HCPS Report
(aka "Homework #2")

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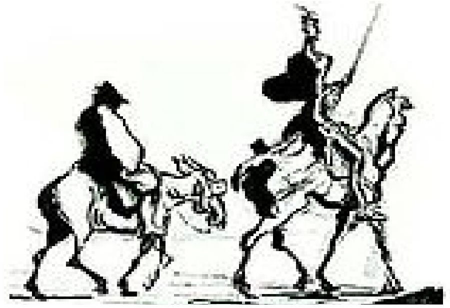
Outline:

- **Charge**
- **Results**
- **Quo Vadis? (aka … GN's currency reference)**

Charge

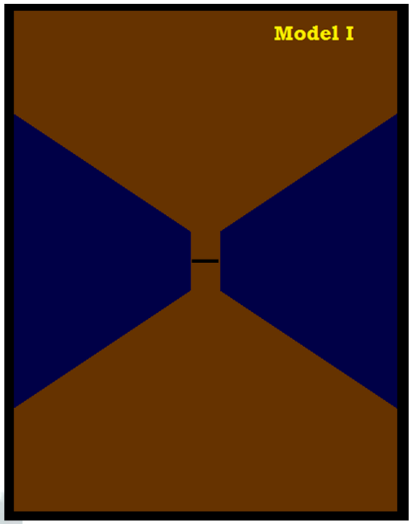


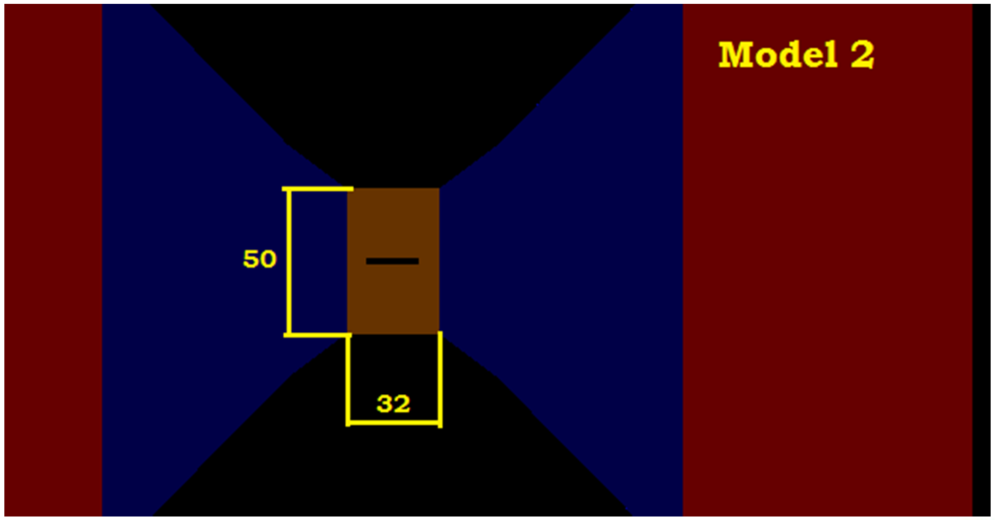
- **Define basic HCPS geometry**
- **Simulate it (G4, fluka) concentrating on:**
  - **Prompt Radiation**
  - **Activation***
  - **Photon beam Spot Size & intensity**
  - ***Power Deposition, Cooling, heat transp., temperature (in the central region)***

- **Beam: E = 11.5 GeV electrons, I = 2.6 uA, (30kW)**
- **1x1 mm raster**

JMU simulation setup

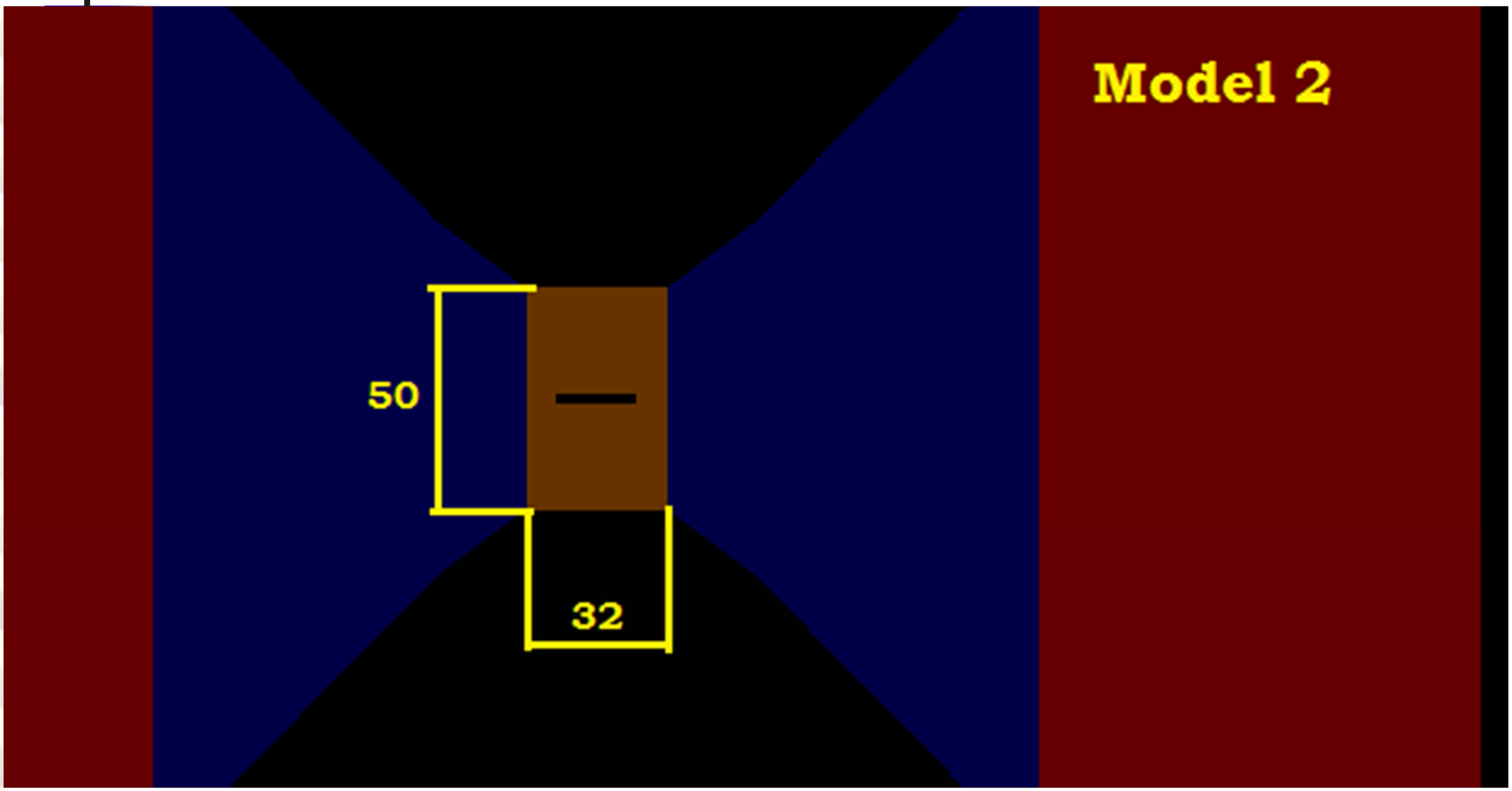
- GN's JMU setup: Same as last time...
- Two versions of the magnet:
  - Small bore (16x34 mm), 1000 mm long (field map BW)
  - Larger bore (32x50 mm), 970 mm long (ditto)
  - Both with a single central slit
  - W Powder shielding + Borated Poly (i.e. just like HW#1)
  - Radiator in/outside magnetic field





