

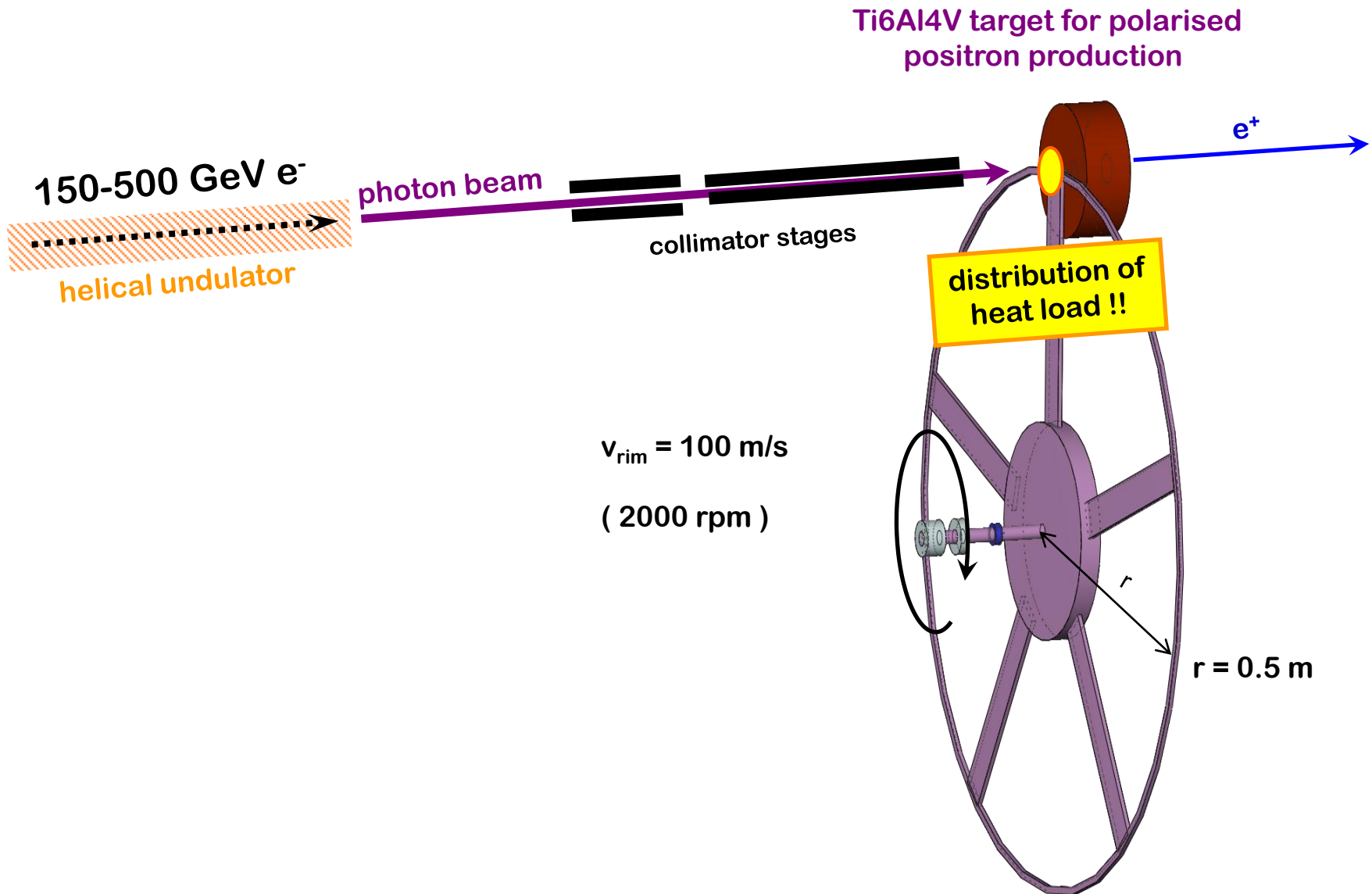
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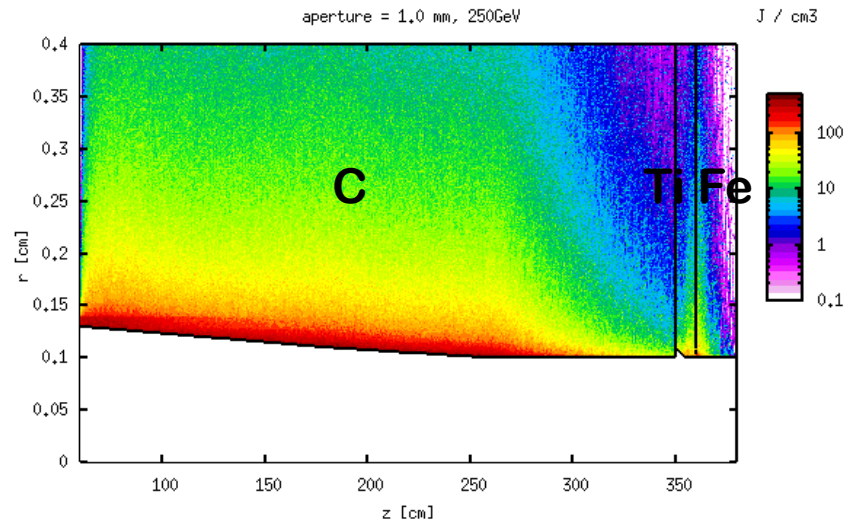
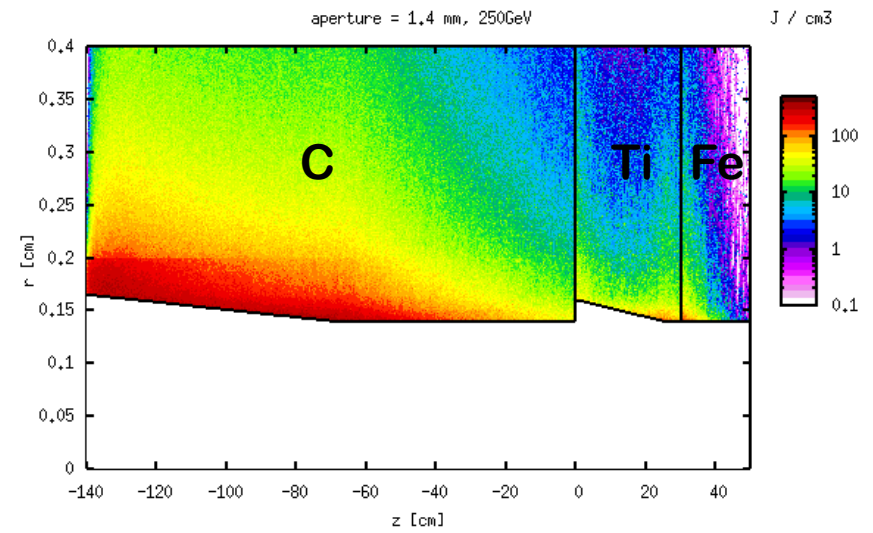
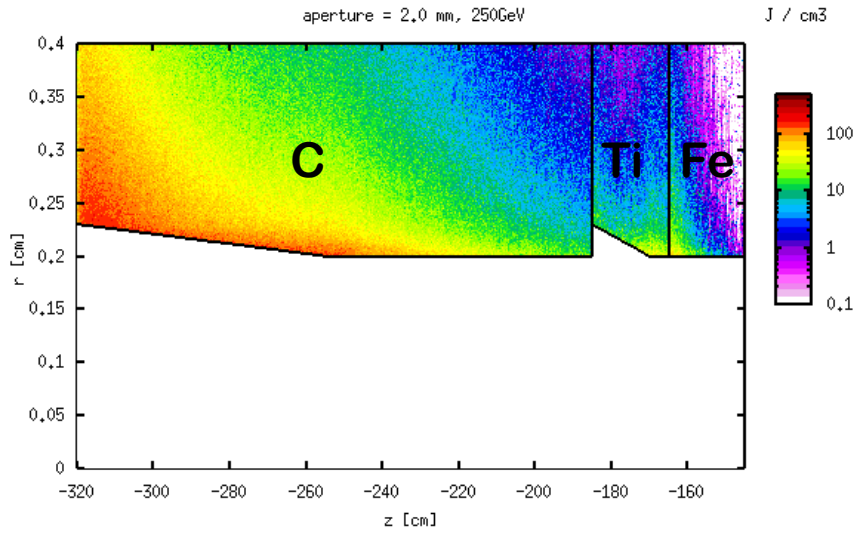
²DESY

- ILC target unit (Ti wheel and collimator stages)
- Parameter table with different collimator settings (250GeV – 500 GeV)
- Collimator cooling design (high lumi)
- Dynamic stress, deformation and temperature evolution in the ILC target wheel (high lumi)
- Velocity and stress calculations in the SLAC target
- Conclusion

ILC target unit (Ti wheel and collimator stages)



250 GeV energy deposition (high lumi)



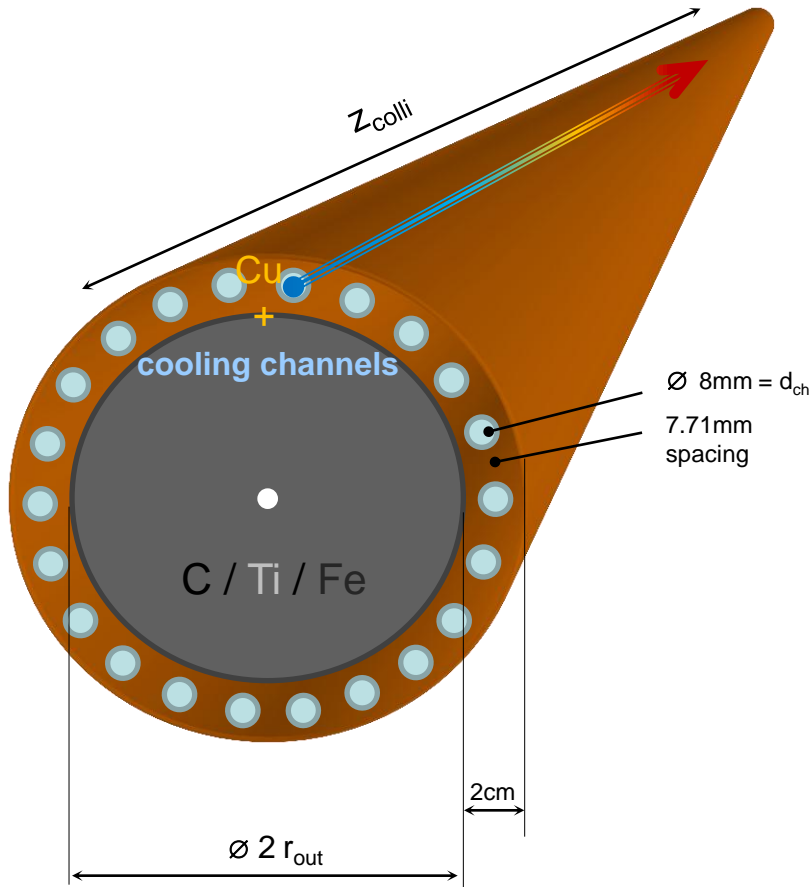
parameter table with different collimator settings

