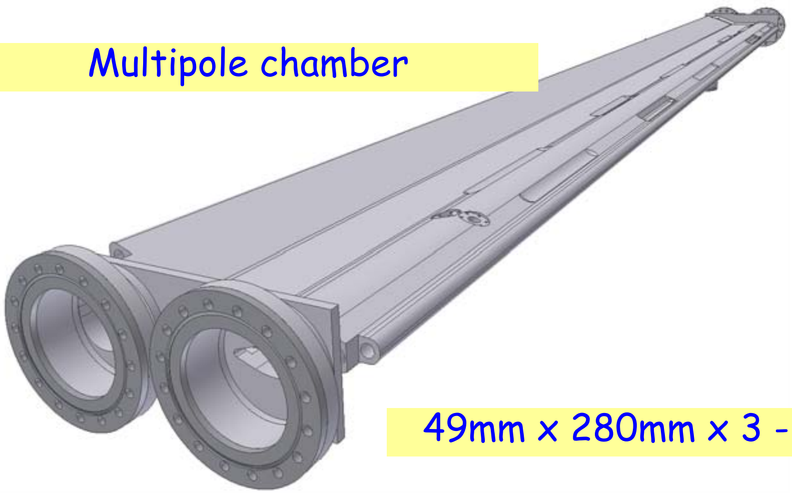
Dipole chamber



31mm x 320mm x 3m

6° bend, ρ = 25m

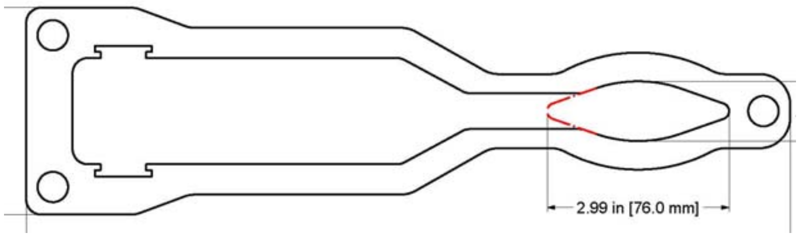
Multipole chamber



49mm x 280mm x 3 - 5m

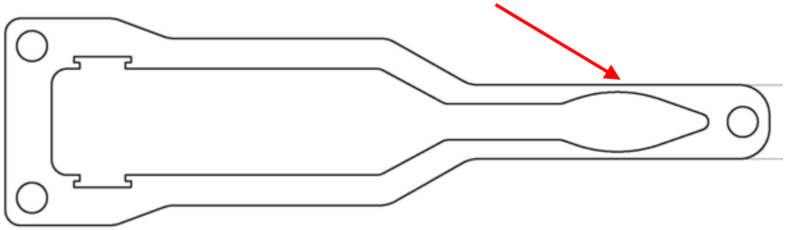
Cell Chamber Cross Sections

Dipole Chamber



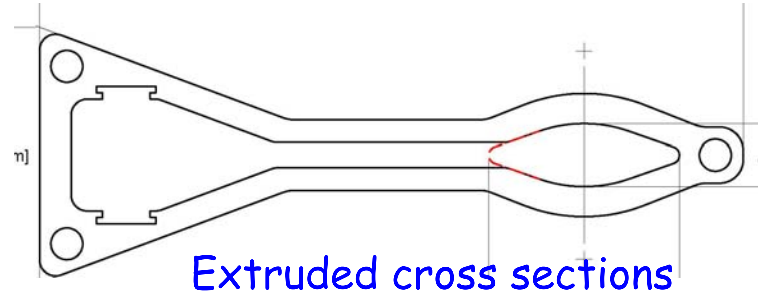
Extruded cross sections

3mm wall

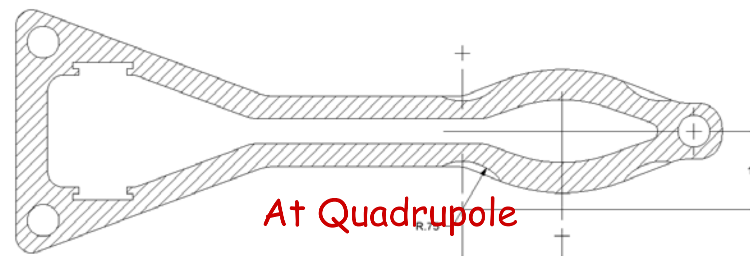


After bending and machining

Multipole Chamber

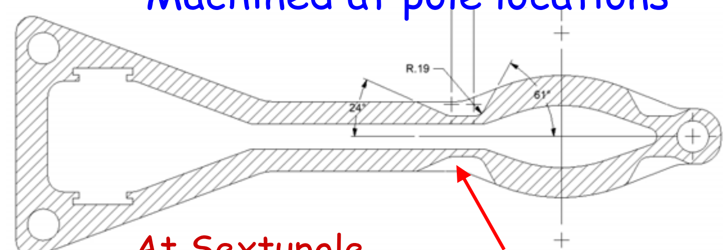


Extruded cross sections



At Quadrupole

Machined at pole locations



At Sextupole

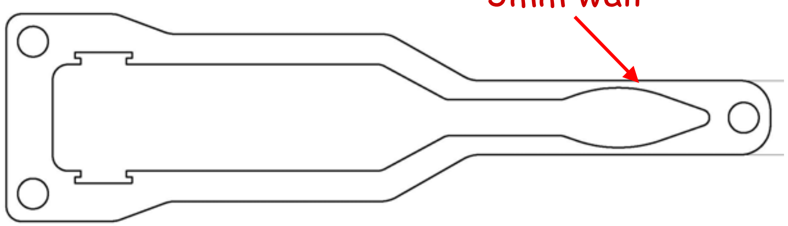
3.1 mm wall

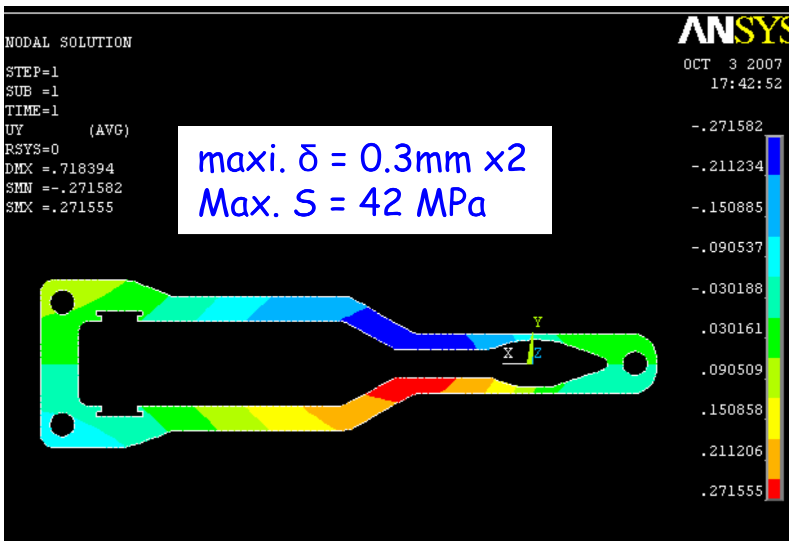
Finite Element Analysis of Stress and Deflection

