LARP Collimation Program
Opening Remarks

06 April 2005
LARP Collaboration Meeting
Port Jefferson NY

Tom Markiewicz
SLAC

Collimation Program Tasks

Package 1: Studies on a rotating metallic phase 2 collimator
Responsible: T. Markiewicz, SLAC

Package 2: Fast set-up and optimization of cleaning efficiency (simulations and tests at RHIC)
Responsible: A. Drees, BNL

Package 3: Improvements with tertiary collimators at the LHC experimental insertions
Responsible: N. Mokhov, FNAL

Package 4: Radiation tests of LHC collimator materials for phase 1 and phase 2 [new proposed work package]
Responsable: N. Mokhov, FNAL & N. Simos, BNL

Collimation Program Collaboration Issues

Since Napa ‘04

- Monthly Video Meetings: SLAC/Fermilab/BNL/CERN
- Better communication / collaboration with CERN:
  - Questions concerning & installation of up-to-date SIXTRACK code for efficiency studies
    - Assmann’s patience in repeatedly explaining system noteworthy
  - Transfer of latest FLUKA model in progress
    - Meeting of Lew Keller & Vasilis Vlachoukis in Houston Jan. ’05
    - Ferrari (CERN) to Fasso (SLAC) hand-off
- More intellectual engagement among US/CERN tasks desirable

At Port Jeff ‘05

- Still need to form subtasks into an integrated package
- Decide how/if/when to incorporate task#4 (Radiation Studies)
- Balance FY06 Budget requests

Task #4: Radiation tests of LHC collimator materials

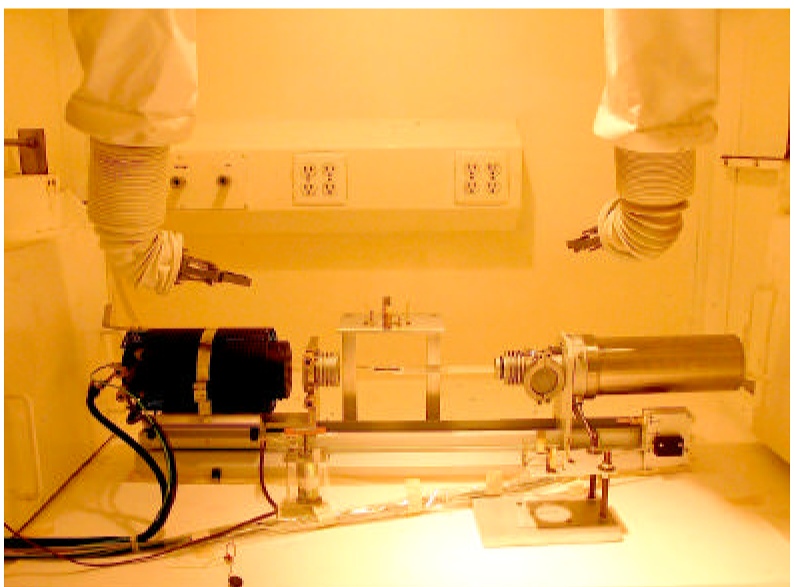
ASSESS the effects of proton irradiation on material properties

BNL AGS/BLIP/Hot Cell FACILITY

Properties: thermal expansion, mechanical properties, thermal conductivity/diffusivity and thermal shock

Materials: 2-d weave carbon-carbon and exact graphite used in phase I jaws plus materials considered viable for phase II jaws

Costs: Hot cell use fee, sample prep, apparatus improvement, postdoc



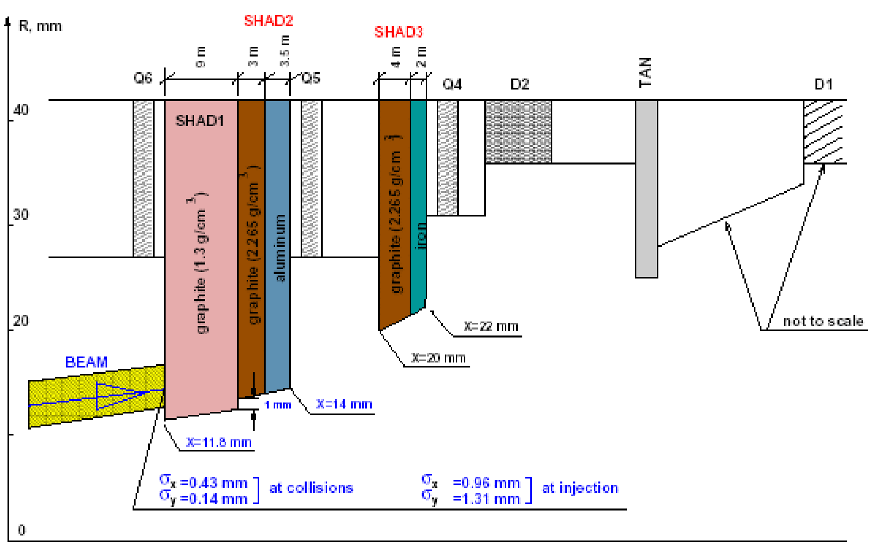
Should this program be added to LARP?

Task #3: Improvements with tertiary collimators at the LHC experimental insertions

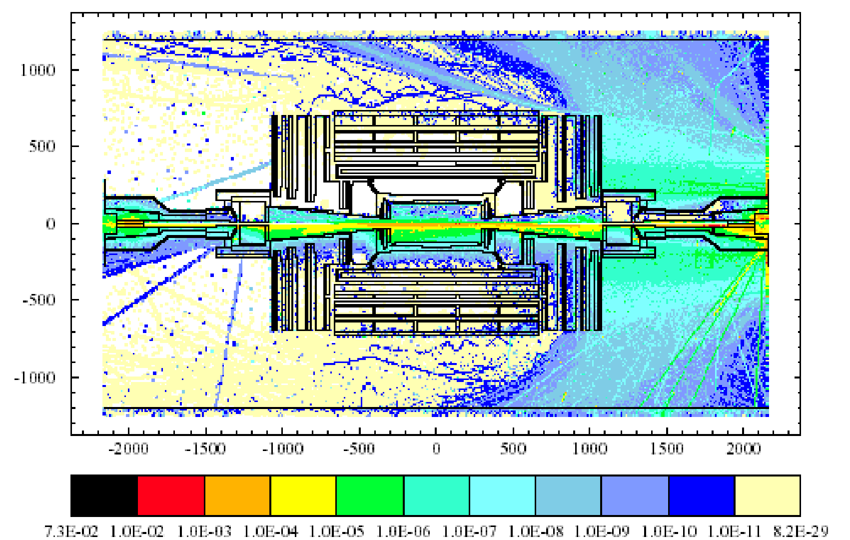
from 21 Oct 2004 Closing Summary

- MARS15 and MAD-STRUCT-MARS developments.
- Refining models for operational and accidental beam loss.
- Modeling in IP5 and CMS with tertiary collimators.
- Uncertainty analysis.