Photon Collimator Parameters			L upgrade			E _{cm} upgrade									
			Centre-of-mass energy E _{cm} (GeV)					Parameter / length of / (r _{coll})							
Parameter			250	350	500	500		1000	Unit	1.coll. (r=2mm)	2.coll. (r=1.4mm)	3.coll. (r=1mm)			
Pulse repetition rate		Hz	5,0			5,0		4,0	pyrolytic C	cm	135 (7.0)	140 (4.5)	290 (4.5)		
Number of bunches	n_b		1312,0			2625,0		2450,0	Titanium	cm	20 (4.5)	30 (4.5)	10 (4.5)		
Positron bunch population	N_+	$\times 10^{10}$	2,0			2,0		1,7	Iron	cm	20 (4.5)	20 (4.5)	20 (4.5)		
undulator period length	λ_u	cm	1,2			1,2		4,3	total length	cm	175	190	320		
Effective undulator field	B_{und}	T	0,9			0,4	0,9	0,9	0,6	0,8					
			K=0.92			K=0.45	K=0.92	K=0.92	K=2.5	K=3.0					
Photon Yield per electron	n_{ph} / e^-		2,0			0,5		2,0	1,6	1,8					
Active undulator length	L_{und}		231,0	196,0	70,0	147,0	70,0	143,5	176,0	176,0					
Photons per bunch train	$n_{ph} / train$	$\times 10^{15}$	11,8	10,0	3,6	4,0	7,2	14,6	12,2	13,3					
Average photon power	P_{photon}	kW	98,5	113,8	83,0	88,0	166,0	346,2	115,1	93,3					
Abs.ph. power in collim.	$P_{collimator}$	%	48,8	60,4	52,3	-	52,3	70,1	45,6	42,8					
Collimator radius	r	mm	2,0	1,4	1,0	-	1,0	0,7	1,0	1,2					
Positron Polarization	P_+	%	55,3	58,5	50,3	28,8	50,3	58,7	51,1	52,2					
collimator r=2.0 / Pyr. C	E_{max}	J/g	177	144	36		72				Pyr. C	Ti	Fe (ST70)	W (annealed)	W26Re (hardened)
collimator r=2.0 / Pyr. C	P	kW	44,8	36,3	7,9		15,8				Fatigue Temperature : (Ansys) T °C 900 600 130 185 500				
collimator r=2.0 / Ti	E_{max}	J/g	16	18	6		11				Fatigue Energy : (Ansys) $E_{fatigue}$ J/g 753 314 58 24 64				
collimator r=2.0 / Ti	P	kW	0,8	0,8	0,2		0,4				Fatigue Yield Strength : (Ansys) $P_{fatigue}$ M Pa 40 340 280 440 600				
collimator r=2.0 / Fe	E_{max}	J/g	13	13	5		10								
collimator r=2.0 / Fe	P	kW	0,2	0,3	0,1		0,2				Exp. Fatigue Yield Strength : 0.4 R_{max} M Pa 36 356 280 440 600				
cooling / Cu	P	kW	2,3	1,9	0,4		0,8				Exp. Yield Strength : $R_{max} / R_{elastic}$ M Pa 90 890 / 820 700 / 340 1100 / 800 1500 / 1200				
collimator r=1.4 / Pyr. C	E_{max}	J/g		183	73		146								
collimator r=1.4 / Pyr. C	P	kW		25,9	12,9		25,8								
collimator r=1.4 / Ti	E_{max}	J/g		22	30		30								
collimator r=1.4 / Ti	P	kW		0,9	0,6		1,2								
collimator r=1.4 / Fe	E_{max}	J/g		13	11		22								
collimator r=1.4 / Fe	P	kW		0,2	0,1		0,2								
cooling / Cu	P	kW		2,4	1,2		2,4								
collimator r=1.0 / Pyr. C	E_{max}	J/g			82		163								
collimator r=1.0 / Pyr. C	P	kW			17,9		35,8								
collimator r=1.0 / Ti	E_{max}	J/g			13		26								
collimator r=1.0 / Ti	P	kW			0,2		0,4								
collimator r=1.0 / Fe	E_{max}	J/g			9		19								
collimator r=1.0 / Fe	P	kW			0,1		0,2								
cooling / Cu	P	kW			1,8		3,6								

$$\xrightarrow{\text{cyl.}} Q = \frac{\lambda 2\pi z_{\text{colli}} \Delta T}{\ln(r_{\text{out}}/r_{\text{in}})}$$

$$Q_{\text{cool}}/\text{chan.} \approx 0.3 \text{ kW/m}^2 \text{ K} \Leftrightarrow \bar{v}_{\text{water}} = 2 \text{ m/s} \xrightarrow{d_{\text{ch}}=8\text{mm}} 0.1 \text{ l/s}$$

$$Re = \frac{\bar{v}_{\text{water}} d_{\text{ch}}}{\nu(T=30^\circ\text{C})_{\text{kin vis}}} = \frac{\bar{v}_{\text{water}} d_{\text{ch}} \rho}{\eta(T=30^\circ\text{C})_{\text{dyn vis}}} \approx 2000 < 2300 = Re_{\text{krit, laminar}}$$



$$r_{\text{out}} = \begin{cases} 7.5\text{cm} \Rightarrow Q_{\text{cool}}(34 \text{ ch}) \approx 10.2 \text{ kW/m}^2 \text{ K} \\ 4.0\text{cm} \Rightarrow Q_{\text{cool}}(20 \text{ ch}) \approx 6.0 \text{ kW/m}^2 \text{ K} \\ 3.0\text{cm} \Rightarrow Q_{\text{cool}}(16 \text{ ch}) \approx 4.8 \text{ kW/m}^2 \text{ K} \end{cases}$$

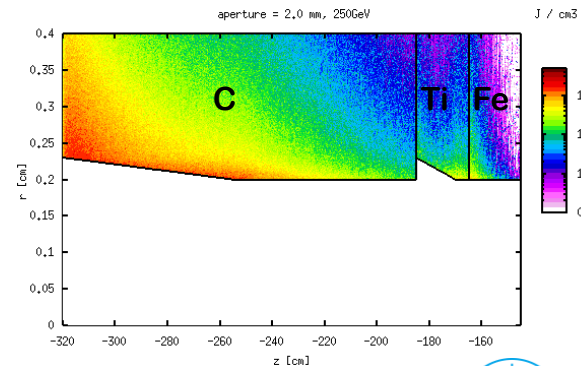
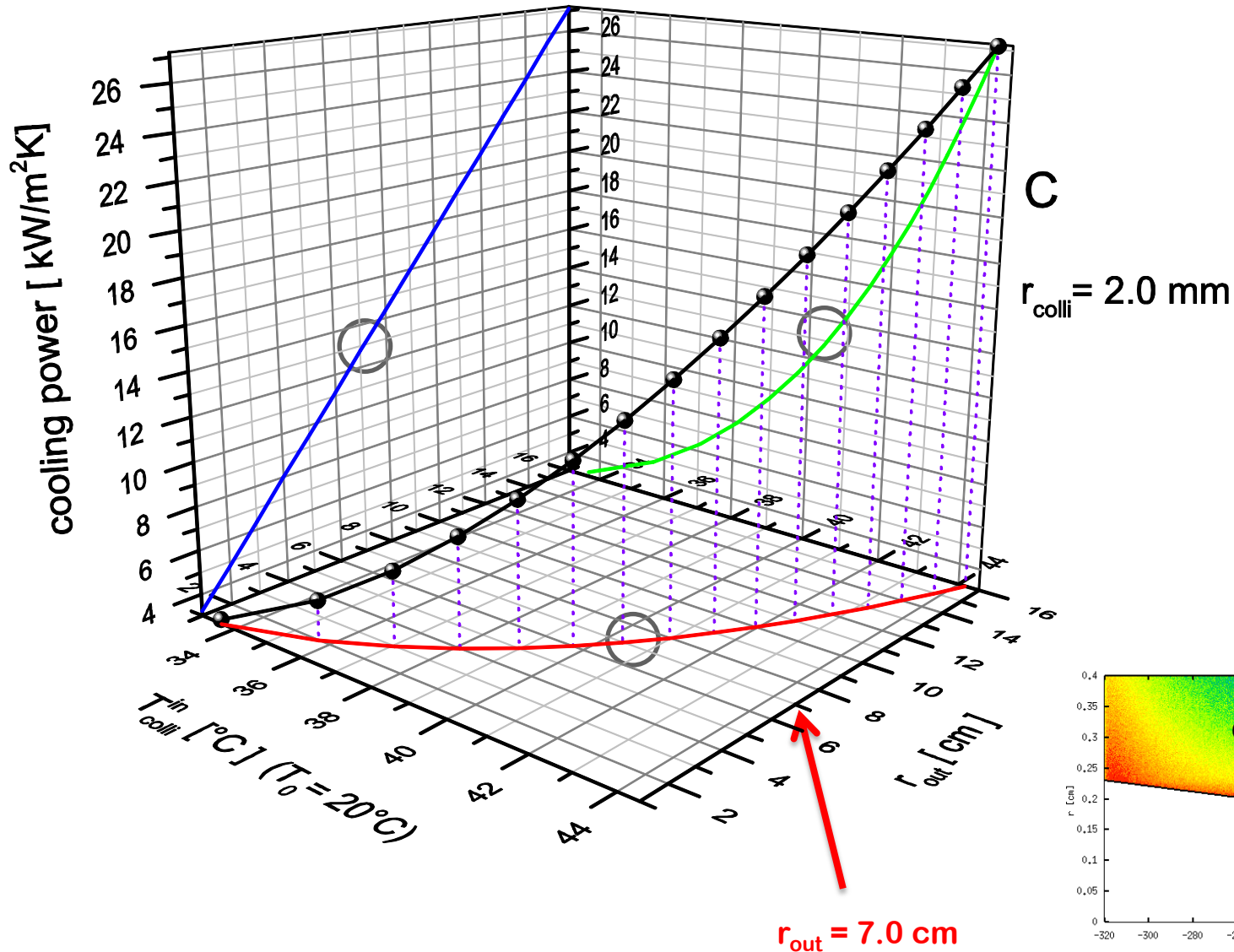
$$\Delta T = T_{\text{in}} - T_{\text{out}}(20^\circ\text{C}) = \frac{Q_0 \ln(r_{\text{out}}/r_{\text{in}})}{\lambda 2\pi z_{\text{colli}}}$$

$$\xrightarrow{+\text{ cooling}} T_{\text{in}} = \frac{Q_0 \ln(r_{\text{out}}/r_{\text{in}})}{\lambda 2\pi z_{\text{colli}}} + T_{\text{out}}(20^\circ\text{C}) + \underbrace{\frac{Q_0 \text{ norm}}{Q_{\text{cool}}}}_{\text{cooling}}$$