At 125°C and 150 psi

Dipole Chamber

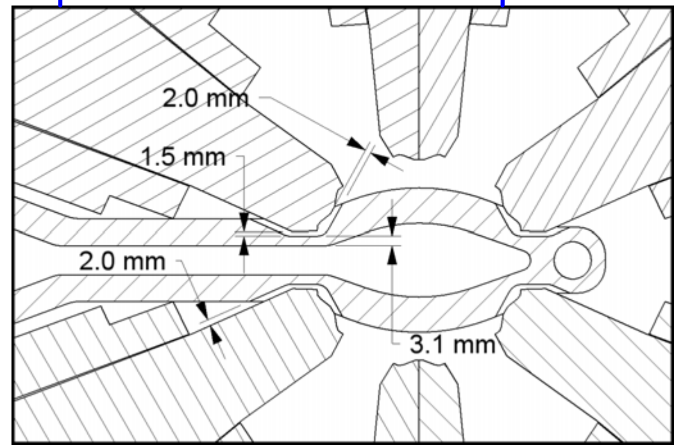
3mm wall

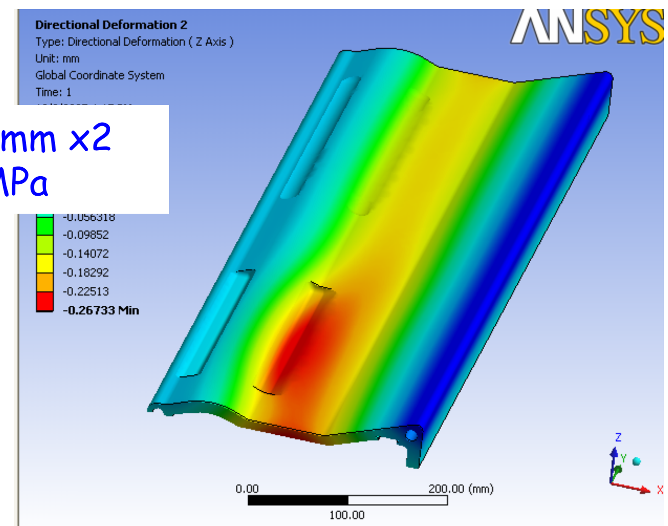




maxi. δ = 0.3mm x2
Max. S = 42 MPa

Multipole chamber at sextupole location





maxi. δ = 0.27mm x2
Max. S = 64 MPa

S_{yield} (A6063T5) = 145 MPa ⇨ S.F. > 2

Fabrication Steps for Cell Aluminum Chambers

Al: low impedance, thermal/mechanical properties, ease of fabrication and cost

V1, V2, V3: vendors
A: APS facility
B: NSLS-II

Based on APS & NSLS experience:

Material: Aluminum 6063-T5 billets, > 350 mm Ø (V1)

Extrusion: few vendors are interested (V1)
~ 1/2 yr to develop the extrusion parameters

Roll Bending: for dipole chamber with ρ = 25 m (V2)

Machining: photon exit ports, BPMs, absorbers, pumps, …. (V3)
end flanges, profiles at dipoles, multipoles, … (V3)

Cleaning: to remove contaminants and reduce oxide layer (A)

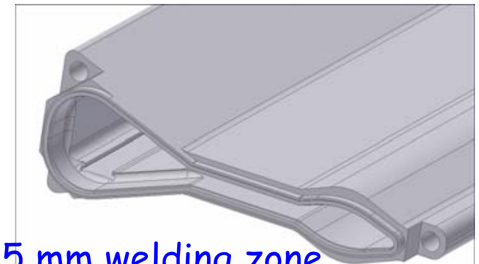
Welding: photon exit ports, end flanges, side ports, etc. (A)

2+ yrs?

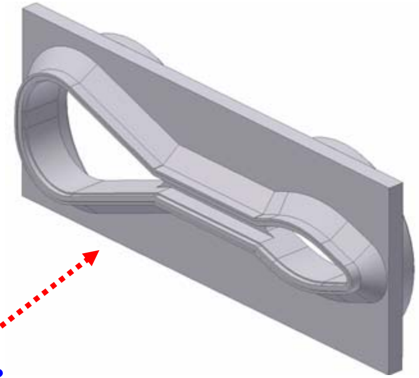
Assembly: BPMs, NEG strips, pumps, gauges, absorbers, testing, (B)
assembled into magnets/girder, alignment, baking etc. (B)