"TERTIARY" COLLIMATOR IN IP5 (1999)



DOSE (Gy) IN CMS with COLLIMATOR (1999)



A peak dose rate at the inner pixels 1.8 kGy/s, 10^5 the nominal.

Task #2:Simulations and tests at RHIC
from 21 Oct 2004 Closing Summary

BNL collaborating with the LHC collimation WG: colltrack code is installed and compiled at BNL

There is a need for code benchmarking and comparison in the world of loss maps

– data will be analyzed with the help of the LHC collimation WG (grad. student for 1-2 months)

Multiple collimator steering will likely require some beam time at RHIC

Hiring process of LARP postdoc started (likely for both fields, collimation and EC)

Task#1: Studies of a rotating metallic collimator for possible use in LHC Phase II Collimation System

If we ALLOW (rare) ASYNCH. BEAM ABORTS to DAMAGE METAL JAWS, is it possible to build a ROTATING COLLIMATOR

- that we can cool to ~<10kW
- that has reasonable collimation system efficiency
- that satisfies mechanical space & accuracy requirements

Overall Plan:

FY 2004:	Introduction to project
FY 2005:	Phase II CDR and set up of a collimator lab at SLAC
FY 2006:	Design and construction of RC1
FY 2007:	Tests of RC1 (two rounds), design and construction of RC2
FY 2008:	Non-Beam Tests of RC2
FY 2009:	RC2 beam tests & final drawing package for CERN
FY 2010:	Await production & installation by CERN
FY 2011:	Commissioning support

RC1=Mechanical Prototype; RC2: Beam Test Prototype

FLUKA/ANSYS results of 90kW Steady State / 450kW (10sec) loss scenarios

Identify materials which

- absorb ~10kw
- have temperature below fracture (and melting) point
- canned be cooled without high pressure water system

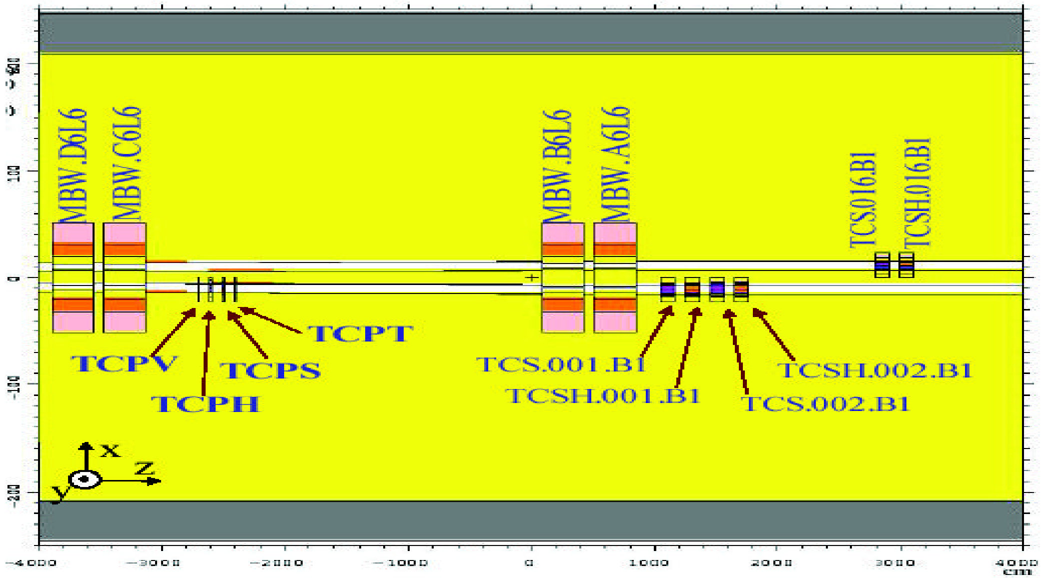
Thin Cu (5mm) over Be

Be

Aluminum

seemed feasible

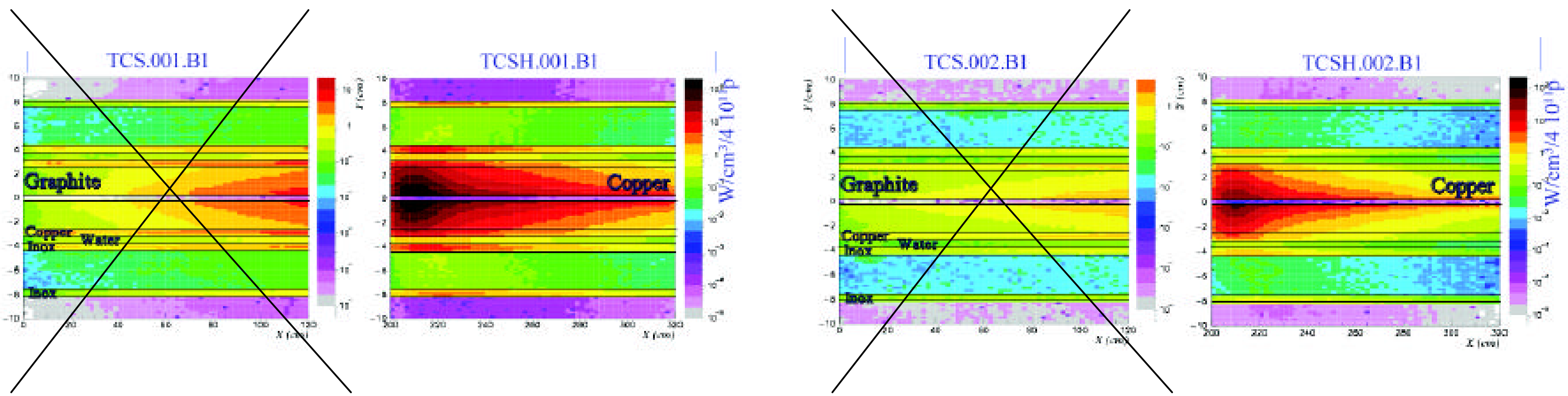
Energy Deposition in Metal Phase II Secondary Collimators w/ Carbon Phase I Collimators Open