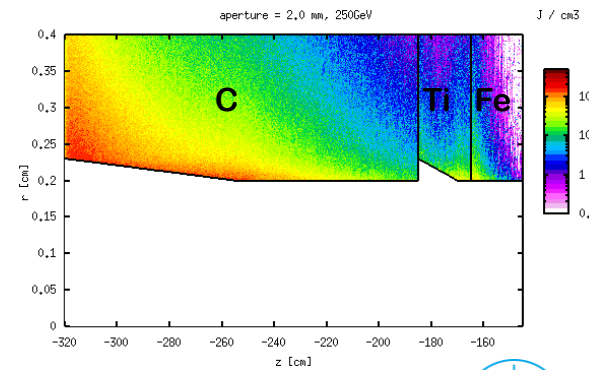
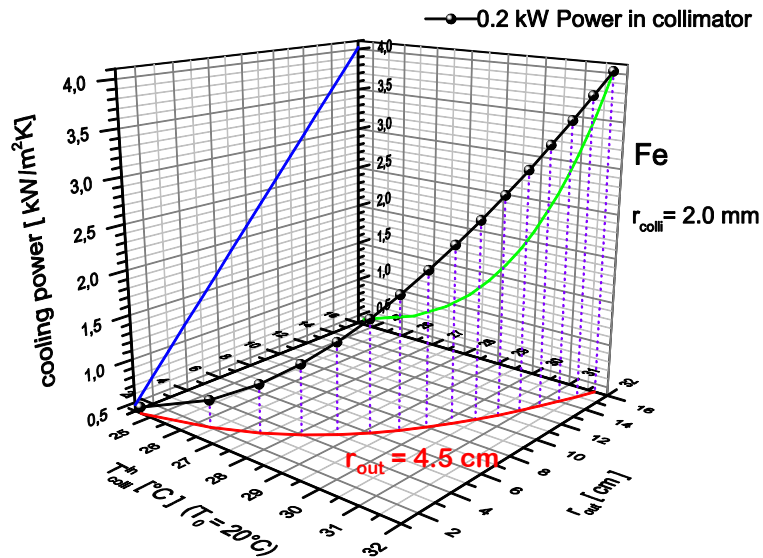
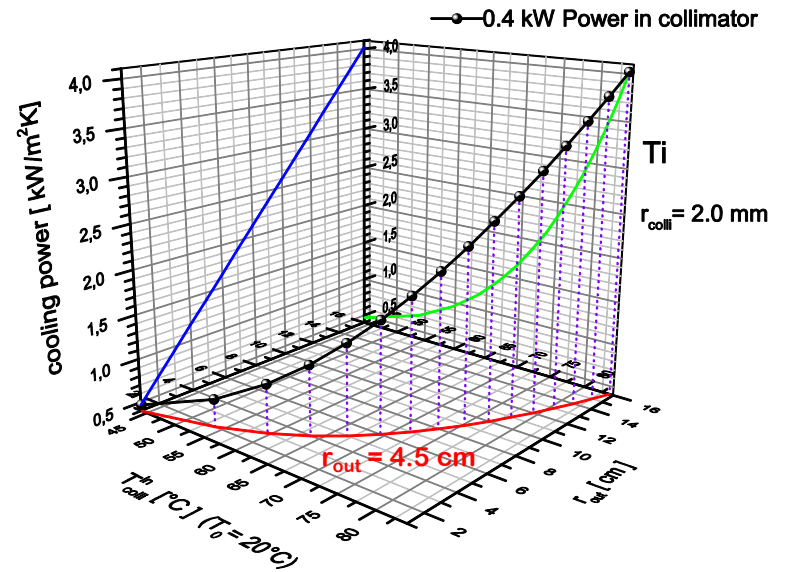
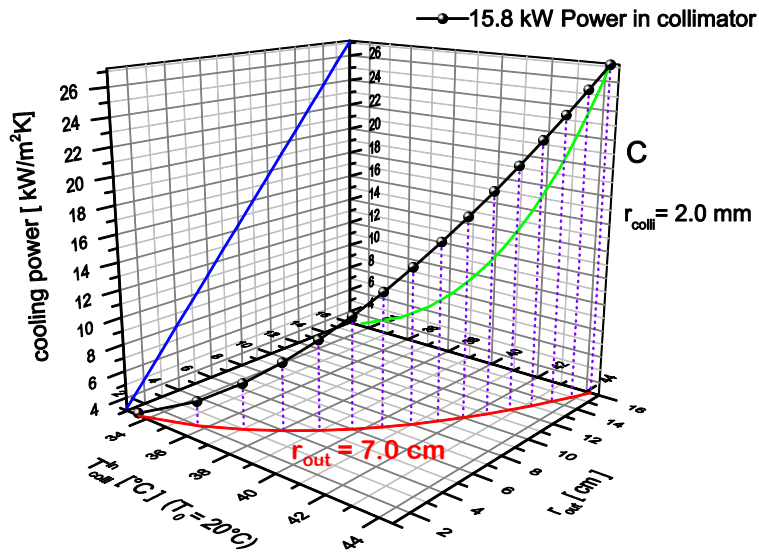
$$Q_0 \text{ norm} = \frac{Q_0}{2\pi r_{\text{out}} z_{\text{colli}}} \text{ kW/m}_2$$