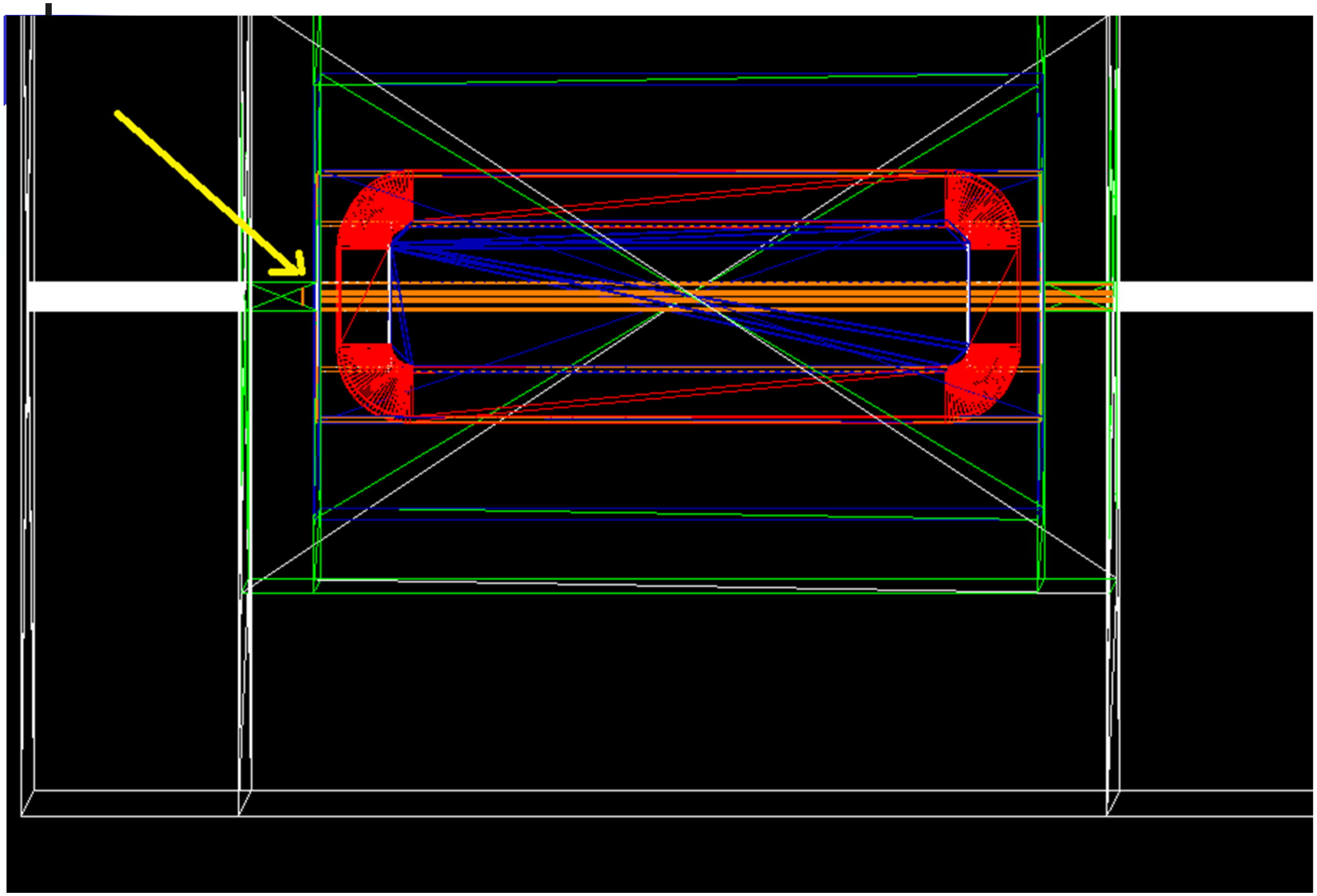
JMU simulation setup

➢ **Close-up view**



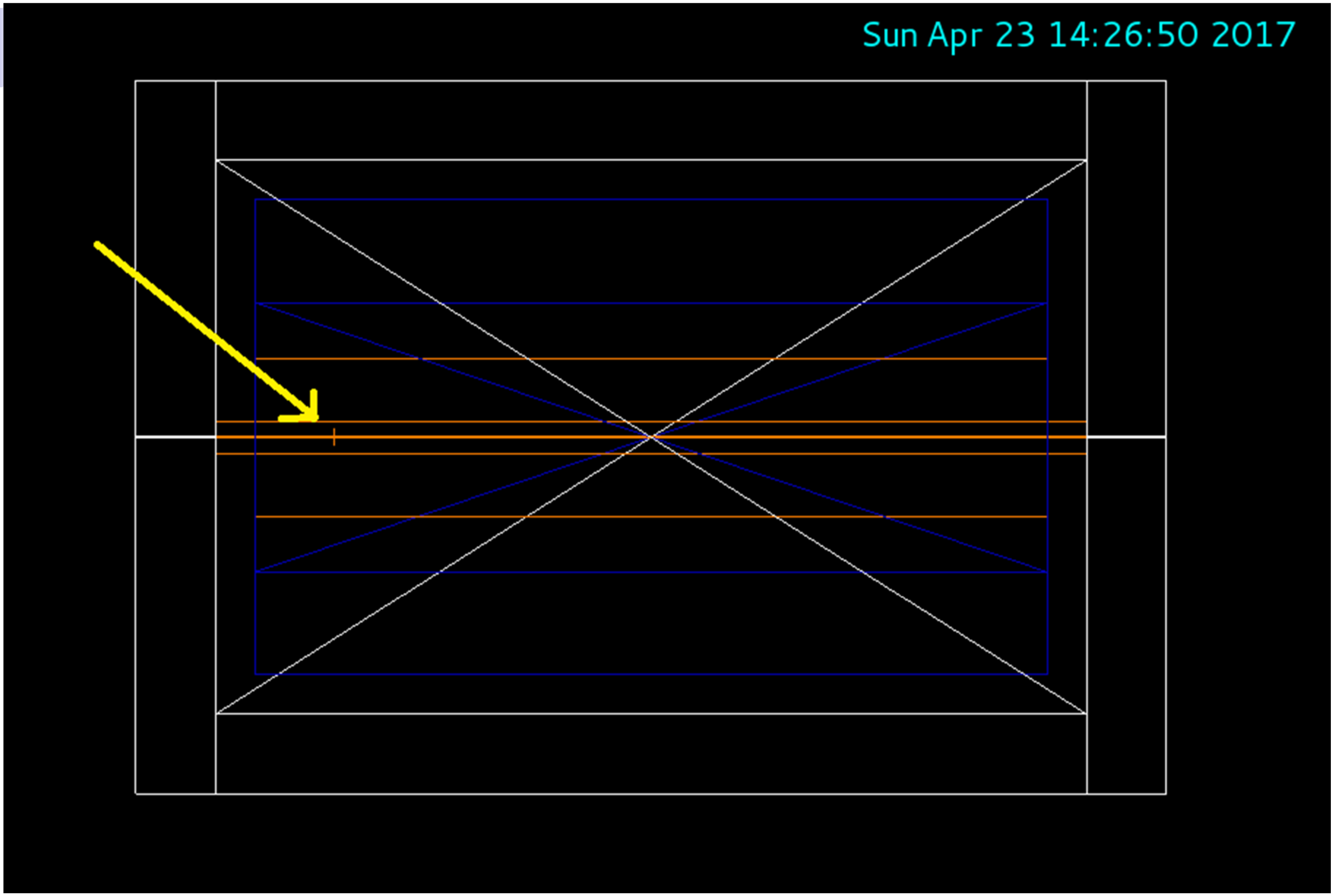
JMU simulation setup

- Side view. Radiator outside