Chamber Fabrication Details

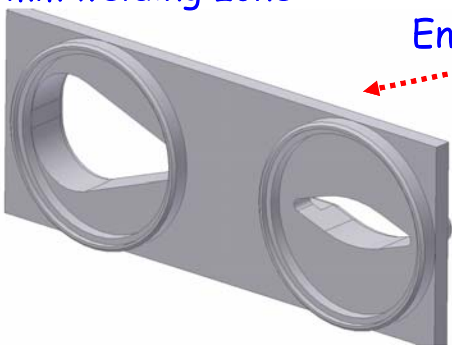
Multipole Chamber

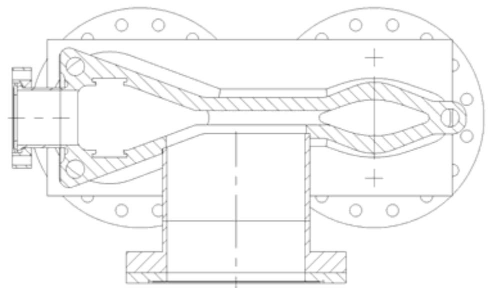


w/ > 5 mm welding zone

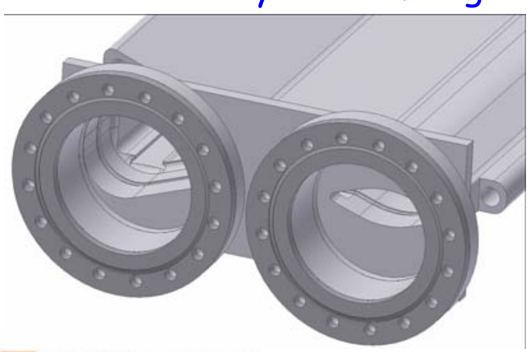


End plate

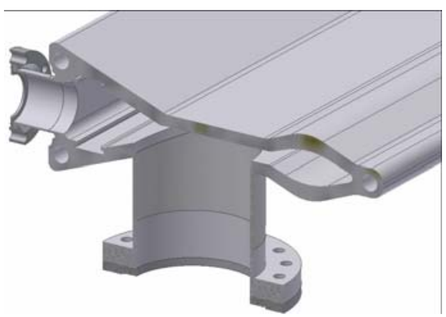




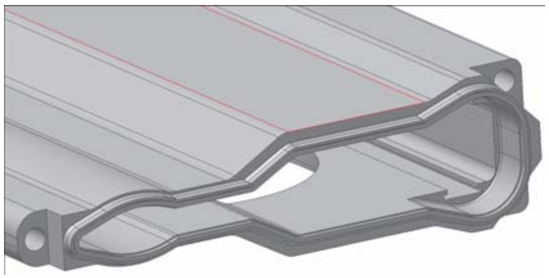
End assembly w/ CF flanges

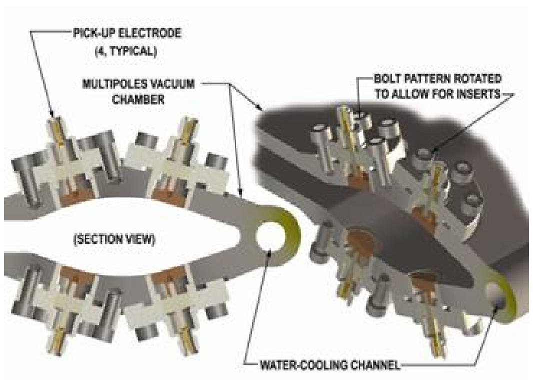


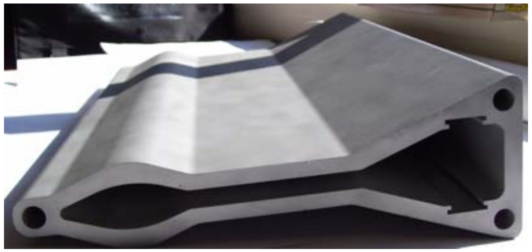
Absorber / pump ports



Dipole Chamber



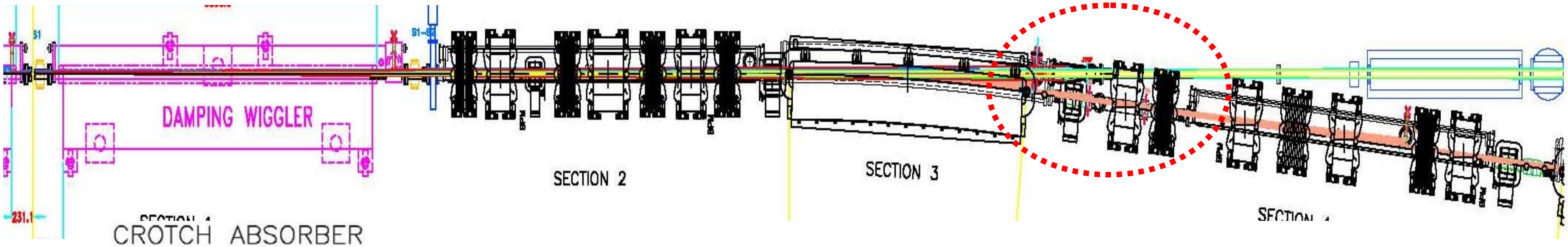


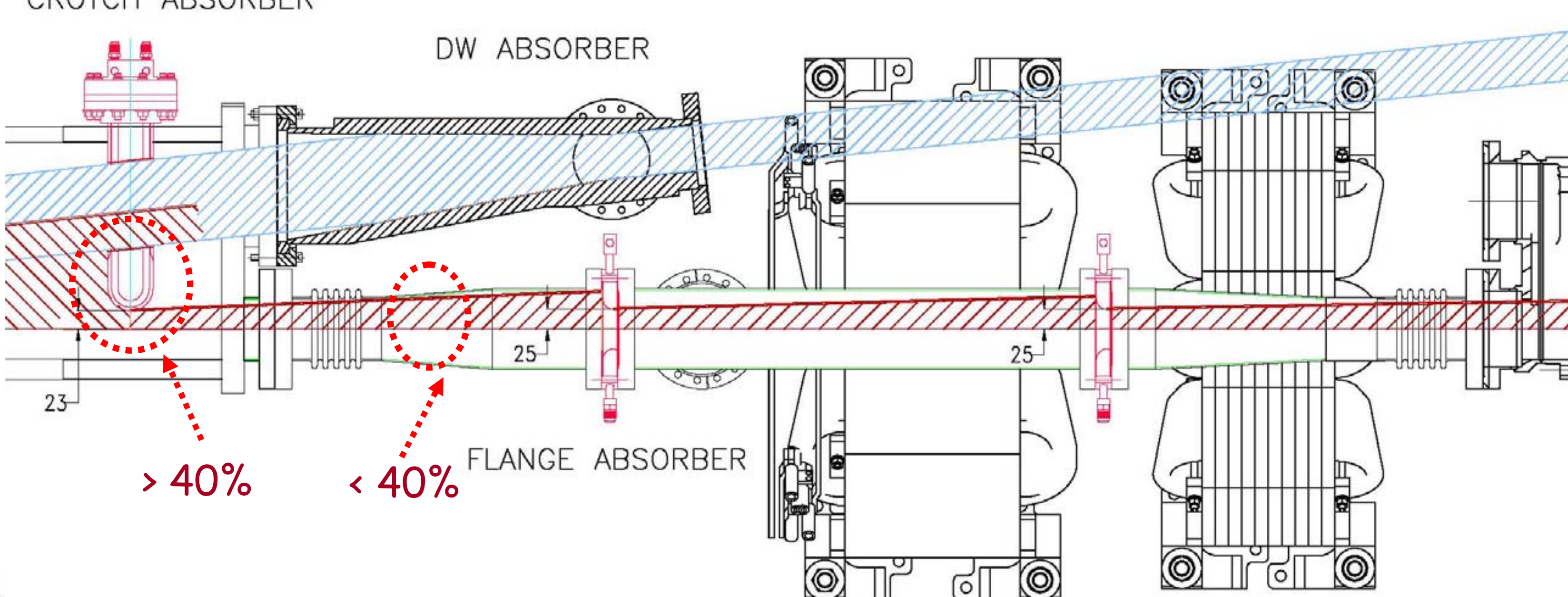


EDM machined test piece

Ray Tracing Effort

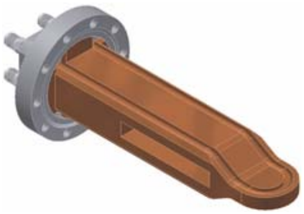
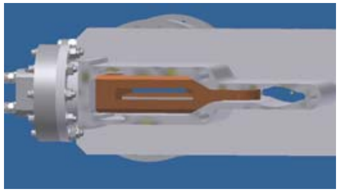
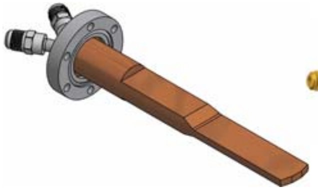
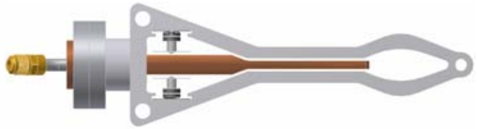
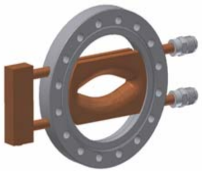
- Define photon fans, chamber widths/clearance and absorber locations
  - with ± 2 mm and ± 0.25 mrad beam deviation limits
- Total power, power density and ΔT for each absorber
- Pressure profile with adequately sized pumping





BM Radiation Absorbers, Power & Photon Flux in One Superperiod

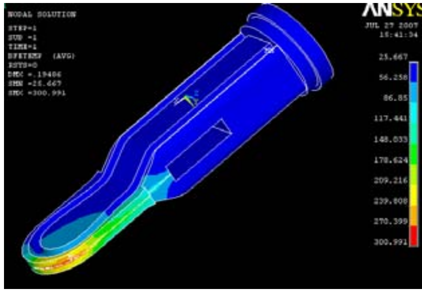
4 crotch absorbers, 10 stick absorbers and 4 flange absorbers per superperiod