250 GeV cooling and temperature (high lumi)

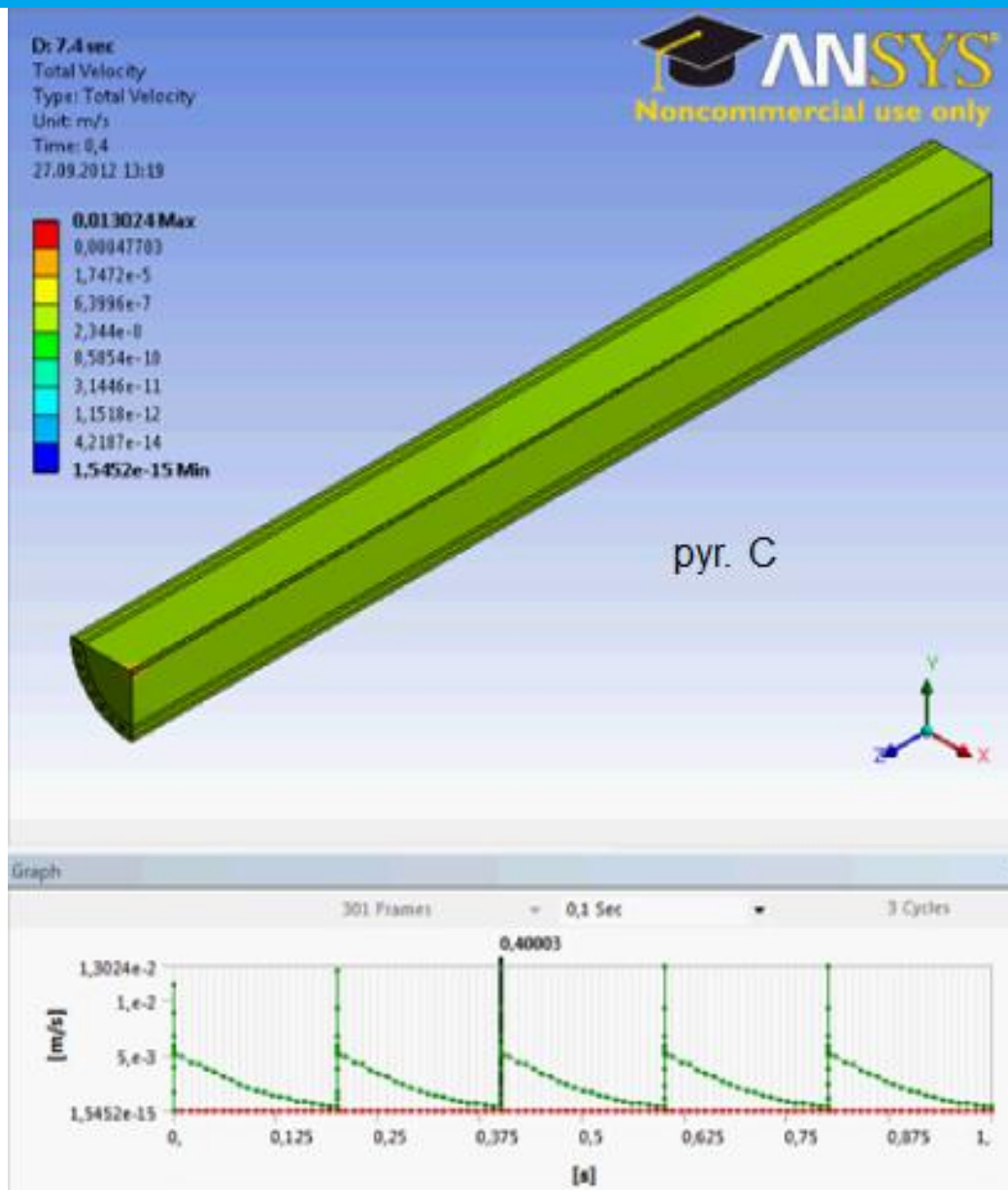
—●— 15.8 kW Power in collimator



250 GeV cooling and temperature (high lumi)

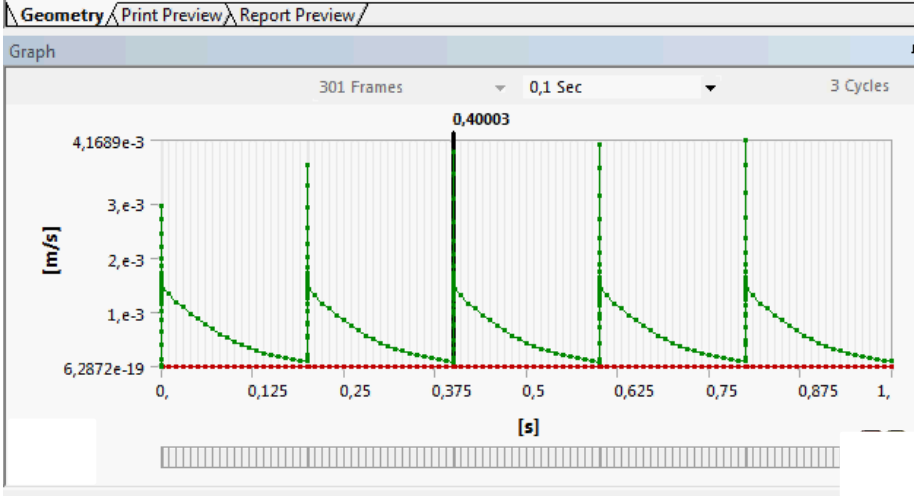
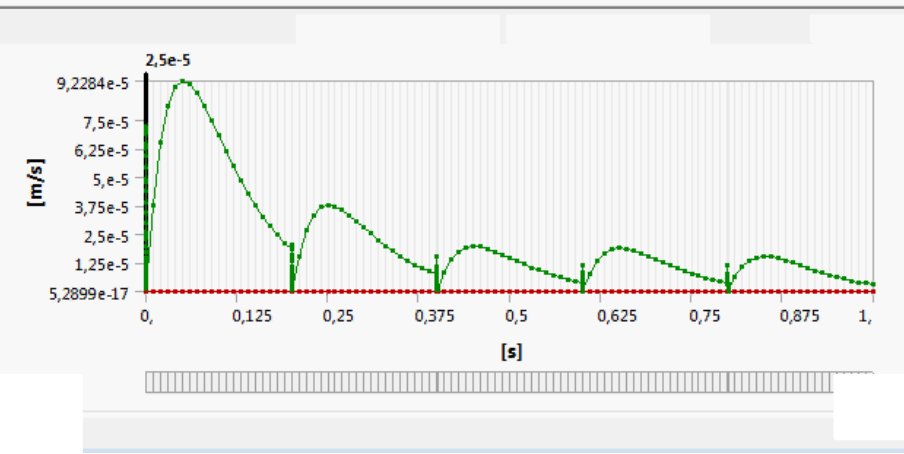
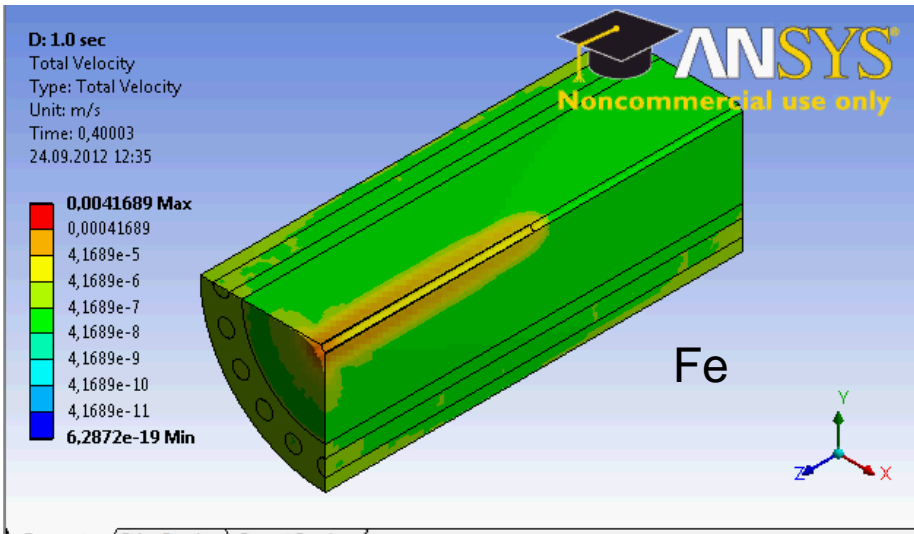
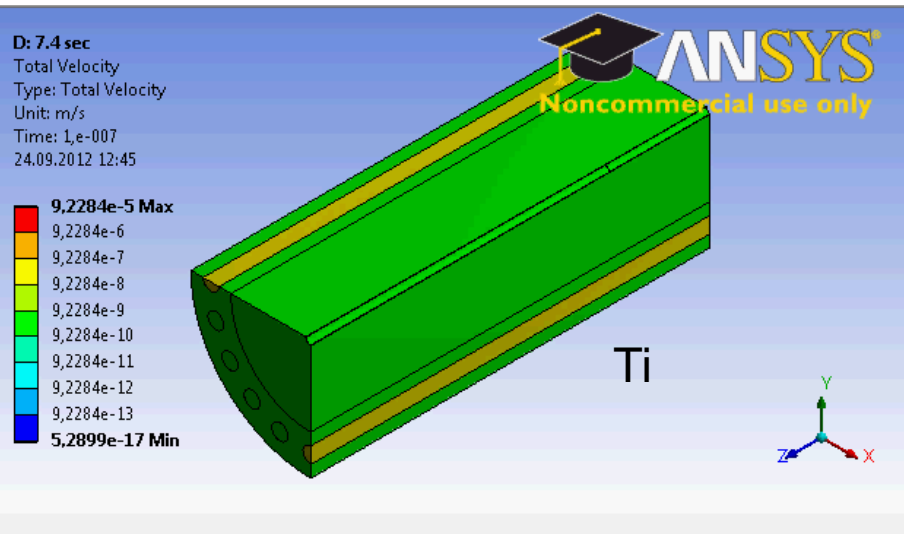


Dynamic stress evolution in the collimator (high lumi)



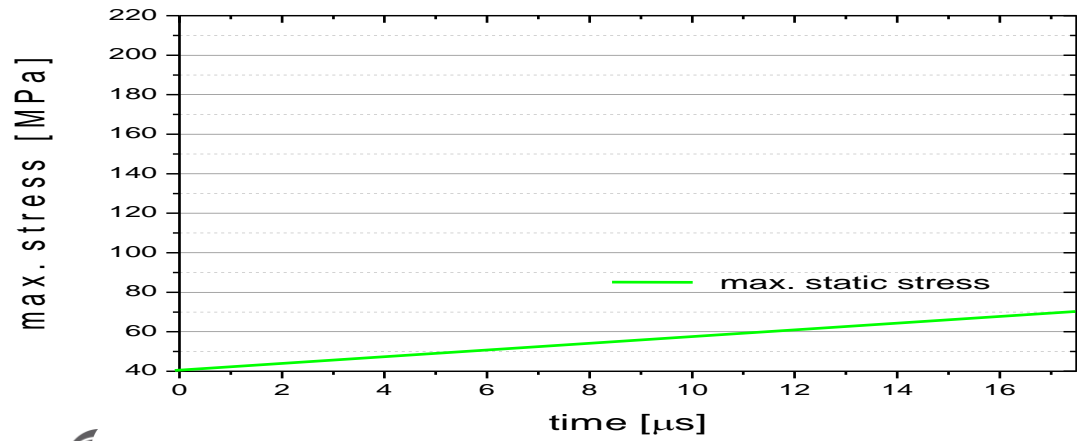
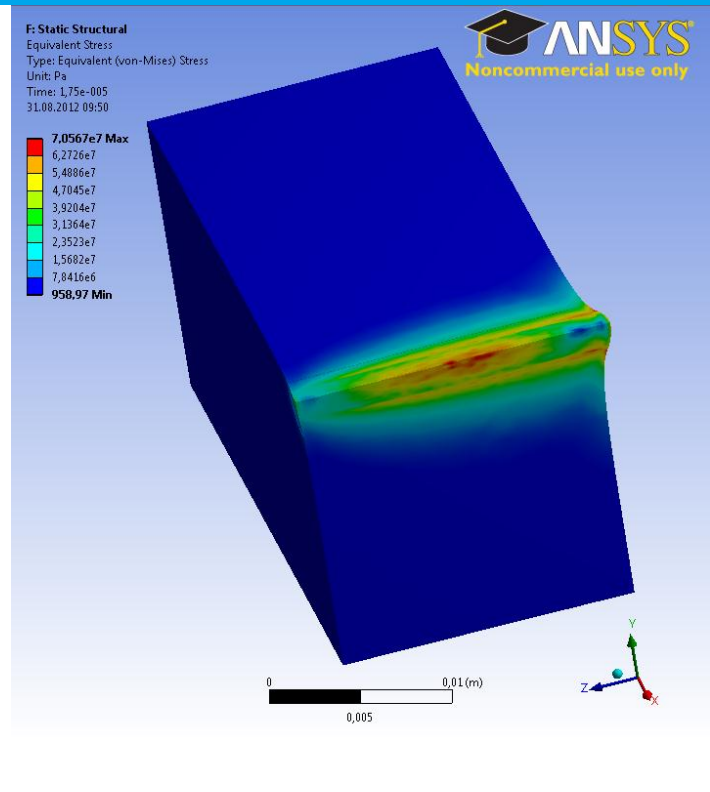
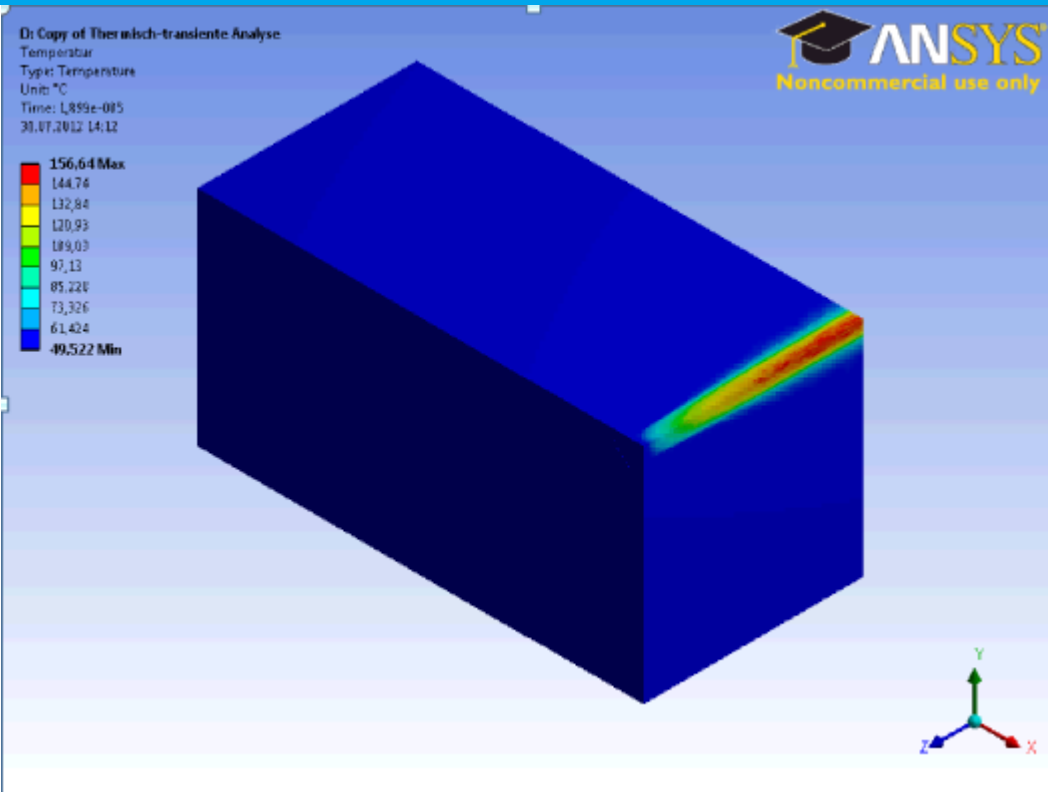
$2 \cdot 10^{10}$ e⁻ / bunch
2625 bunch / train (0.97ms)
0.366μs bunch spacing
5 train / s