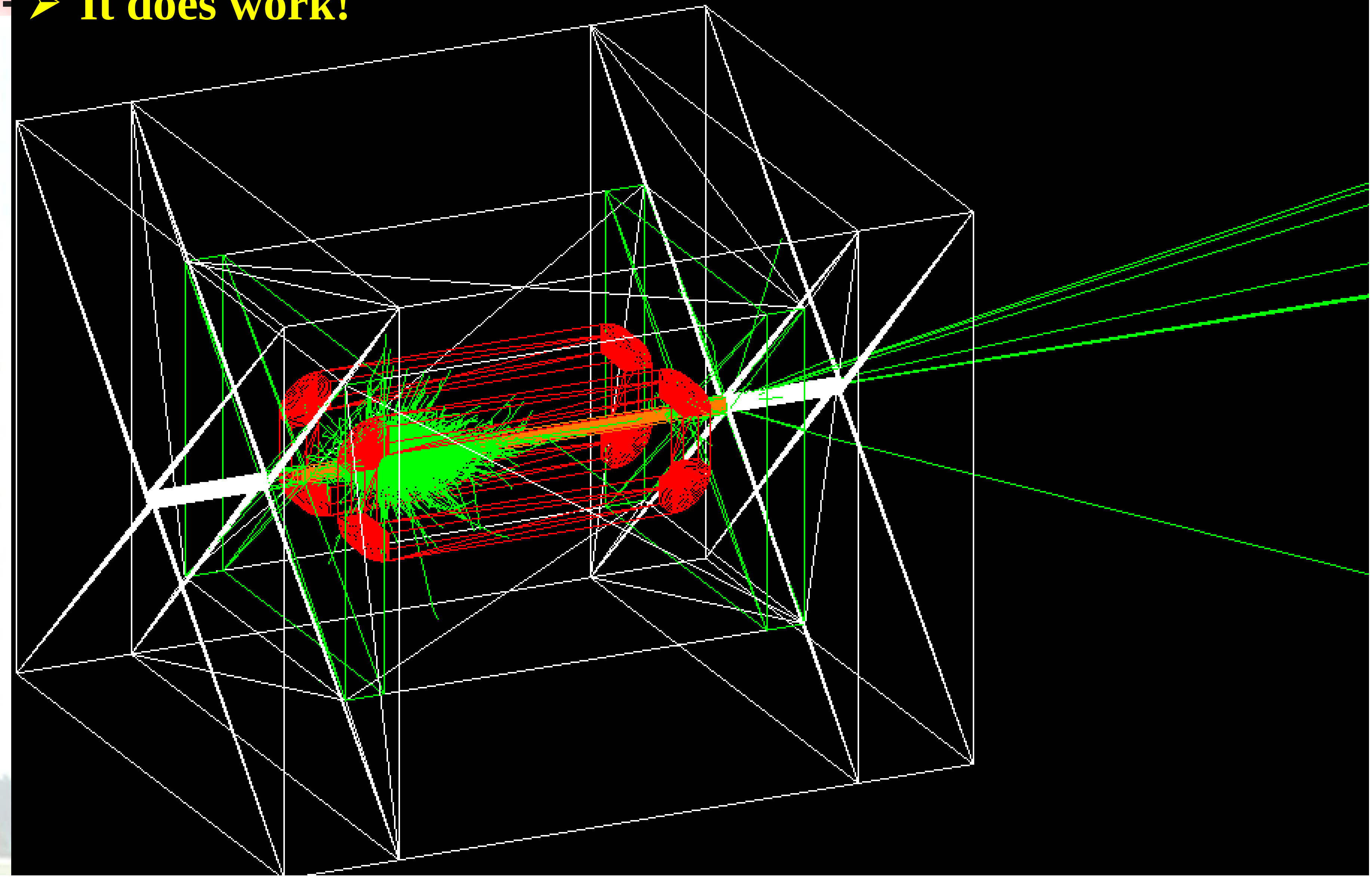
JMU simulation setup

- Side view. Radiator in field.



JMU simulation setup

- It does work!



Radiation Level Results

- Results not dissimilar to HW#1.