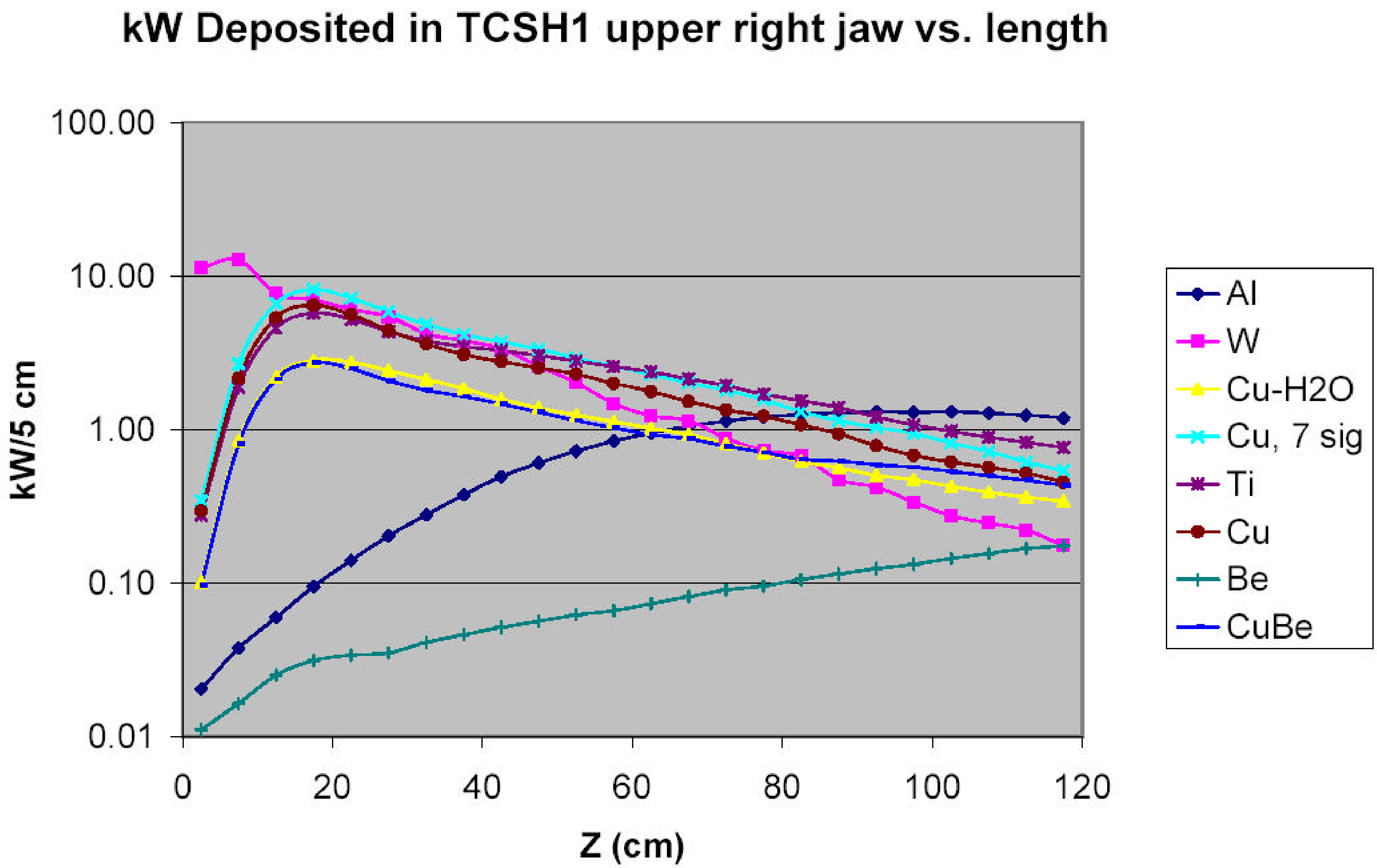
Jaws at 10 sigma

“Pencil” Beam with 80:5:5:10 loss model

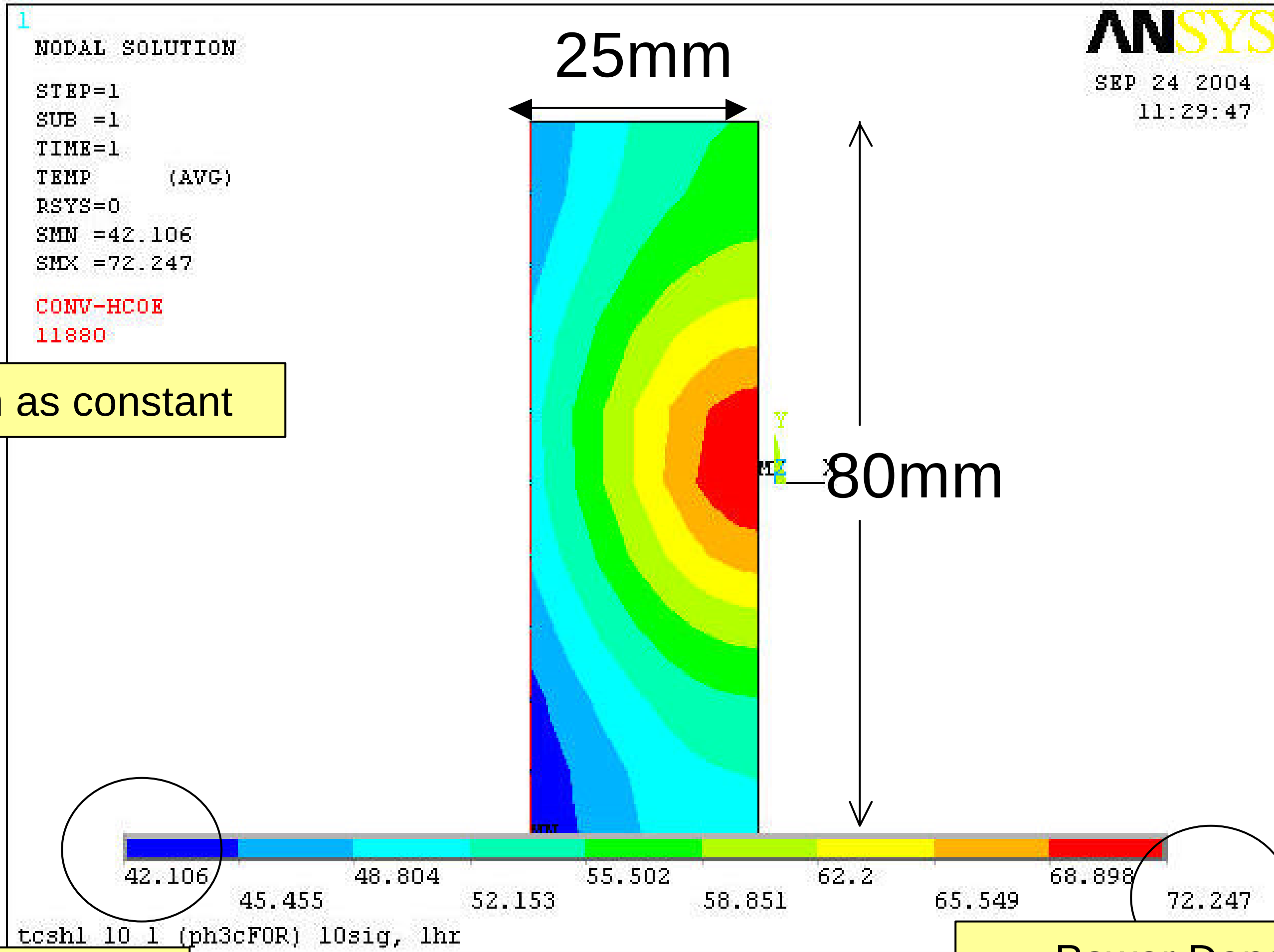
Only 1 TCSH in current (v6.5) collimation configuration



Power absorbed in one TCSH1 jaw at 10σ when 80% (5%) of 450kW of primary beam interacts in TCPV (TCSH1)



Steady State Temperature of TCSH1 at shower max when jaw at 10σ is in contact with 20°C H2O and 80% (5%) of 90kW of primary beam interacts in TCPV (TCSH1)