Dynamic stress evolution in the collimator (high lumi)



2*10¹⁰ e⁻ / bunch
2625 bunch / train (0.97ms)
0.366μs bunch spacing
5 train / s

Dynamic stress and temperature evolution in a test target (high lumi)

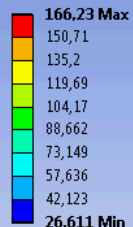


$2 \cdot 10^{10}$ e⁻ / bunch
 2625 bunch / train (0.97ms)
 0.366 μ s bunch spacing
 5 train / s

Stress evolution in the ILC target wheel (high lumi)

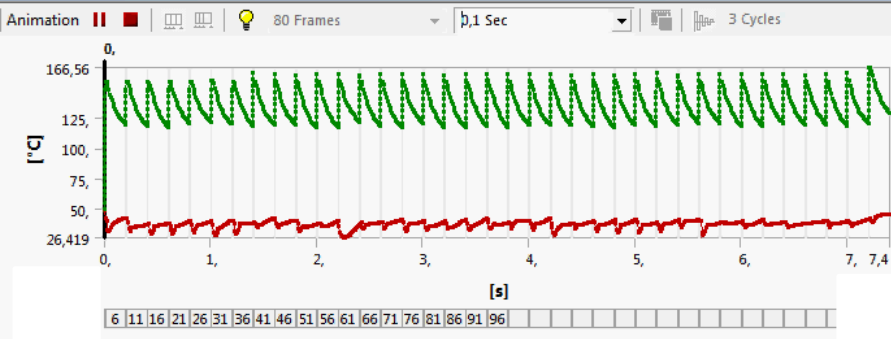
B: Thermisch-transiente Analyse

Temperatur
Type: Temperature
Unit: °C
Time: 7,4
13.09.2012 13:24



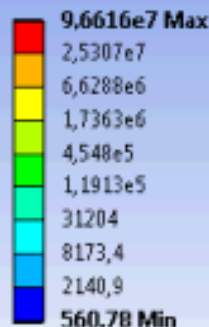
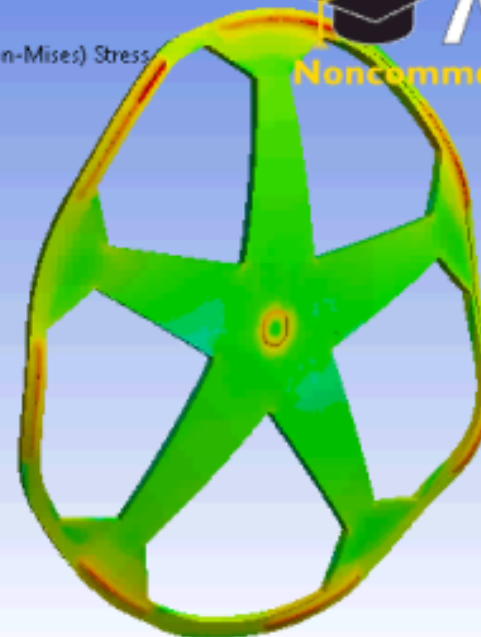
Geometry | Print Preview | Report Preview

Graph



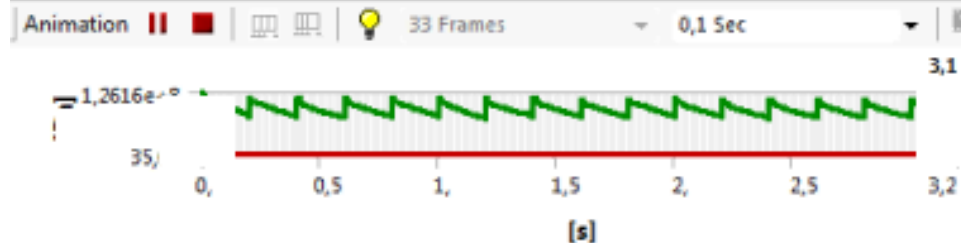
D: 3.2 sec

Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: Pa
Time: 3,1
24.09.2012 14:24

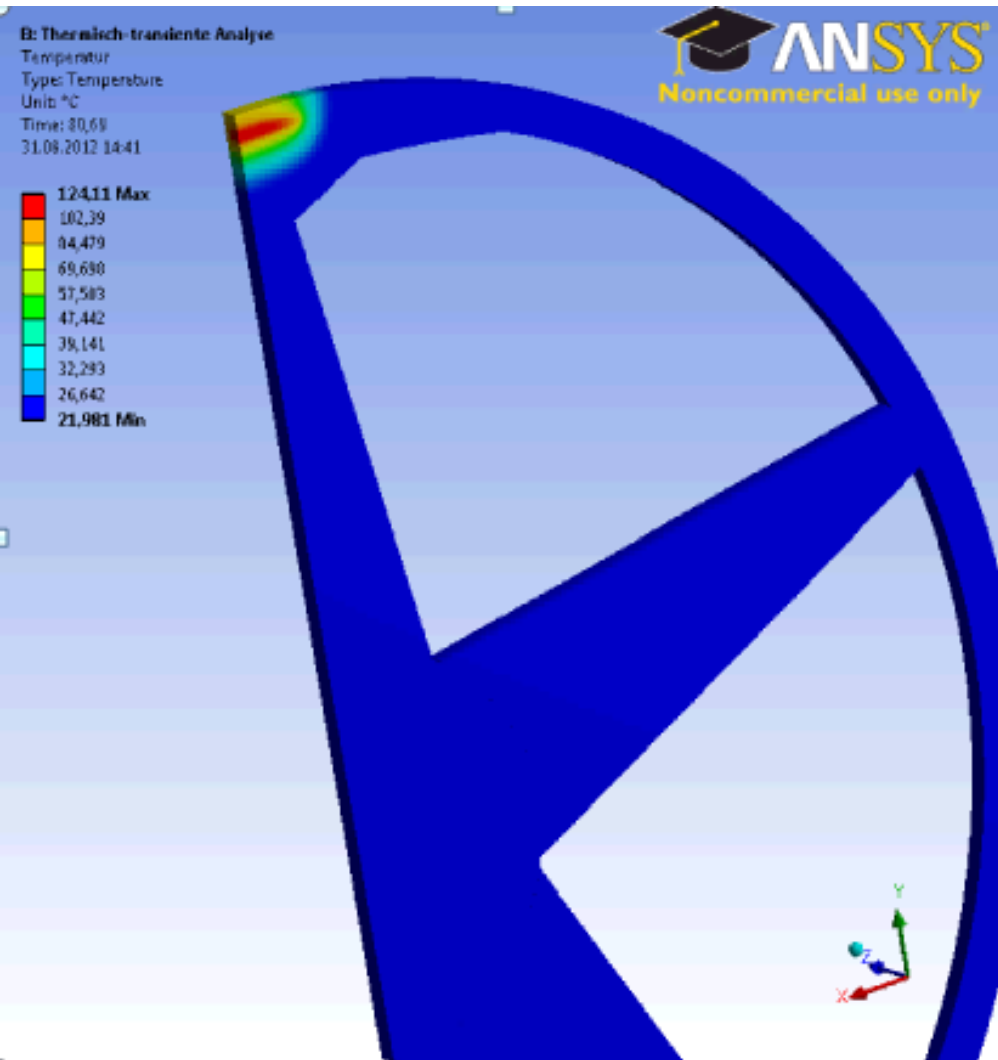


Geometry | Print Preview | Report Preview

Graph



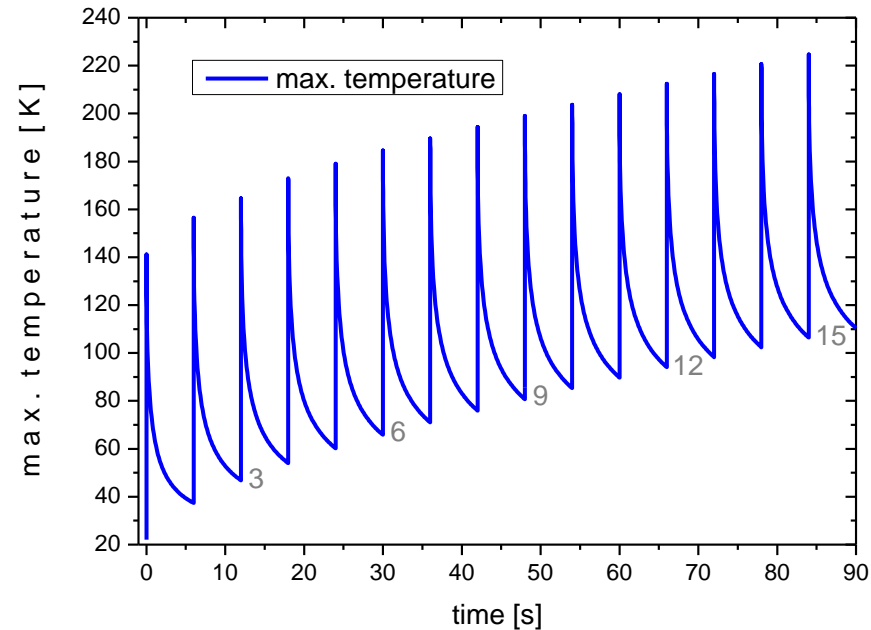
Temperature evolution in the ILC target wheel (high lumi)