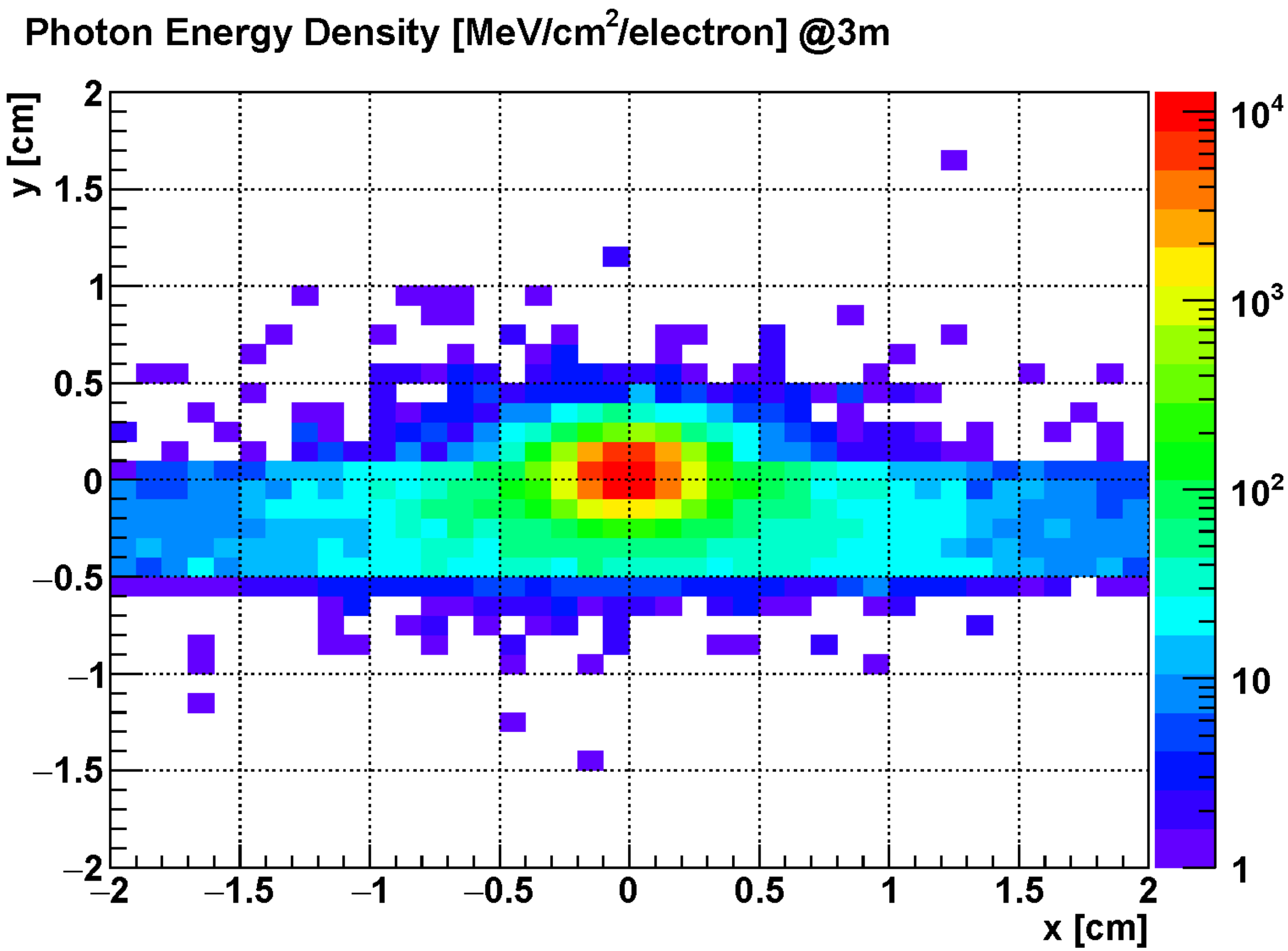
	at 3 m from center								
	Pavel			Igor			Gabriel		
	DINREG/GEANT3			MCNP6			GEANT4		
Dose Rates [rem/h]	n	g	total	n	g	total	n	g	total
3m Fe	146	0.44	146.4	12.5	0.13	12.63	123.2	0.56	123.8
3m Fe+PolyB	0.8	2.8	3.6				0.284	0.56	0.844
1.5m W	13	0.06	13.1	4.5	0.03	4.53	6.34	0.33	6.67
1.5m W+PolyB	2.7	0.003	2.7				1.76	1.28	3.04

- **30 +10 Shielding: 5.58 rem/h**
- **1.5 W+Poly (from last time): 3.04 rem/h**
- **40+10, 30+20: still processing...**

- **Activation simulation not pursued at this time. Same mats. as before so no surprises expected.**

Beam Spot. Intensity.

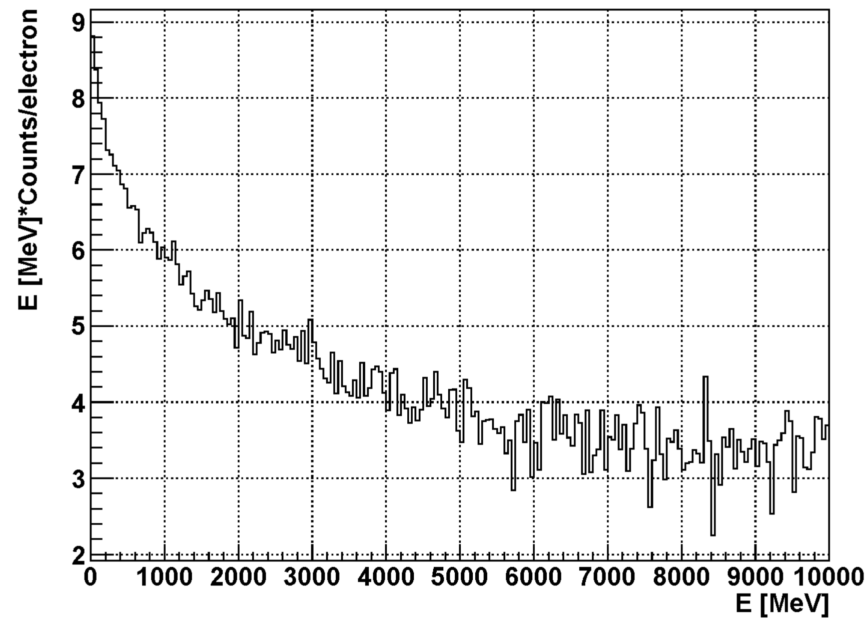
➢ Photon beam at 3 m from center (3.4 m from radiator).