C_V Cu taken as constant

Jaw:
25x80mm
Solid Cu
P_{TOT}=1270W

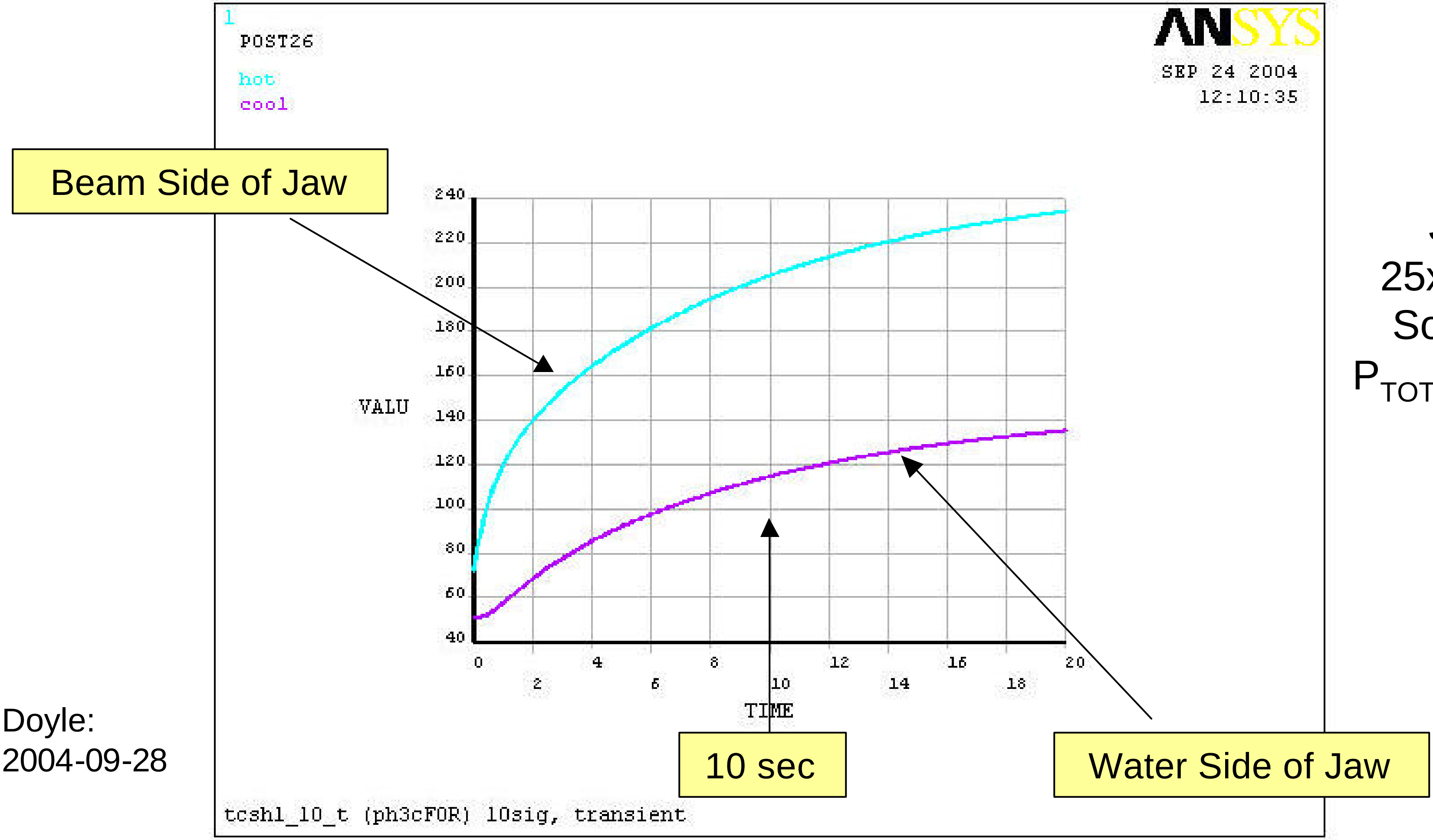
Doyle:
2004-09-28

Boundary Condition:
Convection Coefficient
HC_{H2O}=11880 W/m^2/°C

Power Density to H2O

0.38 MW/m^2
(H2O boils at 1 atm @ 1.3E6)

Time Dependence of Peak Temperature of TCSH1 shower max when jaw at 10σ is in contact with 20°C H2O and 80% (5%) of 450kW of primary beam interacts in TCPV (TCSH1)