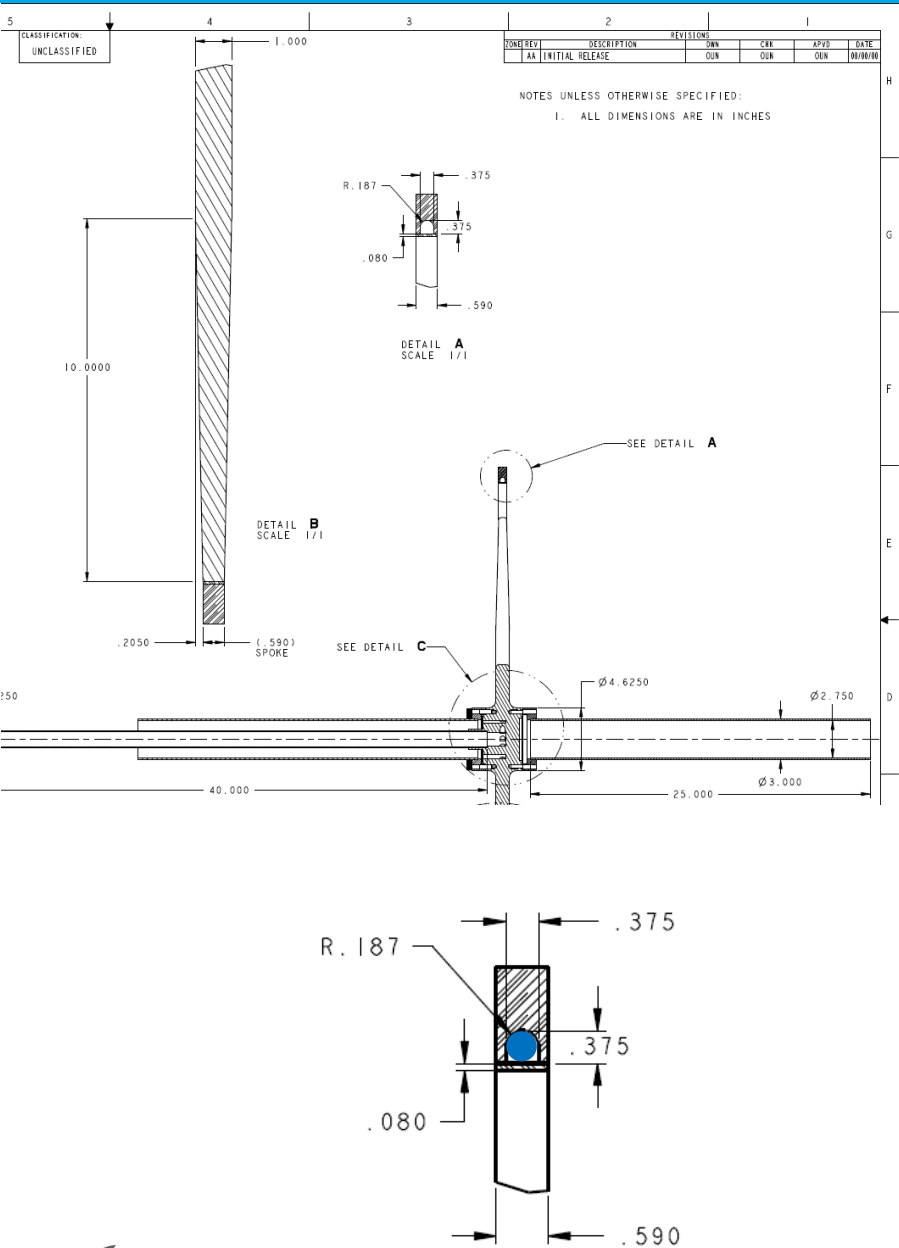
temperature evolution without cooling !

cooling channel for the wheel have to be included and can be evaluated with ANSYS

- max. temperature
- max. velocity
- max stress

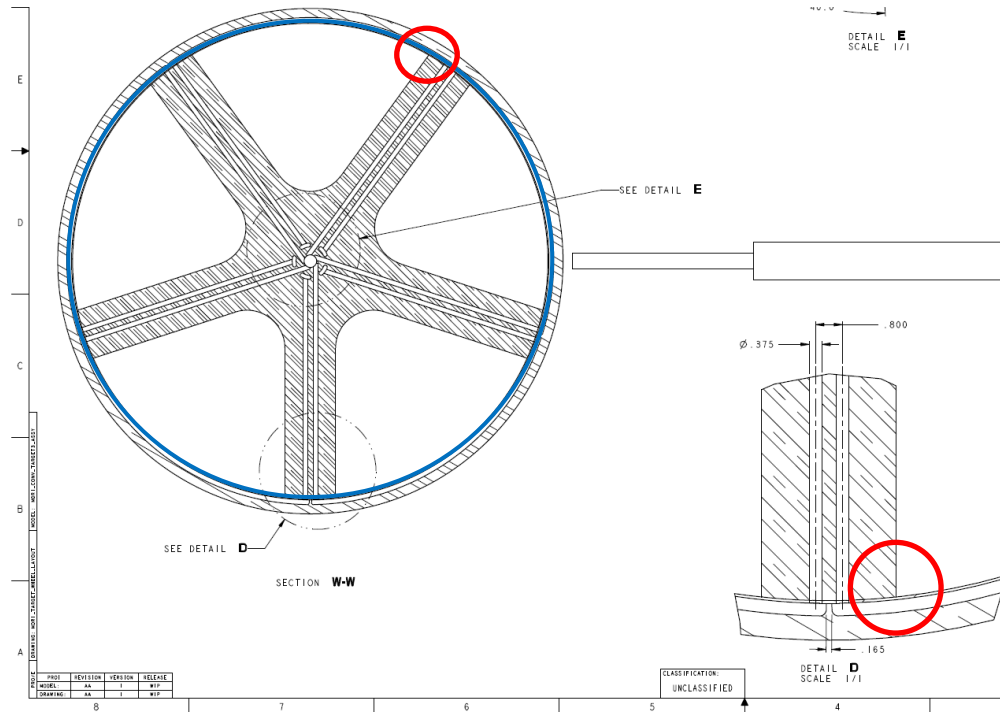


Previous design of the cooling channels



cooling channel for the wheel have to be included and can be evaluated with ANSYS

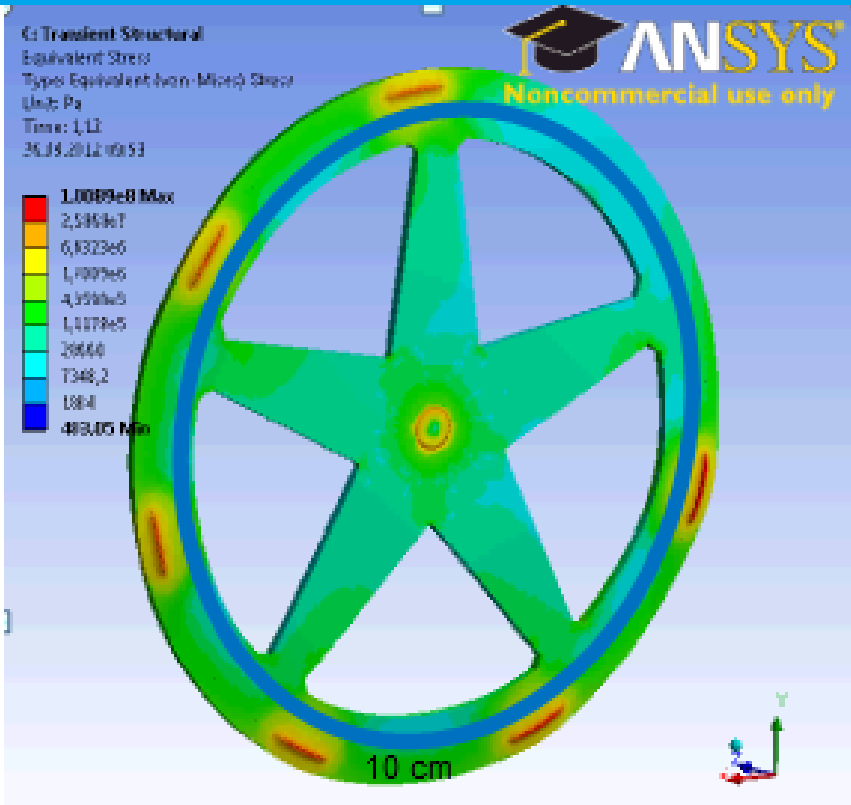
- max. temperature
- max. velocity
- max stress



Previous design of the cooling channels

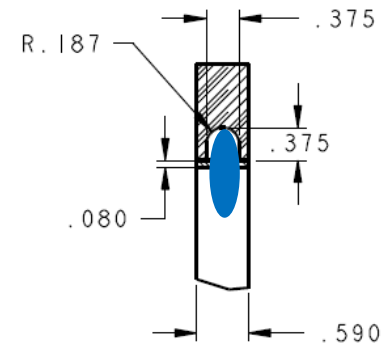
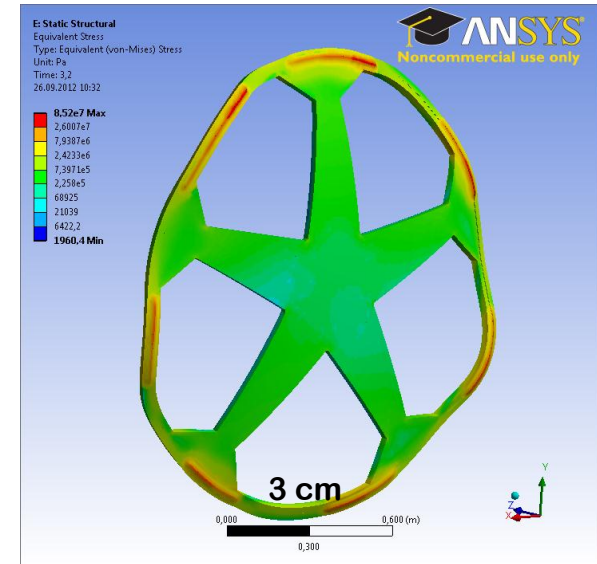
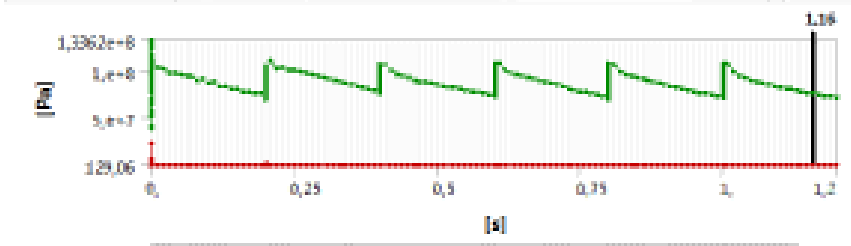
cooling channel for the wheel have to be included and can be evaluated with ANSYS

- max. temperature
- max. velocity
- max stress
- upgrade the channel/wheel design?



Geometry / Print Preview / Report Preview /

Graph



THERMAL SHOCK STRUCTURAL ANALYSES OF A POSITRON TARGET

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V.K. Bharadwaj, D.C. Schultz, J.C. Sheppard, SLAC,* Stanford, CA, USA

Abstract

In the positron source of the Stanford Linear Collider (SLC), the electron beam collides with a tungsten-rhenium target. As the beam passes into the material, thermal energy is created that heats the material to several hundred degrees centigrade on a time scale of nanoseconds. The heating of the material results in thermal stresses that may be large enough to cause material failure. The analyses calculate the thermal shock pressure and stress pulses as they move throughout the material due to the rapid energy deposition. Failure of the target occurred after three years of operation with an elevated power deposition toward the end of the three years. The calculations were made with the LLNL coupled heat transfer and dynamic solid mechanics analysis codes, TOPAZ3D and DYNA3D, and the thermal energy deposition was calculated with the SLAC Electron Gamma Shower (EGS) code simulating the electron-induced cascade. Material fatigue strength, experimentally measured properties for the non-irradiated and irradiated material, as well as the calculated stress state are evaluated in assessing the cause for the target failure.