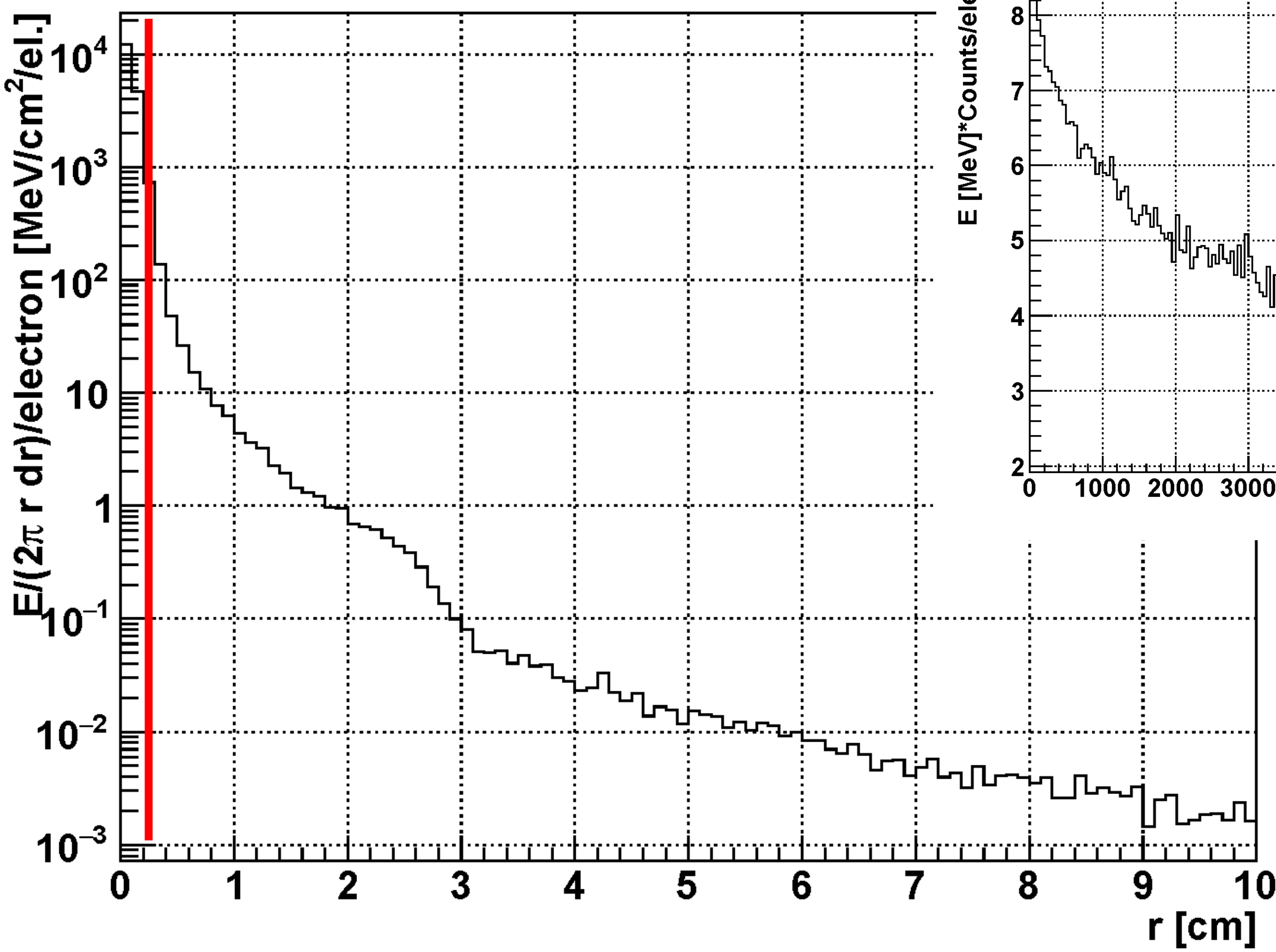
Beam Spot. Intensity.

- Photon energy distribution. Beam intensity.