Jaw:
25x80mm
Solid Cu
P_{TOT}=6400W

Doyle:
2004-09-28

Heat Load & Temperature Summary

Jaw				**Loss = 90kW Steady State**		**Loss=450 kW t=10 sec**	
Material (Tensile Limit)		**Jaw Gap (sig)**	**Jaw Width (mm)**	**Total Power Absorbed TCSH1 (kW)**	**Total Power Absorbed TCSH2 (kW)**	**Max Jaw Temp (°C)**	**H2O pressure to suppress boiling (bar)**
Cu (180°)		10	25	20.7	7.9	205	1.8
Cu		7	25	26.0	9.2	263	4.3
Cu/Be	OK	10	5/20	10.2	12.7	160	N/A
Cu/H2O	OK	10	5/20	10.4	13.7	130	
Be (150°)	OK	10	25	0.8	2.1	30	N/A
Ti (770°)	?	10	25	14.4	6.7	512	N/A
W (680°)		10	25	30.1	8.7	721	26.0
Al (140°)	OK	10	25	7.1	5.5	39	N/A

Progress on Phase II Project Since Napa '04

1) Conceptual engineering of a ~1m metal cylindrical collimator with ~10kW cooling that meets stability/accuracy requirements with 3D cooling and deflection ANSYS analysis
   - Eric Doyle

2) Define exact parameters of a (potentially expensive) prototype

- Is there not a better way of achieving the desired system efficiency by changing the lengths, materials & gaps of the current system that leaves us with an easier collimator to build?
  - Yunhai Cai
    - Exact roles of elastic scattering, inelastic interactions, primary, secondary, tertiary & absorber devices
- What will the heat loads be on each jaw of this system?
  - Lew Keller
    - Incorporate loss maps (previously pencil beam)
    - Correct 7σ gap settings (previously 10σ)
    - Understand heat load on each collimator, not just those after primary

Phase II Collimator Prototype Politics & Plans

SLAC entered LARP without full understanding of the collimator requirements and wanted to make sure there was an exit strategy if it looked like e+e- LC-inspired collimators would not work

- thought was that rotating 130kW beam dumps were called for

SLAC proposed "Go-No Go" decision Spring '05 (~now)

- Peggs keeps asking when/how/who will make this decision

After ~1 year of work SLAC feels that rotating devices are feasible but still have great engineering challenges given LHC requirements

While still not having parameters of a prototype collimator in hand, SLAC:

- would like to get rid off the "Go-No Go" meeting concept
- would like to continue spending LARP money to specify & eventually build and test several prototypes
  - Acquire lab space & infrastructure
  - Begin post-doc search and expand engineering team

Eventually SLAC will need an "Engineering Review" for the prototype

Whether/when/how/who should review state of task is an open question

Progress in Phase II Collimator Engineering

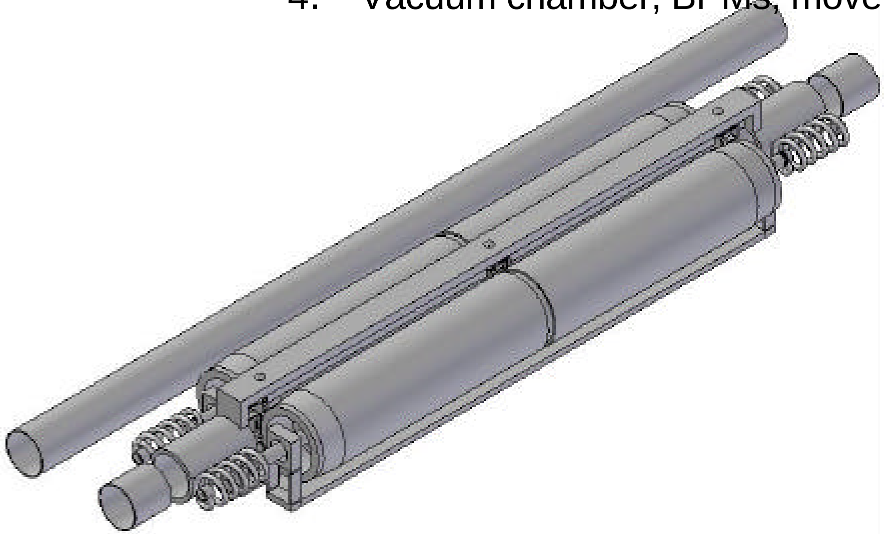
Eric Doyle

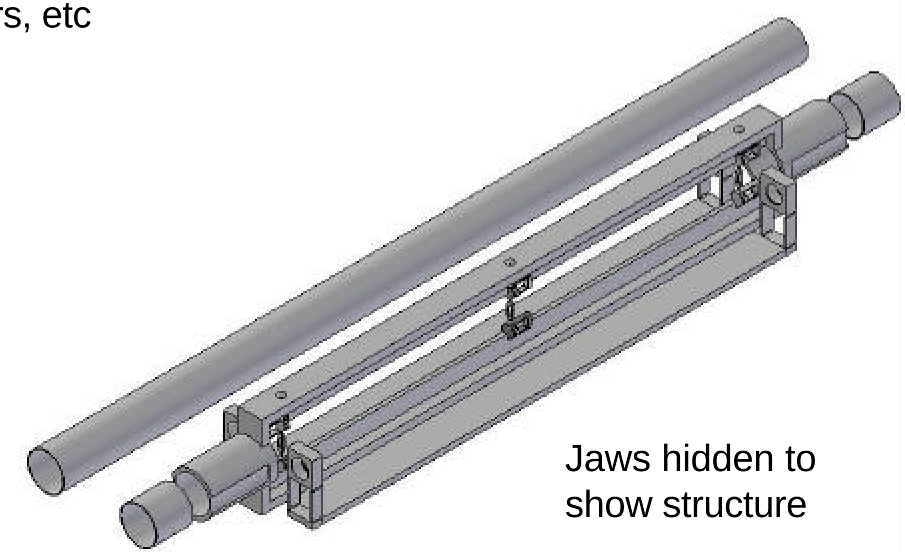
LHC Collimator Mechanism Concept

End and center aperture stops included in same model

Note: Conceptual model. Not much detail engineering yet. Not included:

1. Rotary jaw indexing mechanism
2. Loading springs which hold jaws against aperture stops
3. Open aperture power-off mechanism
4. Vacuum chamber, BPMs, movers, etc

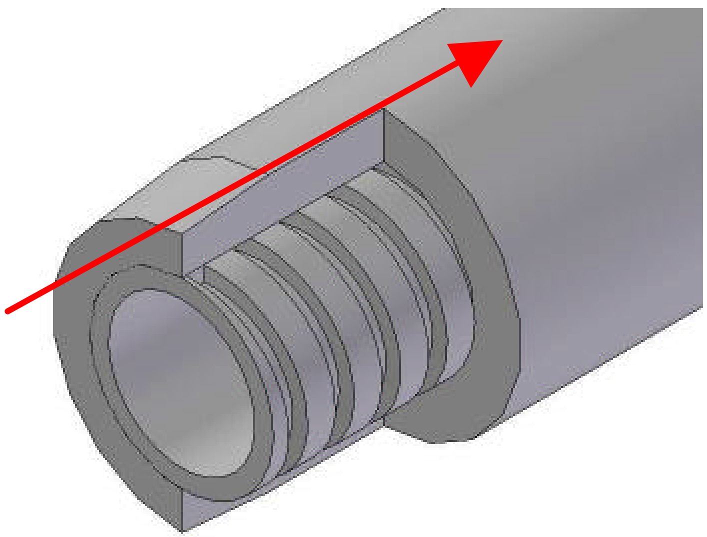


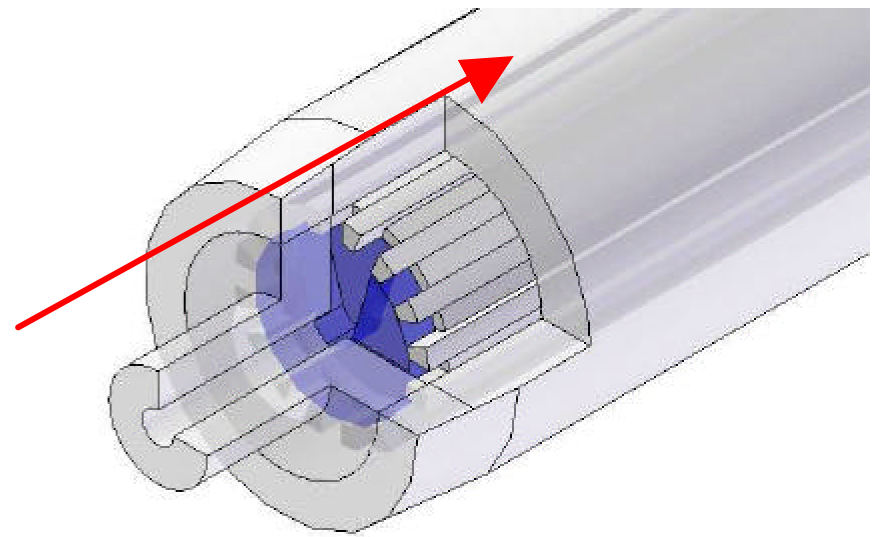


Jaws hidden to show structure

- 1.2m long jaws
- Helical coolant supply tubes flex, allow one rev of jaw
- Jaws supported a both ends for stability, allow tilt control
- Alternative: jaws supported in center
  - thermal deflection away from beam
  - no tilt control