1 INTRODUCTION

The SLC positron target was operated for several years with gradually increasing electron beam power. Inspection of the target showed considerable damage on the backside of the target in the region where the beam exits the target [1, 2]. The damage observed consisted of approximately one millimeter of missing material and cracks propagating in various directions into the target.

In an attempt to determine the cause of the material loss and cracks, a dynamic stress analysis was undertaken to model the pressure-induced stress waves in the material.

2 BACKGROUND

The SLC target consists of a hockey puck-shaped piece of Tungsten and 25% Rhenium (W25Re). Figure 1 shows the geometry of the target. The target consists of a 2.5-inch diameter disc of W25Re with a six-radiation length thickness of 0.81 inches. The target is cooled by two cooling tubes, and they maintain the target at a

temperature before another electron bunch impinges [3]. During operation the target is rotated in a way that the impinging beam pulses strike a different part of the target after every pulse.

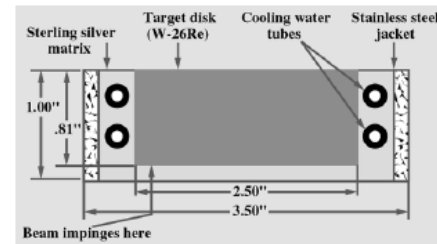


Figure 1: SLC target geometry.

2.1 Electron beam energy deposition

The electron beam of 4.0×10^{10} electrons/bunch at 33 GeV impinging on the target deposits 5 kW of power into the target at a frequency of 120 hertz. The beam has a Gaussian radial distribution with a spot size of 0.8 mm. The SLAC EGS code was used to calculate the energy deposition profile in the target. The energy deposition [4] is very low as the beam enters the target and increases to a maximum as the beam exits the back of the target (see Fig. 2).

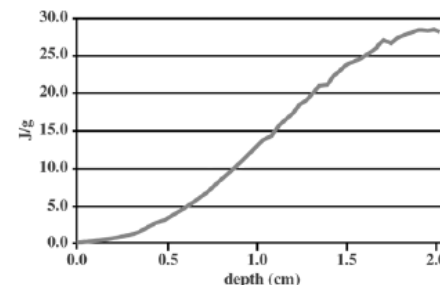
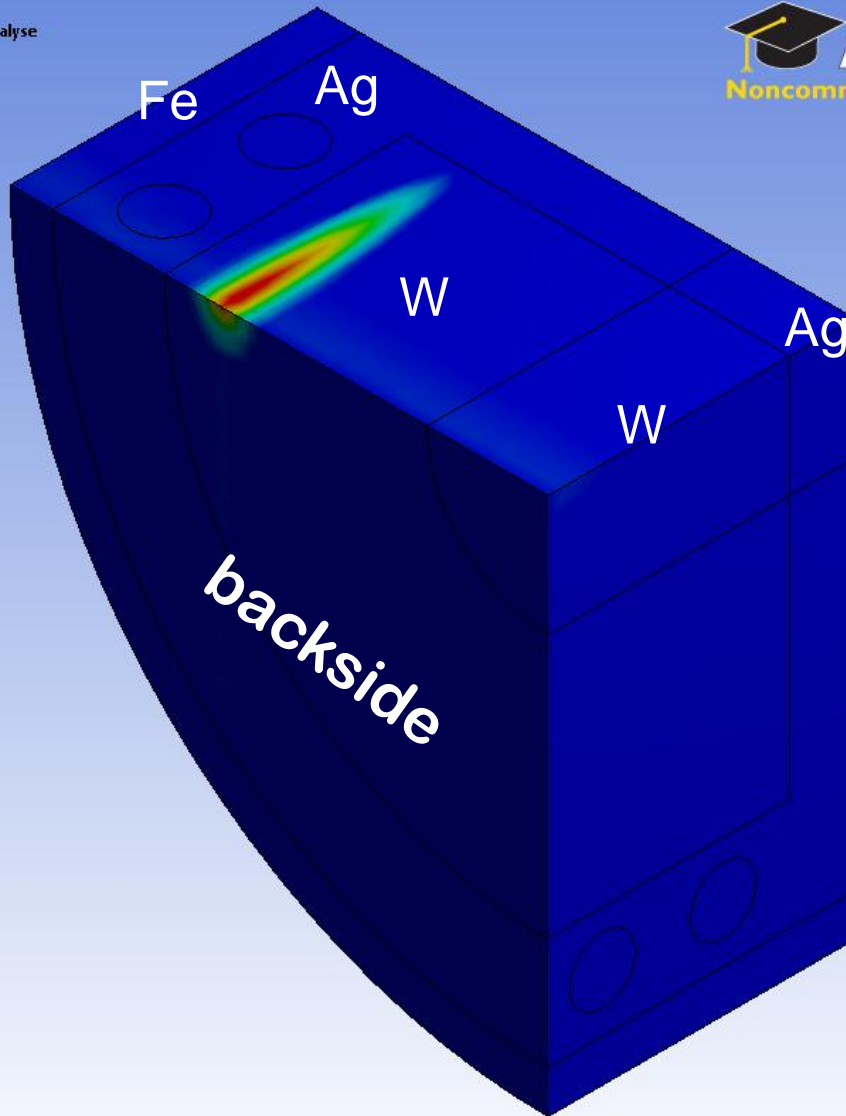
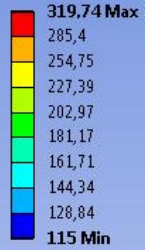


Figure 2: Beam centerline energy deposition, J/g, versus depth into target, cm.

Temperature evolution in the SLAC target

B: Thermisch-transiente Analyse

Temperatur
Type: Temperature
Unit: °C
Time: 2,e-010
03.09.2012 15:43



SLAC

33 GeV e^-
 $4 \cdot 10^{10}$ e^- /pulse
 $\sigma = 0.8$ mm
120 Hz \approx 8 ms

Figure 2a: Target - Beam Entry Face



Figure 2b: Target - Beam Entry Face Detail



Figure 3a: Target - Beam Exit Face

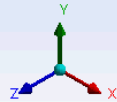
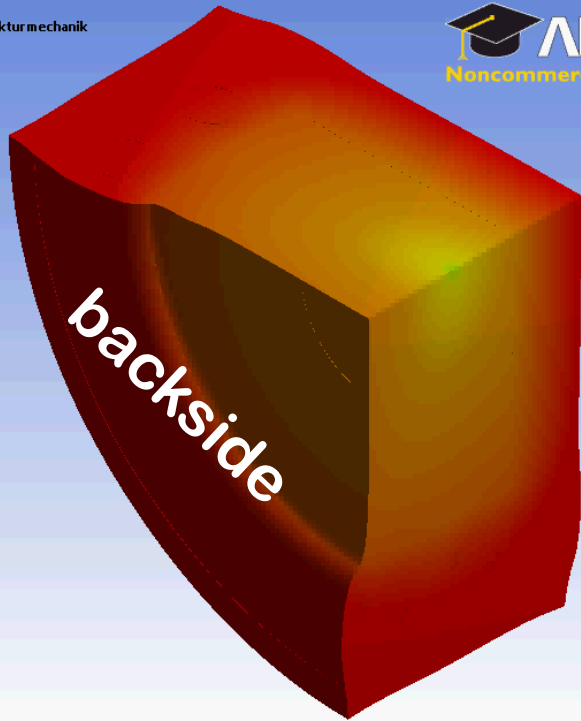
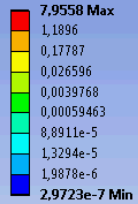


Figure 3b: Target - Beam Exit Face Detail

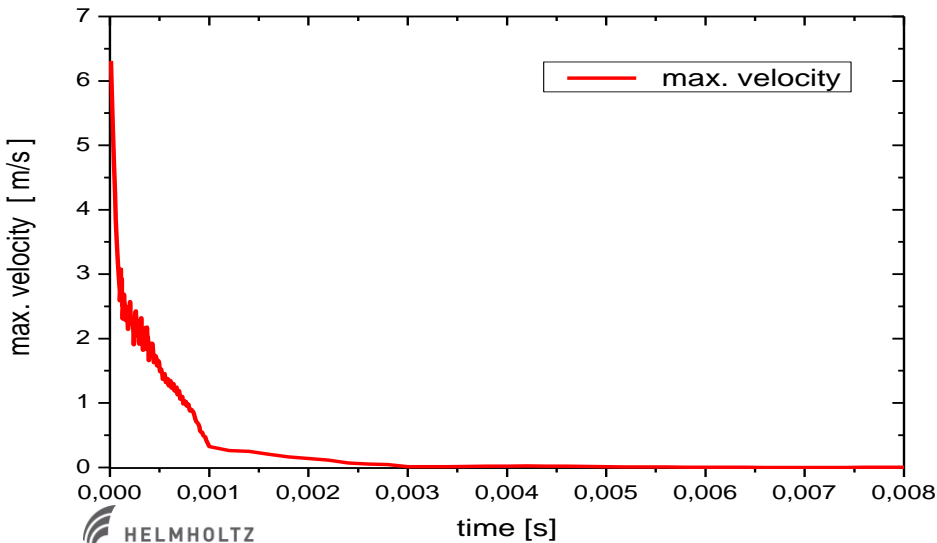
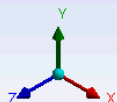
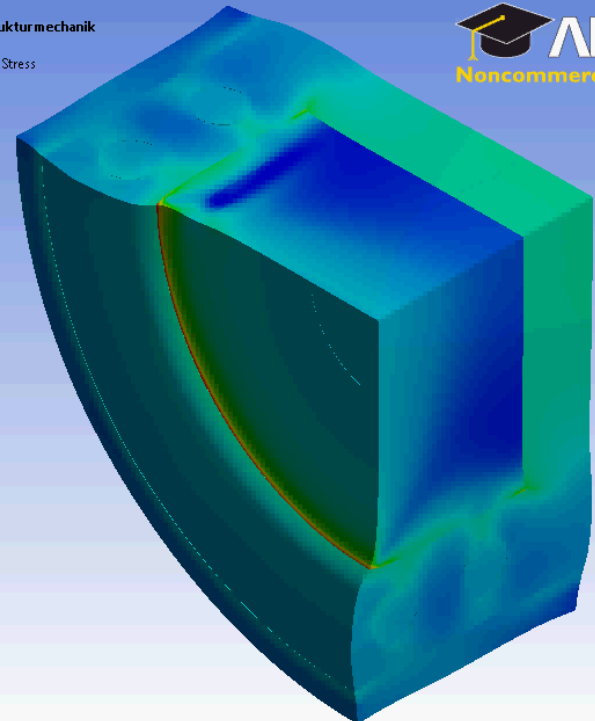
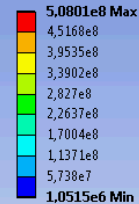