Photon Energy Spectrum @3m



Photon Energy Density vs radius @3m



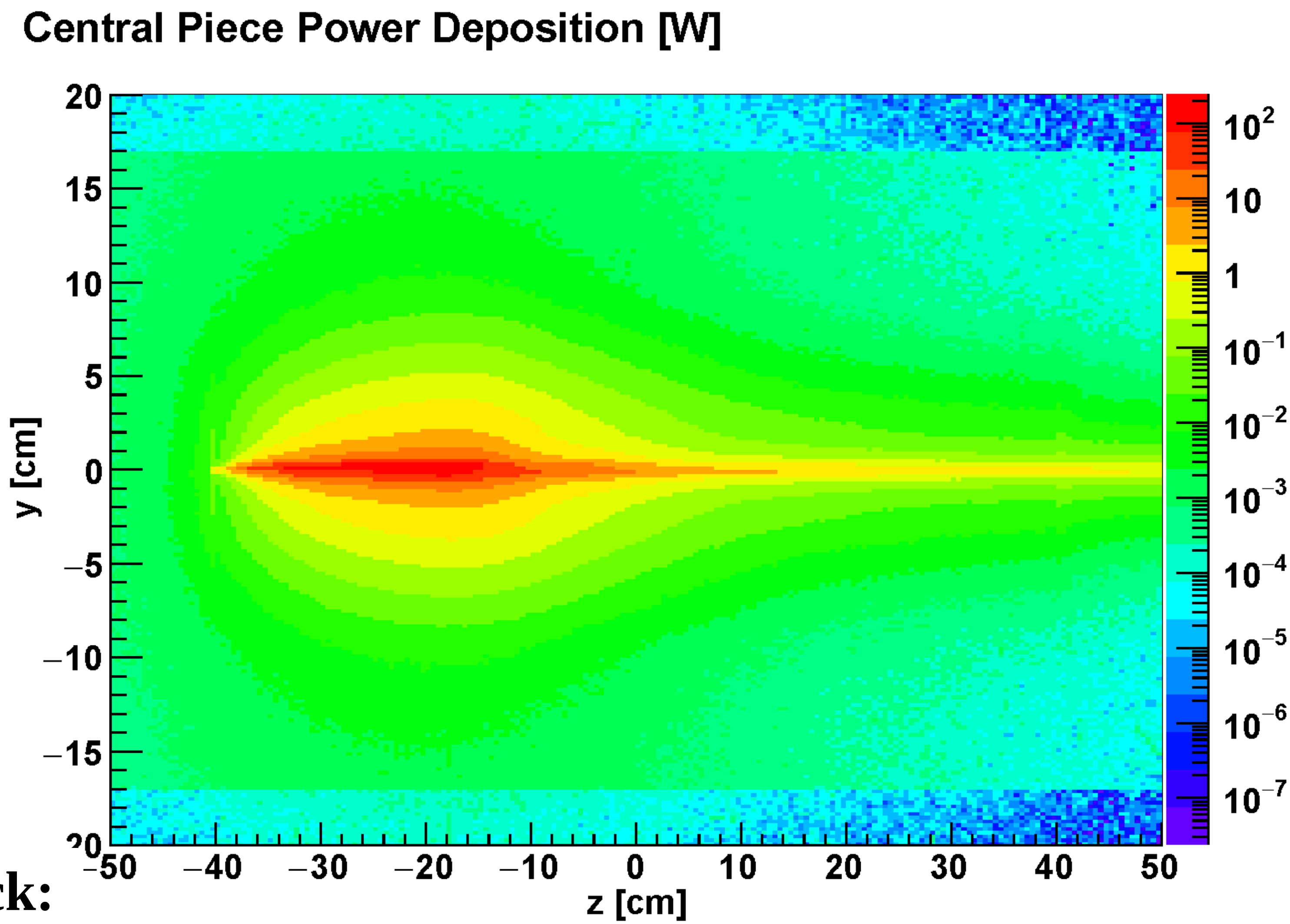
Power Deposition

- To collect power deposition in the central piece of the HCPS:
- Modify “standard” G4 code to have smaller step size in CP.
- 100 um vs 700 um
- ~eV range IR cutoff
- YES, it does take awhile to run!!
- Collect eDep data in a 0.5x0.5x5 mm mesh in the CP.

- Analyze G4 output to get the power (density) deposited...

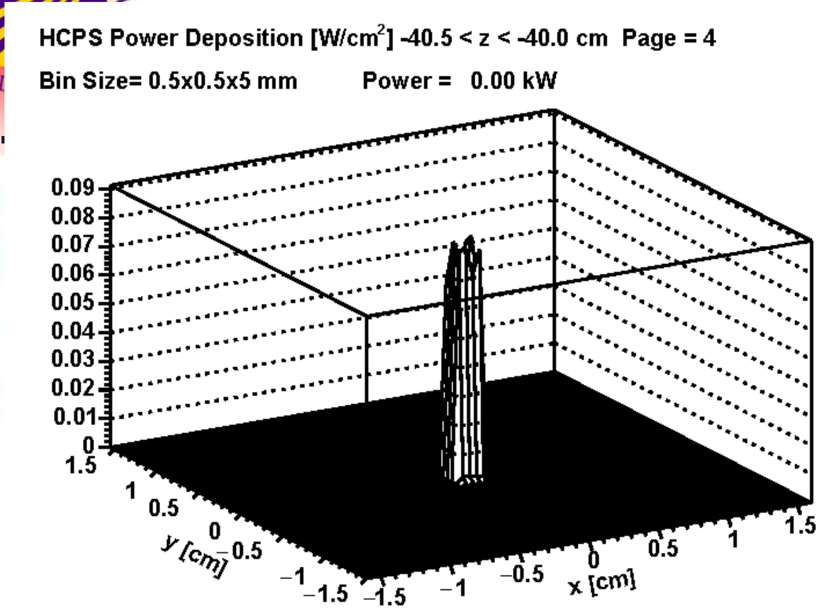
Power Deposition

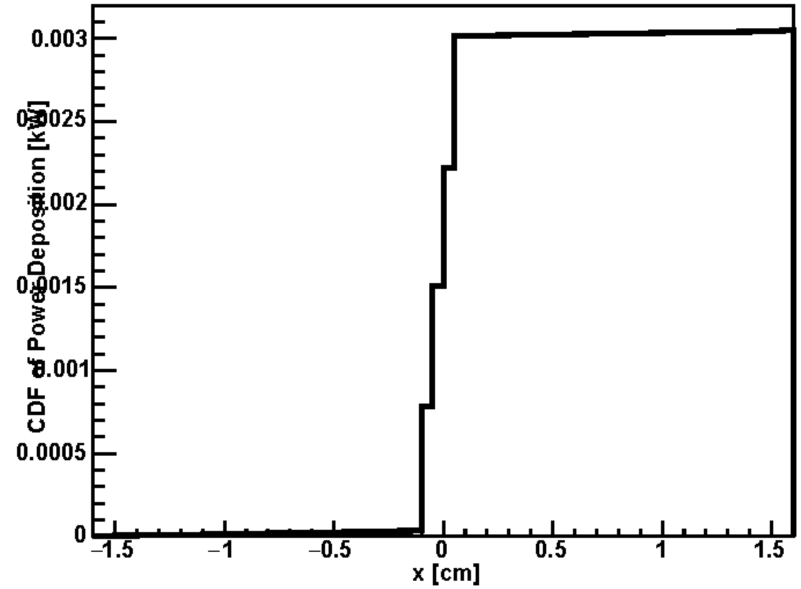
- ... and get things like this.

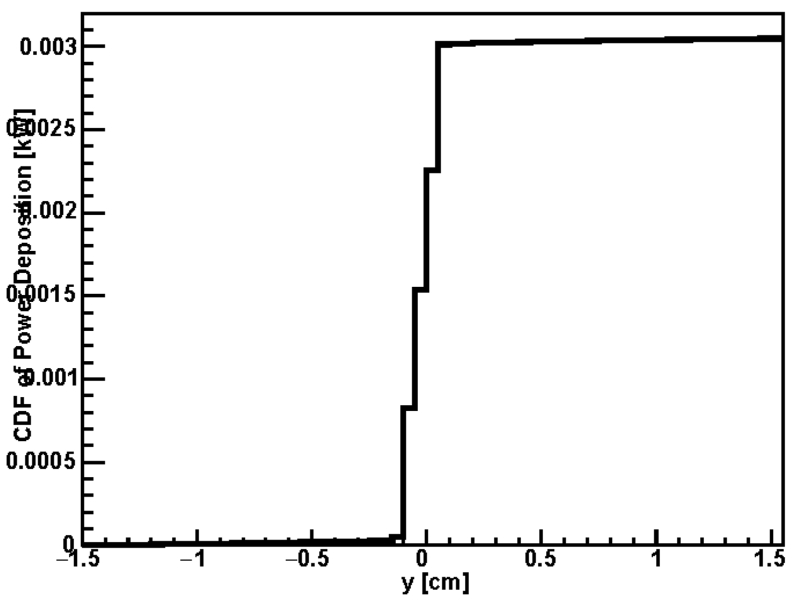


- Built-in check:
- Integrate all this power deposition. We get 27.001 kW! (10% radiator)