360º & limited arc coolant channel concepts

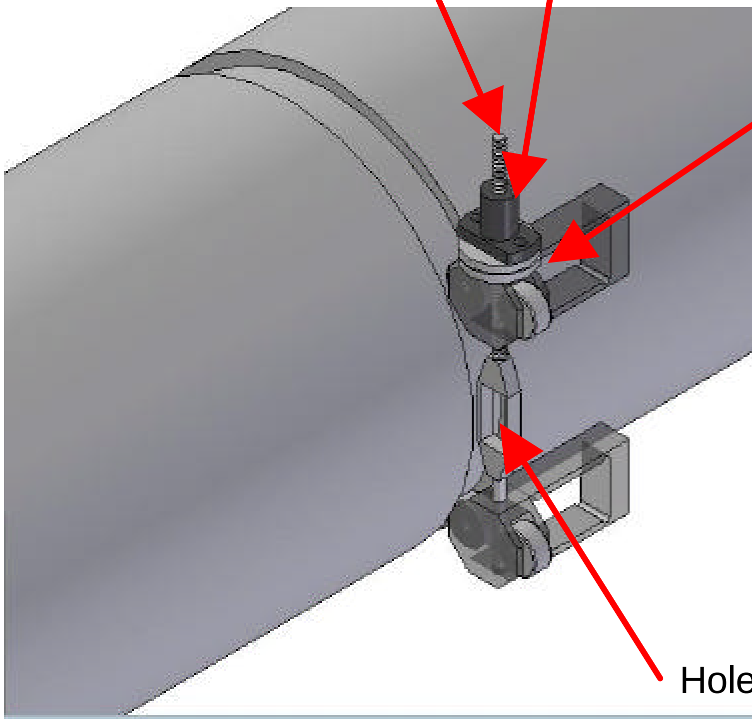


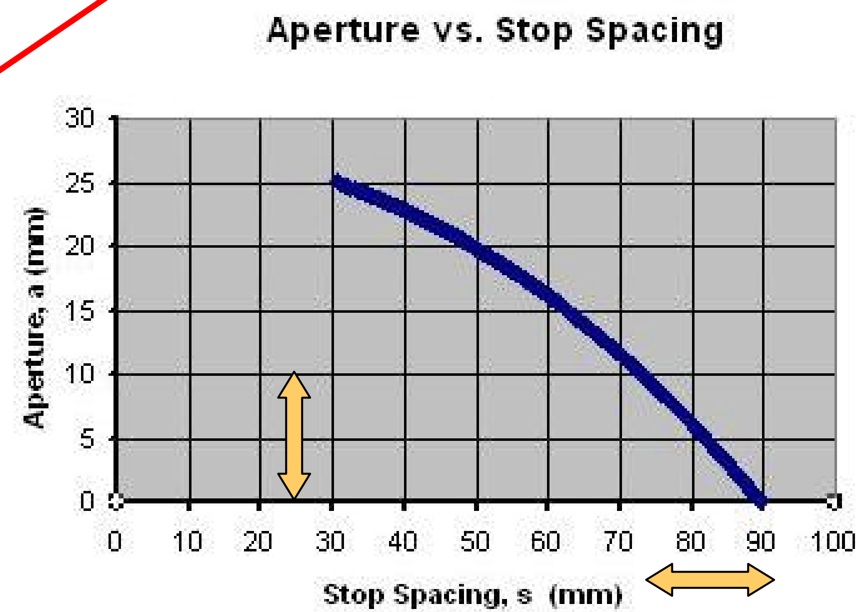


360º cooling by means of a helical channel. Lowers peak temperatures but, by cooling back side of jaw, increases net ΔT through the jaw, and therefore thermal distortion. Could use axial channels.

Limited cooling arc: free wheeling distributor – orientation controlled by gravity – directs flow to beam-side axial channels regardless of jaw angular orientation. Far side not cooled, reducing ΔT and thermal distortion.

Stop Roller Details

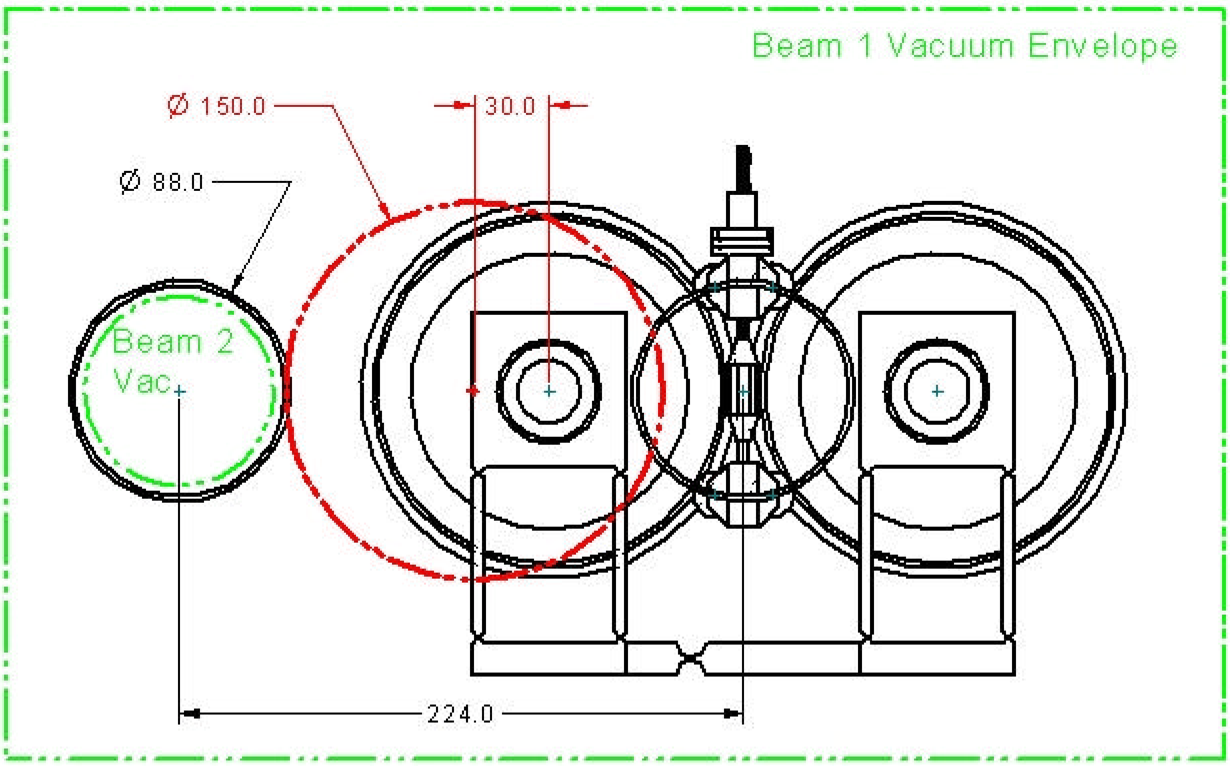




As shown in current model: aperture range limited to ~ 10mm. This can be improved but this mechanism will not be able to produce the full 60mm aperture. Auxiliary jaw retracting mechanism needed. Also note possible vulnerability of mechanism to beam-induced heating.

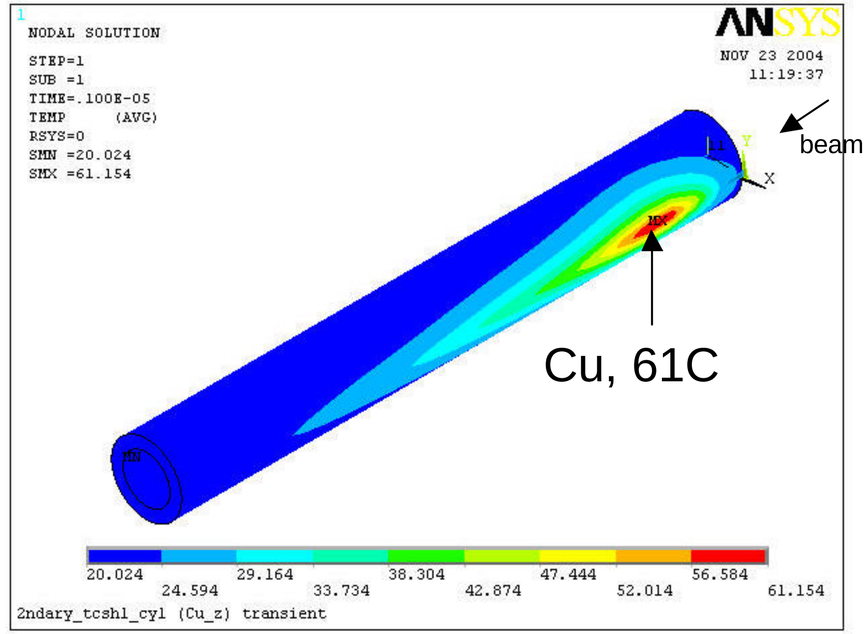
Geometrical limits due to 150mm rotor, 224 mm Beam Axis Spacing, 8.8cm beam pipe