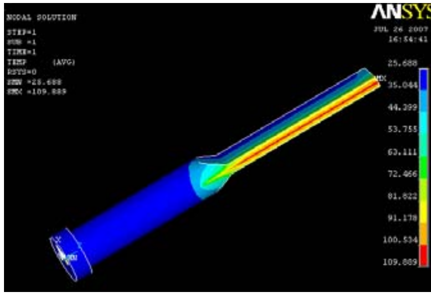
T_{max}(GlidCop) < 400°C

At 3.6 GeV

Section #	Absorber Type	S (m)	X (mm)	BM Fan on Absorber (degree)	Power 3 GeV (watt)	# hv 3 GeV
S6	Stick		25			
S1-LS	Stick	0.00	22	0.210	84	7.1E+17
DW	Stick		37			
S3	Crotch	11.04	23	2.459	983	8.3E+18
S4	Flange	11.55	25	0.851	340	2.9E+18
	Flange	12.20	25	0.549	220	1.9E+18
	Stick	15.78	27	0.659	264	2.2E+18
S5	Crotch	20.28	25	3.611	1444	1.2E+19
S6	Stick	23.64	25	1.969	788	6.7E+18
S1-SS	Stick	24.61	22	0.086	34	2.9E+17
EPU	Stick	29.13	32	0.115	46	3.9E+17
S2	Stick	32.95	25	0.092	37	3.1E+17
S3	Crotch	36.14	23	3.366	1346	1.1E+19
S4	Flange	36.66	25	0.851	340	2.9E+18
	Flange	37.31	25	0.549	220	1.9E+18
S4	Stick	40.89	27	0.659	264	2.2E+18
S5	Crotch	45.38	25	3.611	1444	1.2E+19
S6	Stick	49.03	25	1.998	799	6.8E+18



< 35W/mm², T_{max}~ 300°C

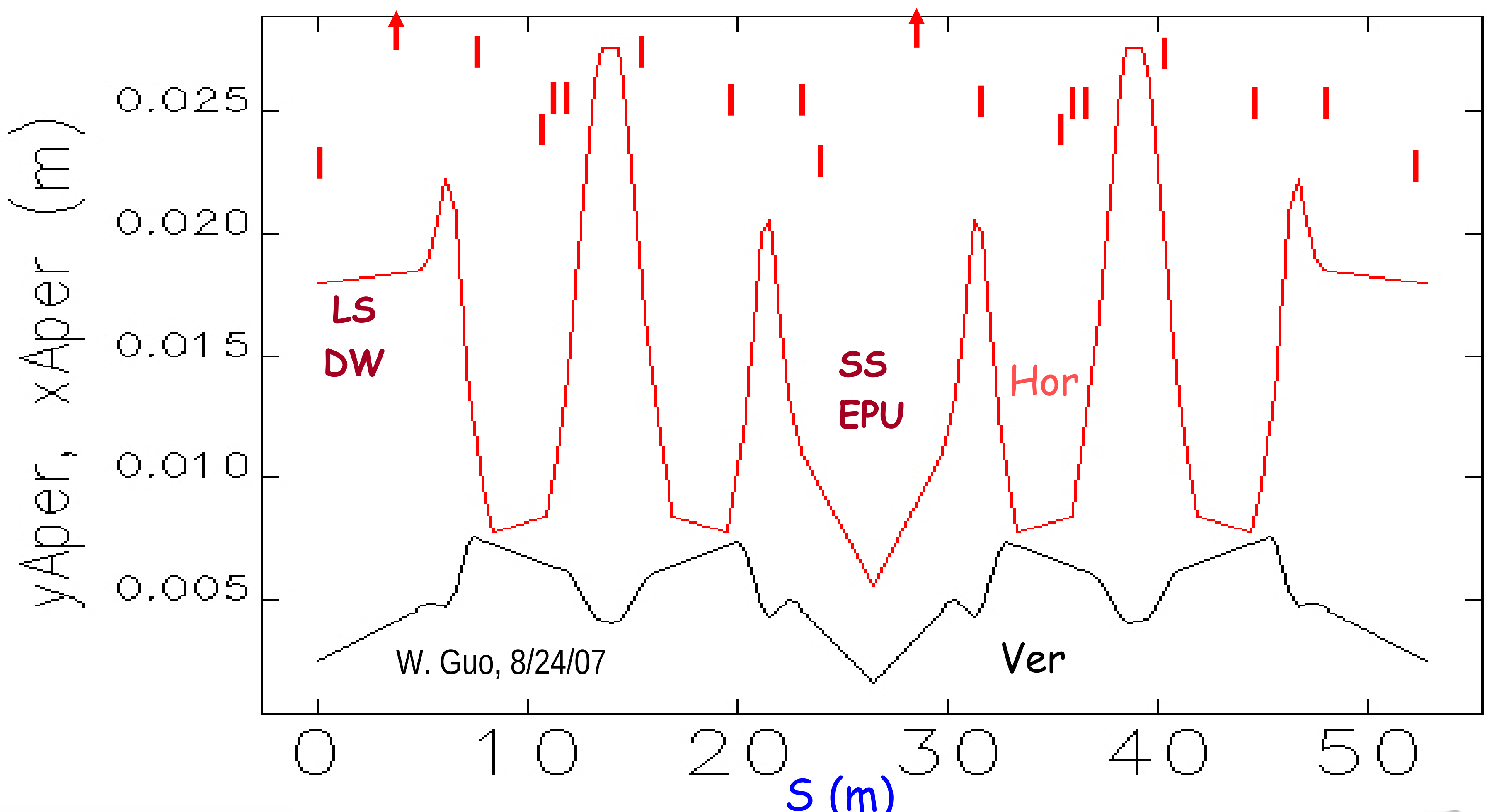


< 9 W/mm², T_{max}~110°C

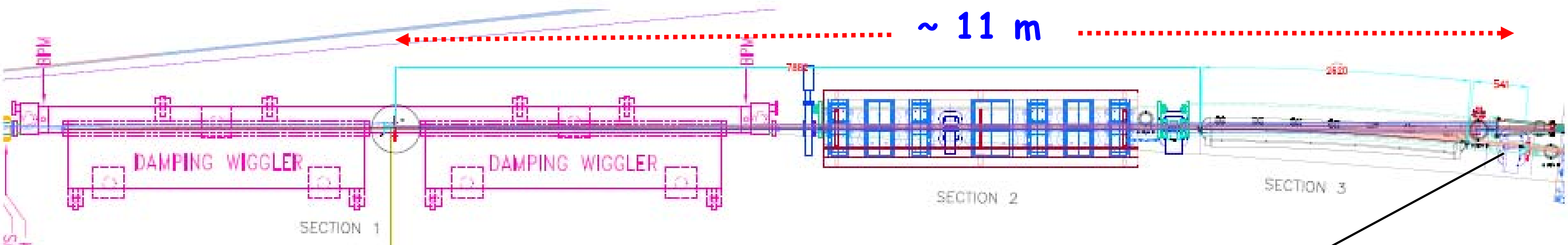
Chamber Aperture Requirement and Absorber Locations