Power Deposition

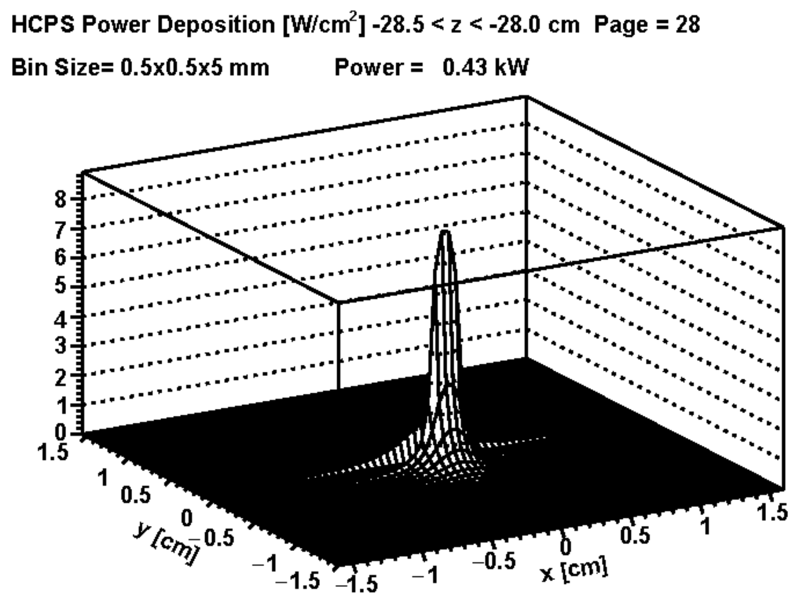


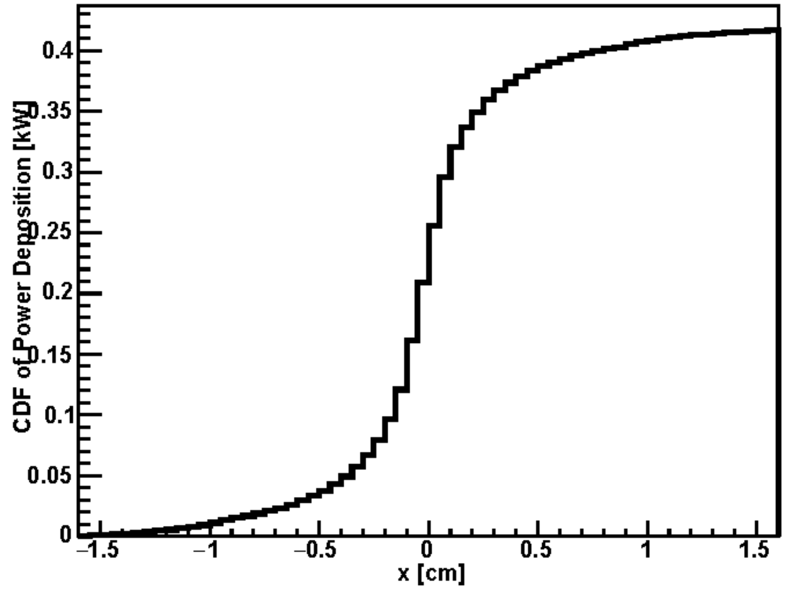


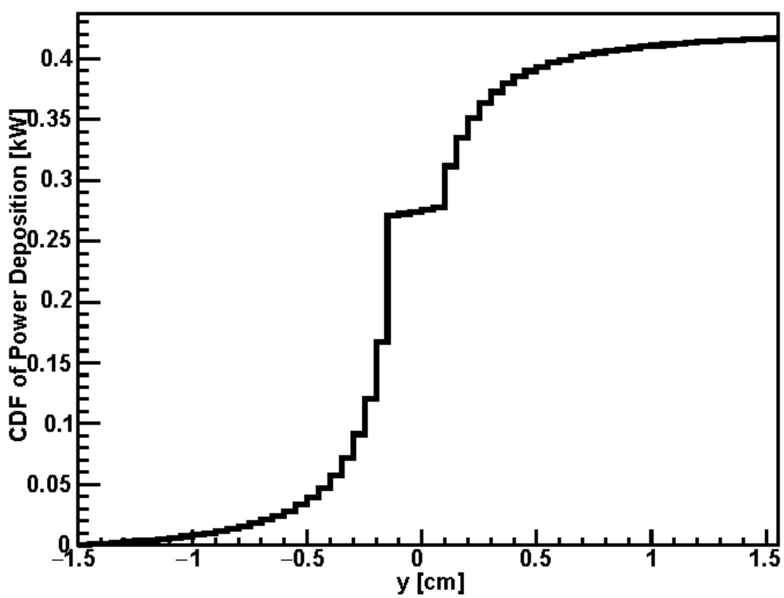


- **More detailed look(s)**
- **XY Power Deposition for a 5 mm z slice.**
- **This particular one is the radiator itself***