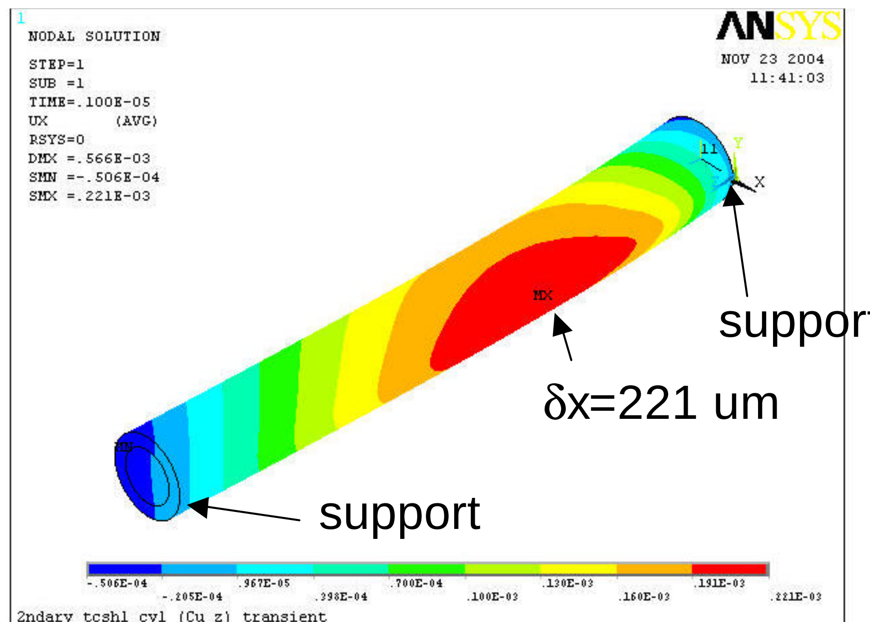
30mm jaw travel (in red) causes jaw to intersect adjacent beam pipe. No space for vacuum chamber wall. Resolution: 1) smaller jaw diameter 2) vacuum envelope encloses adjacent beam pipe 3) less jaw motion 4) reduce diameter of adjacent beam pipe.



3D Time Dependent Thermal Distortion Simulations

- 150mm OD, 25mm wall, 1.2m long
- Simply supported
- ANSYS simulation: FLUKA energy deposit for 10x10x24 rectangular grid mapped to similar area of cylinder
- Most cases: TCSH1 receives 80% of debris from primary (TCPV) plus 2.5% of direct beam per jaw. TCSH1 at 10σ.
- Steady state: 1hr beam lifetime
- Transient:10 sec @ 12 min beam lifetime
- I.D. water-cooled 20C, h=11880 W/m^2/C
    - -Temperature rise of H_2O not modeled
- Materials: Al, 2219 Al, Be+Cu, Cu, Invar, Inconel
    - -Ti, W rejected based on 2-D analysis
- Variations
    - - 45^{o} of ID nearest to beam cooled (not whole 360^{o})
    - - solid cylinder (not thick wall) 45^{o} cooled





Material Comparison for SS & Transient Thermal Deflection: LHC Spec. is 25um

primary debris + 5% direct hits		SS @ 1 hour beam life			transient 10 sec @ 12 min beam		
material	cooling arc (deg)	power (kW) per jaw	Tmax (C)	defl (um)	power (kW)	Tmax (C)	defl (um)
BeCu (94:6)	360	0.85	24	20	4.3	41	95
Cu	360	10.4	61	221	52	195	829
Cu - 5mm	360	4.5	42	117	22.4	129	586
Cu/Be (5mm/20mm)	360	5.3	53	161			
Super Invar	360	10.8	866	152			
Inconel 718	360	10.8	790	1039			
Al	360	3.7	33	143			
2219 Al	360	4.6	34	149	23	79	559
C R4550	360	0.6	25	5	3.0	41	20
BeCu (94:6)	90	0.85	25	8	4.3	41	86
BeCu (94:6)	45	0.85	27	2	4.3	46	101
Cu	45	10.4	89	79	52	228	739
Cu - solid	45	10.4	85	60	52	213	542
2219 Al	45	4.6	43	31	23	89	492

Notes:

1. BeCu is a made-up alloy with 6% Cu. We believe it could be made if warranted
2. 2219 Al is an alloy containing 6% Cu
3. Cu/Be is a bimetallic jaw consisting of a 5mm Cu outer layer and a 20mm Be inner layer
4. Cu – 5 mm is a thin walled Cu jaw
5. Super Invar loses its low CTE above 200C, so the 152um deflectio n is not valid
6. Green shading: meet our suggested alternative spec of 50um for SS and 200um (1σ) for the transient.

Issues with present LHC Collimator Concept

- Deflection spec will be very hard to meet
  - Relax deflection spec
  - Permit use of Be
  - Reduce jaw length
- Aperture stop mechanisms vulnerable to beam heating/damage
  - Relocate ball screw outside beam path – like NLC (jaw ends only)
  - Stop rollers unavoidably within region of beam pipe
- Space limitations prevent the use of 150mm diameter jaw while maintaining the 60mm max aperture. Some combination of the following required to fix the problem
  - Reduce jaw diameter
    - Will likely increase deflection
    - Adversely affects aperture stop mechanism
    - May require re-tooling of FLUKA and ANSYS simulations
  - Reduce opposing beam pipe diameter
  - Include a pass-through for the opposing beam in the collimator vacuum chamber
  - Reduce the maximum required aperture