- Horizontal location of absorber from BC

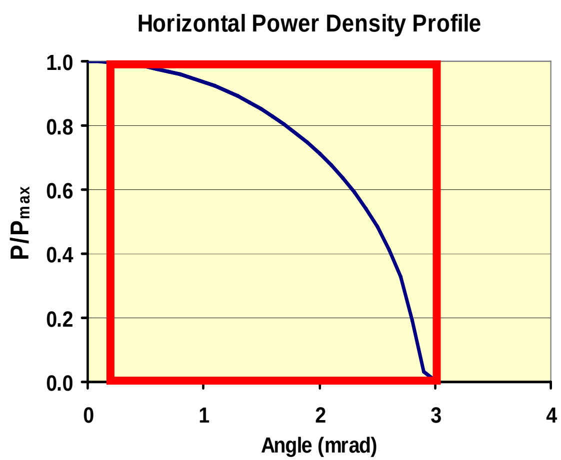
Most at 25mm, some at 22, 23, 27, 32 and 37mm

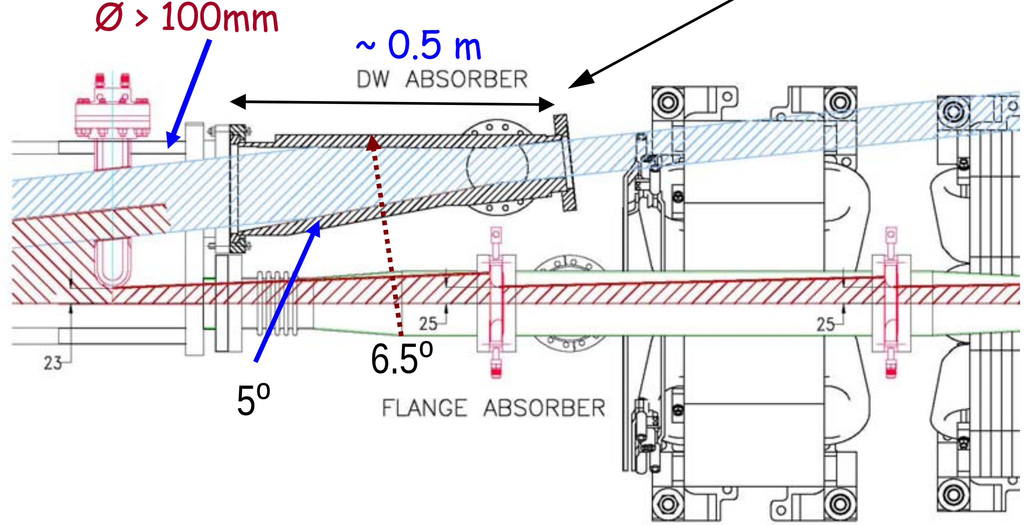


SR Wiggler Absorber- Canted Damping Wiggler



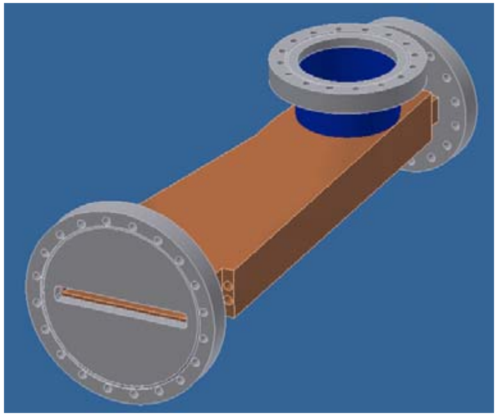
±2.6 mrad, 3.5 mrad canting



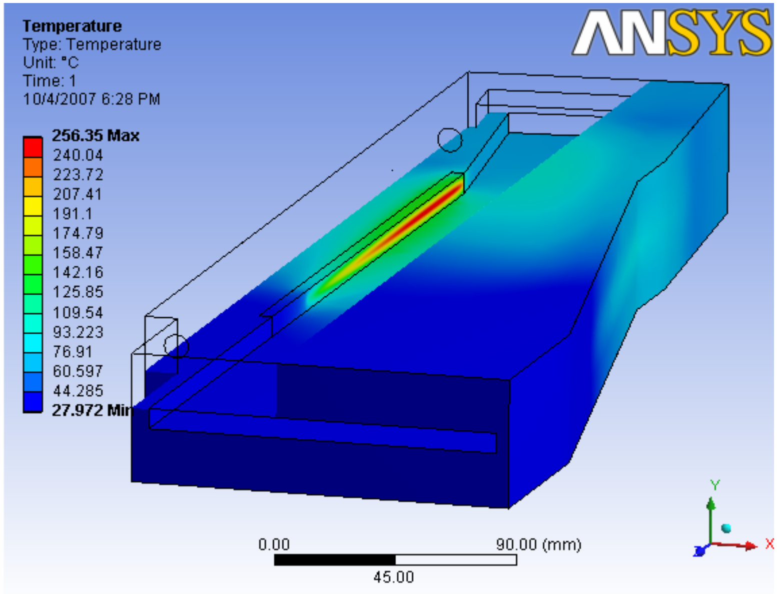


Wiggler absorber clips the two DW fans by ~2.2 mrad on each side and allows (2.6+0.4) mrad fan from each DW to pass through.

Wiggler Absorber Thermal Analysis



Electron energy	3.0 GeV (3.6)
Beam current	500 mA
K	16.81
Field	1.8 T
Wiggler length	3.5 m



~2.2 mrad trimmed from one side of each DW fan

E (GeV)	3.0	3.6
P (kW) DW – 3.5m	33	47
P (kW) absorber/each side	11	17
P (W/mm^2) – max at 6.5°	25	51
T (°C) - max	256	440

Types & Quantities of Major Vacuum Components

- Cell chambers ~9 types; Absorbers 3 types/ 10 variations
  RF Bellows > 5 types (Excluding those for ID, RF, Inj. diagnostics)
- Need to standardize as much as possible for fabrication cost & schedule
- Tracking components for "different" assembly and installation

Cell Chambers	Section #	Quan	Comment	RF bellows	Section #	Quan	Comment
Dipole	S3	30		125mm ID	S2-S3	15	
	S5 - A	30	15 3PW	100mm ID		105	
Multipole	S2 - A	15		Special	S4, SS	~ 70	
	S2 - B	15	Large bellows for	Total		**190**	
	S4	30		Absorbers			
	S6 - A	15	Soft X-ray exit port		Wiggler	8	
	S6 - B	15	3PW exit port		Crotch	60	Five types
Long Straight	S1 - A	26	Two chambers each		Stick	90	Three types
Short Straight	S1 - B	15			Flange	60	Two types
Total		**191**		Total		**258**	

UHV Pumping and Pressure Profiles - $P_{avg} < 1$ nTorr

Thermal outgassing (after 120°C in-situ baking)

$q < 1\times10^{-12}$ Torr.l/s/cm^2 , Q (chamber) ~ 1×10^{-8} Torr.l/s/m

Pressure will be dominated by *PSD*

photons (60 BM) ~ $1\times10^{+21}$/s ≈ 3×10^{-4} Torr.l/s ⇨ 5×10^{-6} Torr.l/s/BM

($\eta < 1\times10^{-5}$ molecules / *hv* for Cu after 100 A.hr)

photons (each 7m DW) ~ $6\times10^{+20}$/s

15% (45%?) intercepted by ring DW absorber ⇨ 3×10^{-5} Torr.l/s/DW

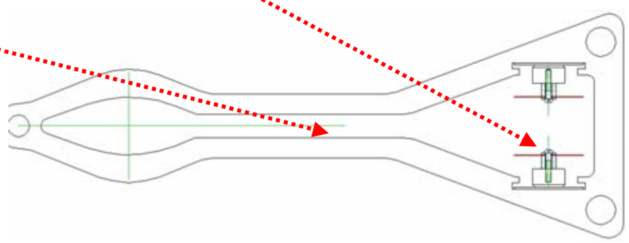
NEG strips ~ 700 m for active gases, S > 200 l/s/m