Velocity and stress evolution in the SLAC target

D: Kopie von Transiente Strukturmechanik
Gesamtgeschwindigkeit
Type: Total Velocity
Unit: m/s
Time: 0
27.08.2012 15:48



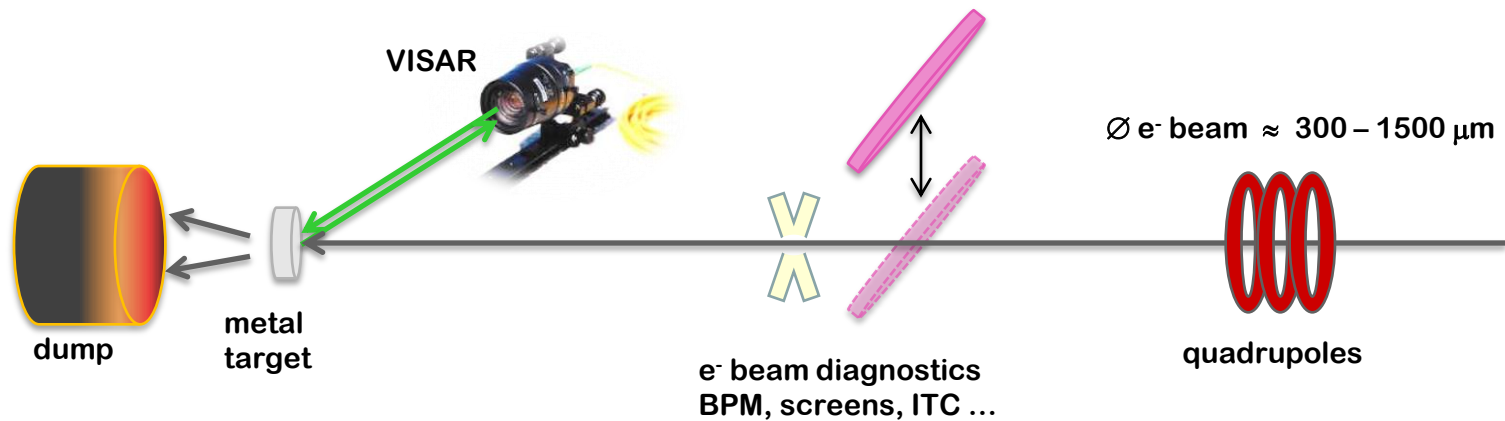
D: Kopie von Transiente Strukturmechanik
Vergleichsspannung
Type: Equivalent (von-Mises) Stress
Unit: Pa
Time: 0
27.08.2012 15:55



SLAC

33 GeV e^-
 $4 \cdot 10^{10}$ e^- /pulse
 $\sigma = 0.8\text{mm}$
120 Hz ≈ 8 ms

Experimental setup for material tests

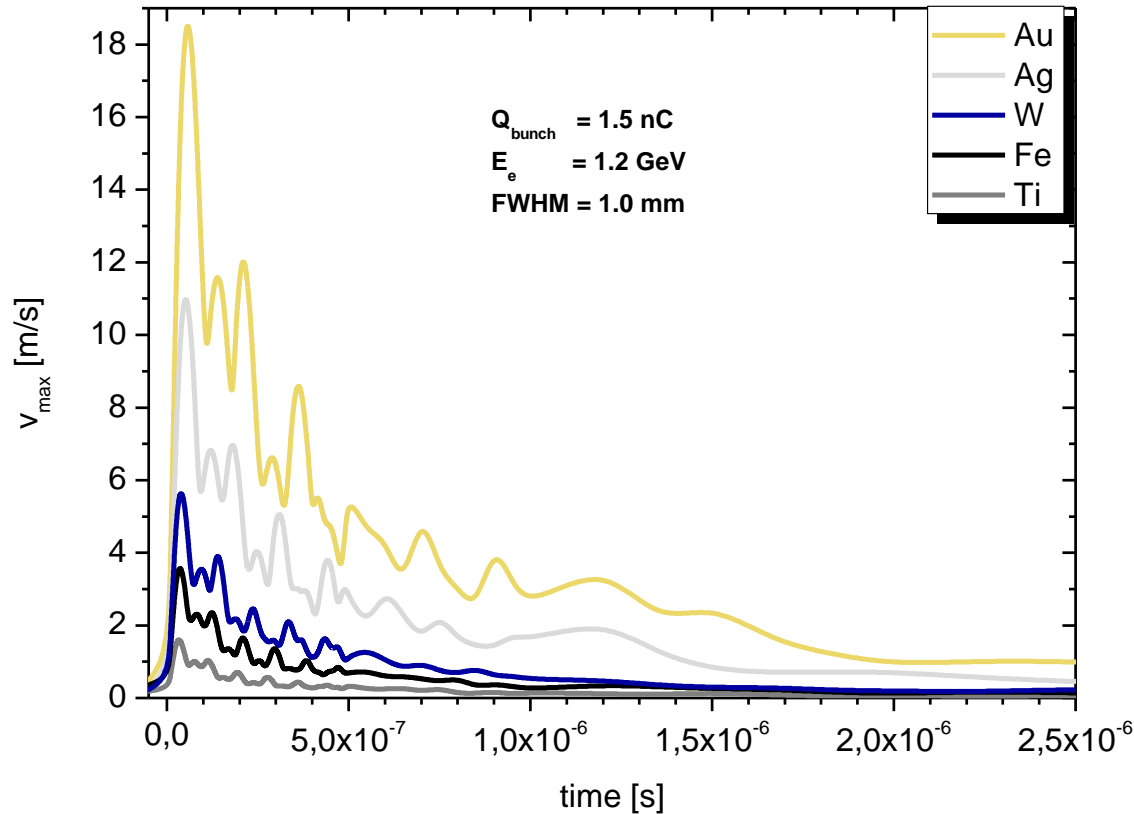


- Quadrupoles \Leftrightarrow focus beam to the test material (e.g. Ag, Brass, Fe, Ti)
- Radiation issues : disturbed beam has to be absorbed in the dump

FLASH e⁻ beam

$E_{e^-} = 1.2 \text{ GeV}$ (1 bunch, 1.5 nC)

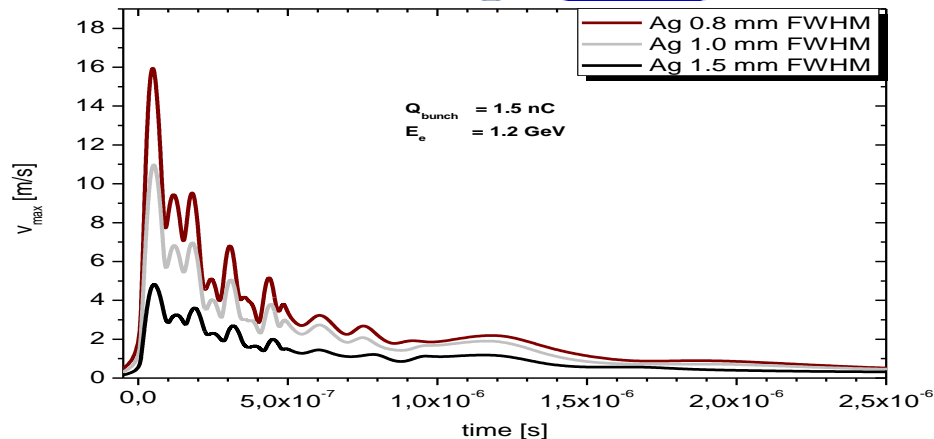
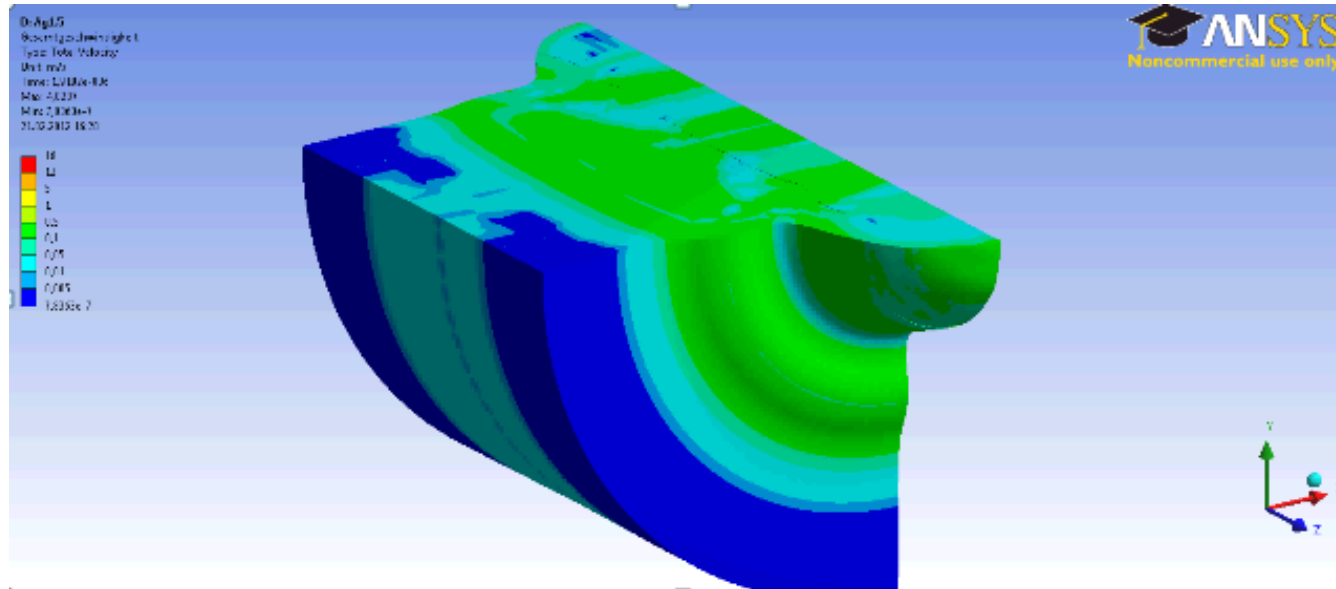
beam $\varnothing = 1000 \text{ } \mu\text{m}$ (FWHM)



FLASH e⁻ beam

$E_{e^-} = 1.2 \text{ GeV}$ (1 bunch, 1.5 nC)

beam $\varnothing = 800, 1000, 1500 \mu\text{m}$ (FWHM)



Conclusion

- The collimator design achieved in the static case the fatigue stress limits of the materials for the proposed parameter sets (including safety factors)
- Collimator cooling should be not difficult for this introduced design

- The dynamical calculations for the Ti6Al4V ILC target with ANSYS is ongoing
- Dynamical calculations for the collimator are performed

- The dynamical ANSYS calculations (life time) of the SLAC target should be consistence with the experience

- to do:** - a cooling channel design for the Ti-target wheel have to be updated
 - a material test experiment at a suitable accelerator have to be performed