Reside in ante-chambers

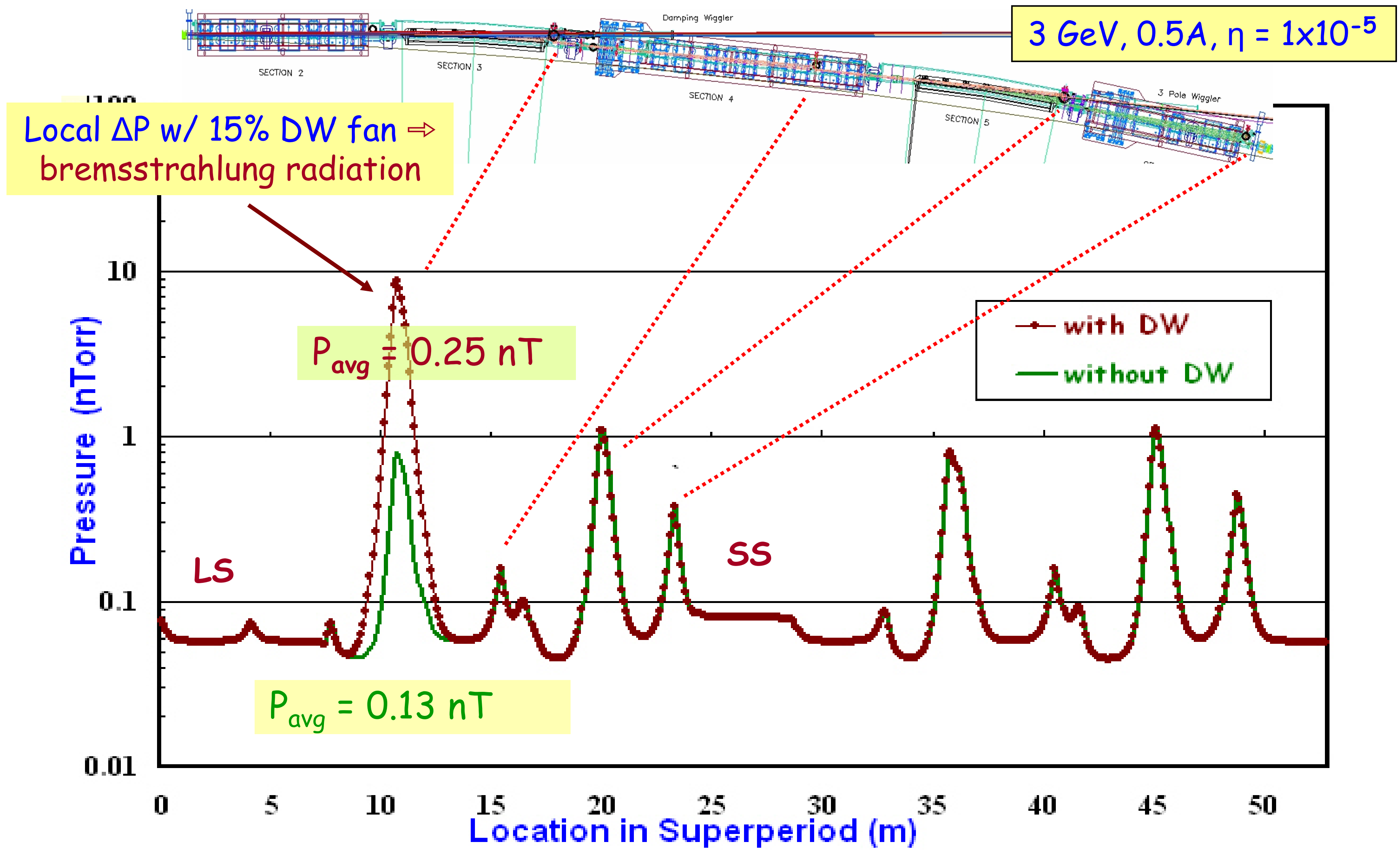
Pump thru the photon slots (*C* < 135 l/s/m)

IP and TSP of ~ 500 l/s at absorber locations

7 IP/TSP per cell + 2 for each ID location

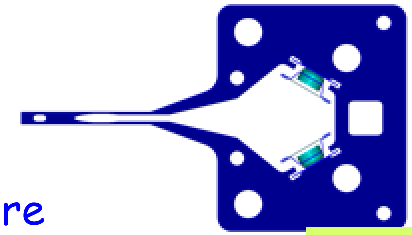


Pressure Profile with and without DW

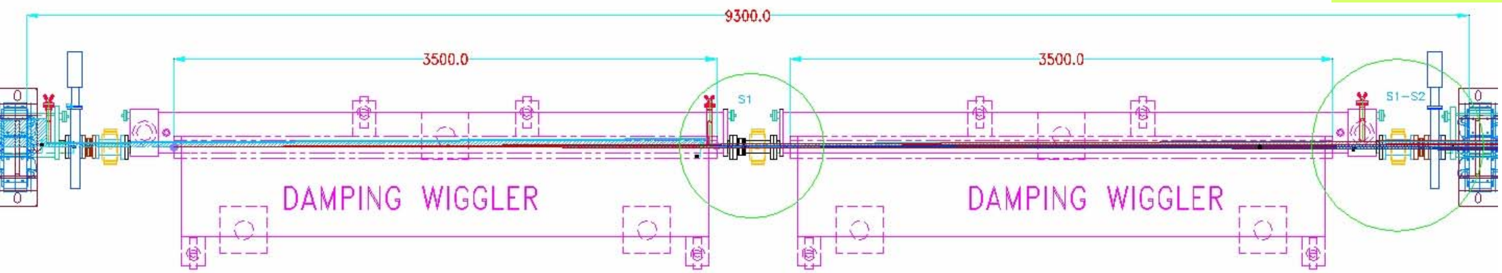


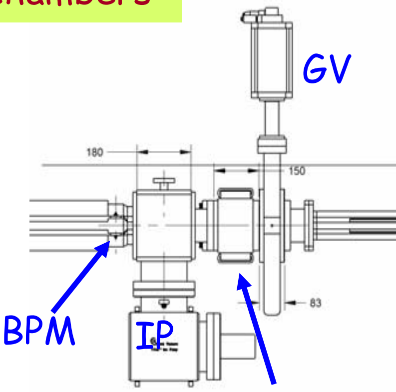
Insertion Device Chamber Layouts

ID Chamber Baseline Design:
Extruded Al with NEG strips in antechamber
Chamber vertical ID = magnet gap - 3 mm
Possible upgrade with NEG coating in the future

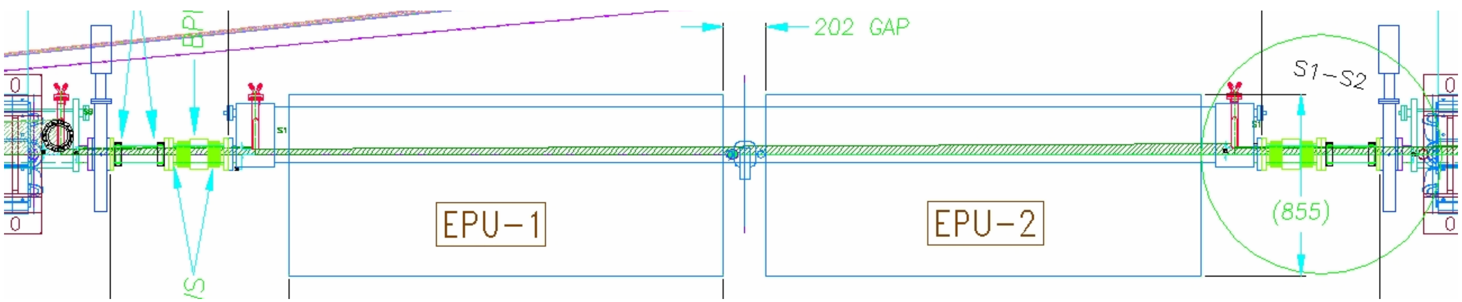


APS ID chambers





9.3m straight for 2 x 3.5m DW

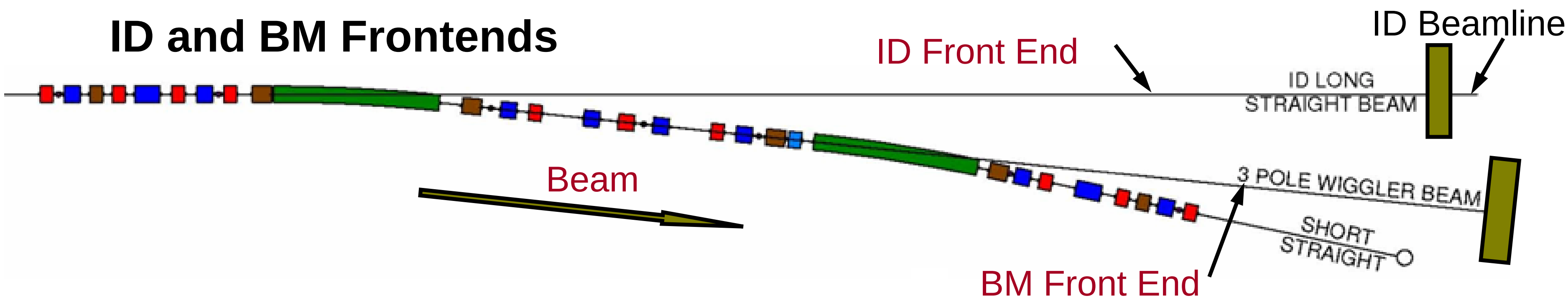


6.6m straight for 2 x 2m EPUs

APS end box

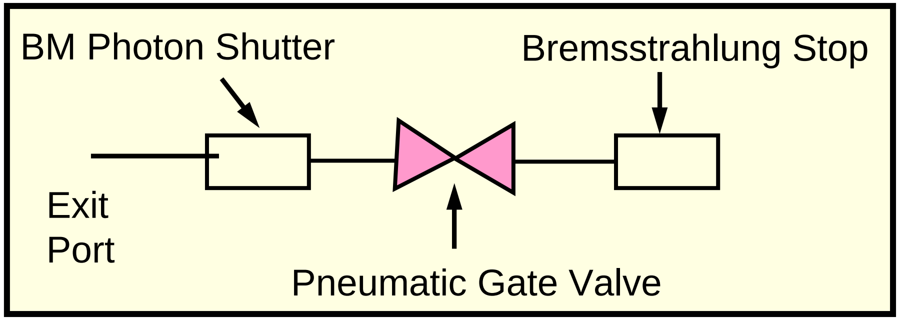
Schematic Layout of Front Ends

ID and BM Frontends

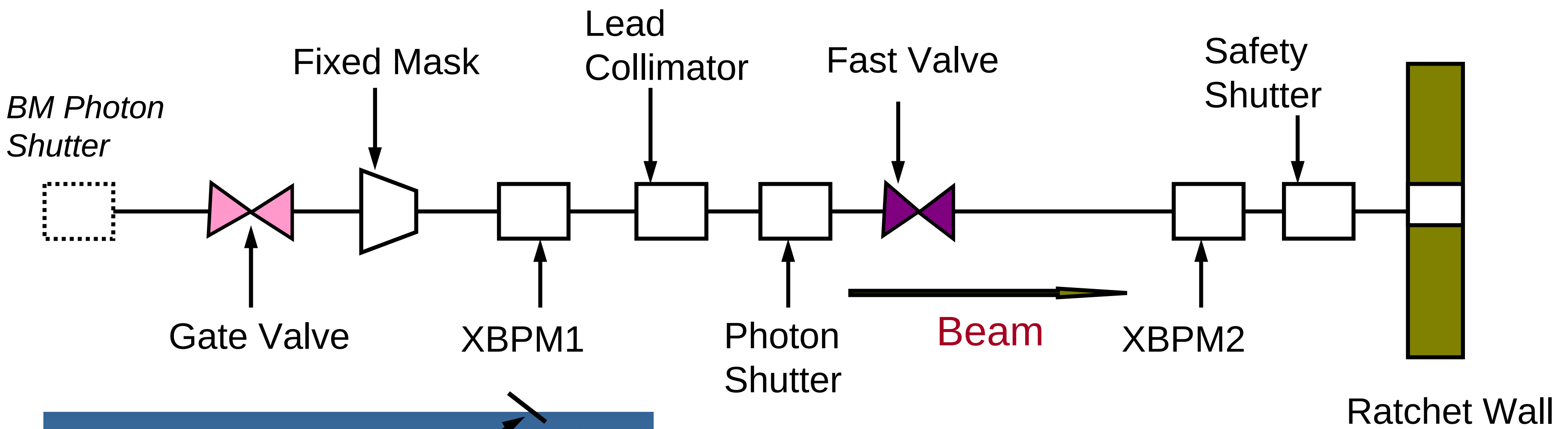


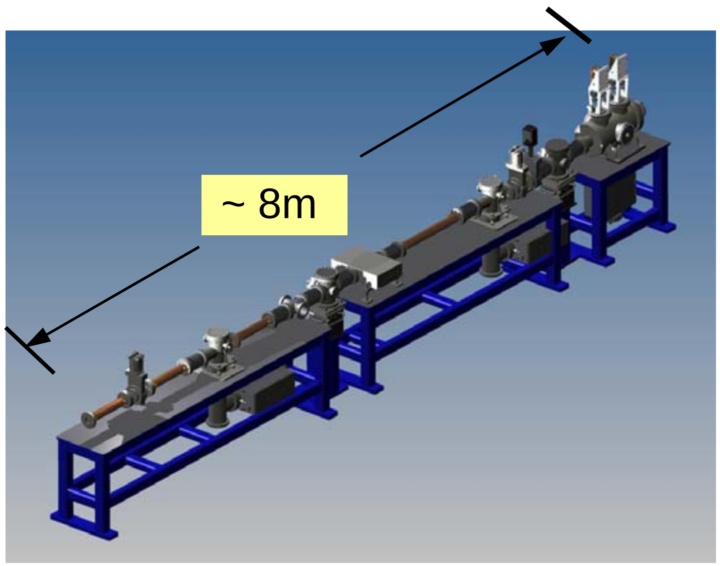
- The BM photon shutter is attached to an pneumatic actuator.
- Since this shutter protects the gate valve, there is no need to provide another gate valve in the front end.

Day One Front End
(no ID, no beamline)



Typical NSLS-II Front End

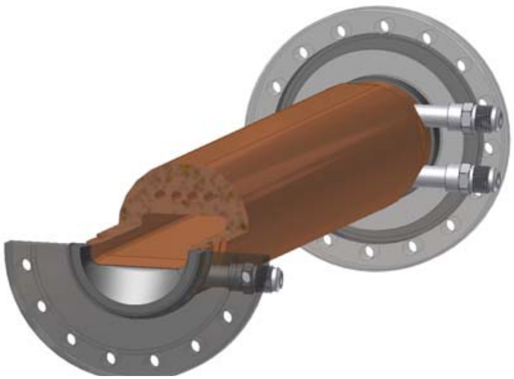


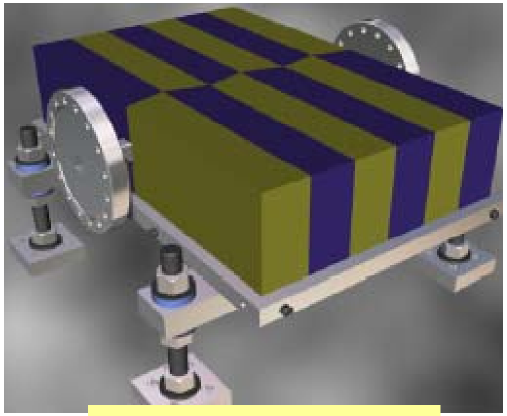


- One fixed mask, one photon shutter and one safety shutter are used in a front end.
- Two XBPMs are preferred.

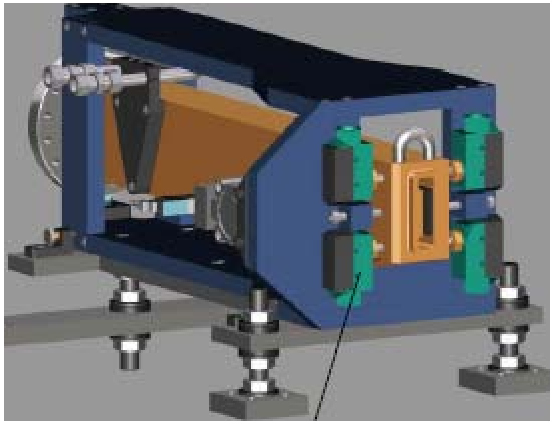
Front End Standard Components

APS designs will be adopted – NSLS-II has similar requirements and power densities



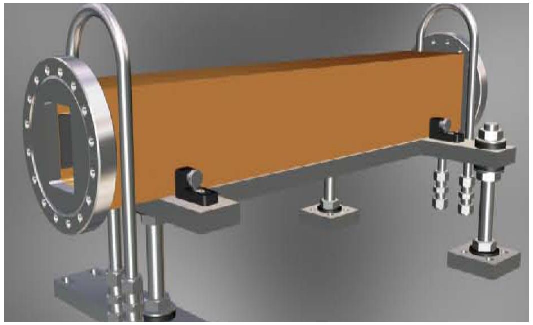


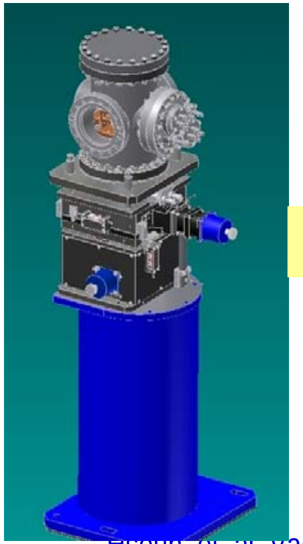
Lead Collimator



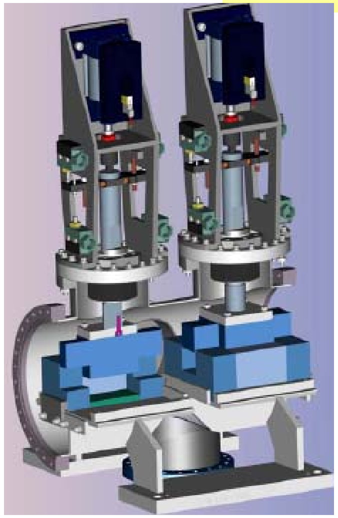
Photon shutter

APS fixed mask design





XBPM



APS Safety Shutters

Office of Science
U.S. DEPARTMENT OF ENERGY

BROOKHAVEN NATIONAL LABORATORY
BROOKHAVEN SCIENCE ASSOCIATES

Vacuum R&D and Design

Cell and chamber details

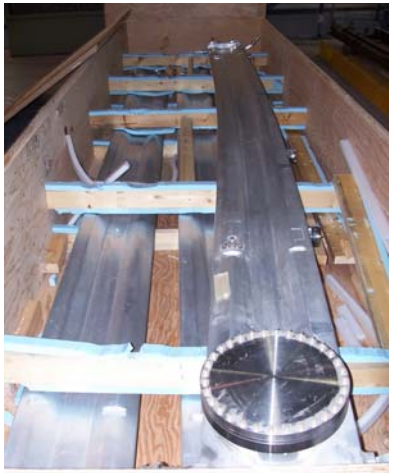
- Chamber detail and cross sections with ray tracing
- Absorber and pump locations, pressure simulation
- Layout of straight sections for insertion devices, injection, RF…

Extrusion development – PO placed last week

- Test extrusion with two vendors, Tabor & Tai Lain
  - 12 multipole chambers & 20 dipole chambers
- Develop fabrication process – bending, machining, welding …

Acquire APS cell chambers and bellows for R&D – received!

- Set up vacuum development area (~ 600 m^2) in Building 905
- R&D in NEG supports, in-situ bake and activation
- BPM sealing development
- Detailed layout of production facility



APS Chambers for R&D

Review Recommendations

- TE mode interference to BPM (observed at APS)
  - Absorbers symmetrical in photon exit gaps; pumping ports away from beam channel and BPM
- 10-15% scattered photons ⇨ chamber heating and desorption
  - Simulation codes? New DW absorber layout reduces scattered photons and ΔP
  - DW photons hitting exit gaps – 1.2% in S2 and 2.2% in S3 (R. Kerseven, ESRF)
- Manual gate valves at photon exit ports on day one - no
  - Small δ in cost, APS is replacing manual ones; Petra-3 has no manual one
- Verify pressure profile at DW absorber - done
  - Proportional to % of DW fan intercepted by wiggler absorbers
- FE analysis with 120 C and 150 psi in-situ bake – done
- BPM sealing test – ready to start
- NEG coating for cell chambers – No (Cost, schedule, activation, capacity, etc)
- TiN coating – Is it necessary? Technical, cost and schedule?
- Start RF shielded bellows design early - MP limited
- Alternatives to in-situ bake with high T, high P water – develop with APS chambers

Summary

- Vacuum layout, detail design and ray tracing continue
  - Both cross sections done
  - End assemblies and side ports being detailed
  - Straight section layouts with realistic component dimensions
  - Absorber analysis and front end development continue
- Vacuum chamber development
  - Test extrusion of cell chambers – PO placed
  - Set up of vacuum R&D area - started
  - APS cell chambers for R&D - started
- Areas of concerns
  - Staffing - 4 FTE now to ~ 15 by 2009
  - Hot water bakeout system ⇨ alternatives?