Power Deposition

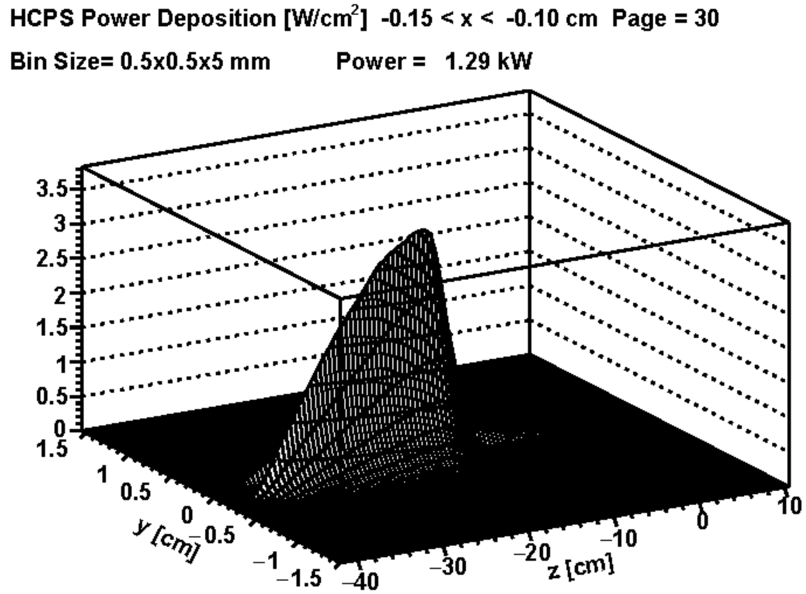


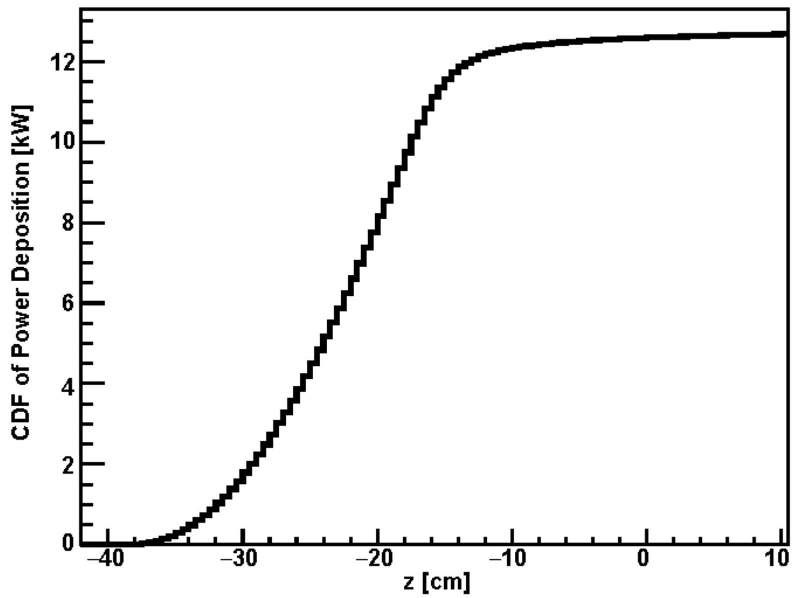


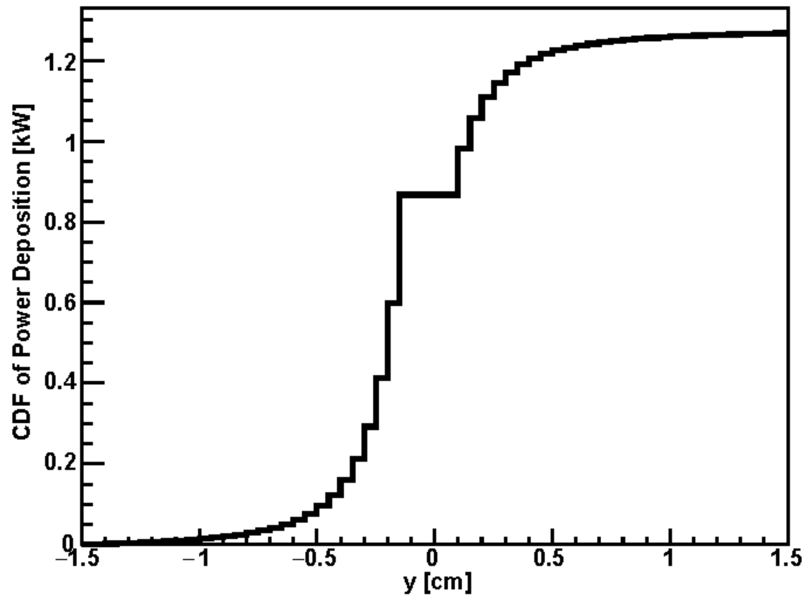


- **More detailed look(s)**
- **Peak: ~0.7kW @ z=-18 cm**
- **+ 166 more slides like this!**

Power Deposition







- More detailed look(s)
- YZ distributions for slices in X
- ...for 64 total slices.

Heat Flow. Cooling.

- **Use the power deposition data to do a heat-flow/cooling calculations**
- **Calculation of coolant flow (BW)**
- **2D heat transport for z-slices of the CP region (GN)**

		Units		Units		Units
d			6	mm	0.019685	ft
L	10	m	10000	mm		
epsilon					0.000005	ft
nu	0.00001216	ft^2/sec				
Coil Power	15	kW				

$$v = -2\sqrt{\frac{2g\Delta P}{0.433}\frac{d}{L}}\,\log_{10}\left(\frac{\varepsilon}{3.7d} + \frac{2.51}{\frac{d}{\nu}\sqrt{\frac{2g\Delta P}{0.433}\frac{d}{L}}}\right)$$

$$\frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{\varepsilon}{3.7d} + \frac{2.51}{\frac{d}{\nu}\sqrt{\frac{2g\Delta P}{0.433}\frac{d}{L}}}\right)$$

$$q\left(\frac{gpm}{circuit}\right) = v\frac{\pi d^2}{4} = v\left(\frac{ft}{sec}\right)\frac{\pi d^2}{4}\left(ft^2\right)\times\frac{gal}{0.1337\ ft^3}\times 60\,\frac{sec}{min}$$

$$\mathrm{Re} = \frac{vd}{\nu} \qquad \Delta T = \frac{3.8P}{q}$$

DeltaP (psi)	$\sqrt{\frac{2g\Delta P}{0.433}\frac{d}{L}}$ (ft/sec)	$\left(\frac{\varepsilon}{3.7d} + \frac{2.51}{\frac{d}{\nu}\sqrt{\frac{2g\Delta P}{0.433}\frac{d}{L}}}\right)$ (no units)	(no units)	f	v (ft/sec)	Re	q (gpm)	DT (deg.C)
30	1.63619567	0.001016	5.98598	0.027908	9.794235	15855.25	1.337681763	42.61103
35	1.76729331	0.000946	6.048238	0.027336	10.68901	17303.75	1.459889005	39.04406
40	1.88931602	0.000889	6.101889	0.026858	11.5284	18662.58	1.574531024	36.20126
45	2.00392225	0.000842	6.148984	0.026448	12.32209	19947.43	1.682931854	33.86946
50	2.11231952	0.000803	6.190921	0.026091	13.0772	21169.84	1.786064648	31.91374
55	2.21541941	0.000769	6.228695	0.025775	13.79917	22338.59	1.884670139	30.24402
60	2.3139301	0.000739	6.263041	0.025494	14.49224	23460.55	1.979328035	28.79765
65	2.40841481	0.000712	6.294513	0.025239	15.1598	24541.22	2.070502398	27.52955
70	2.49933016	0.000689	6.323544	0.025008	15.80462	25585.09	2.158571746	26.40635
75	2.5870525	0.000668	6.350475	0.024796	16.42901	26595.87	2.243849749	25.40277
80	2.67189633	0.000649	6.375581	0.024601	17.03489	27576.69	2.326599875	24.49927
85	2.7541277	0.000632	6.399087	0.024421	17.6239	28530.2	2.407046032	23.68048
90	2.83397403	0.000616	6.421178	0.024253	18.19745	29458.68	2.485380464	22.93411
95	2.91163153	0.000601	6.44201	0.024097	18.75676	30364.11	2.56176972	22.25024
100	2.98727092	0.000588	6.461713	0.02395	19.30289	31248.2	2.63635925	21.62073
105	3.0610418	0.000575	6.480401	0.023812	19.83678	32112.48	2.709276988	21.03882
110	3.13307617	0.000564	6.498168	0.023682	20.35925	32958.28	2.780636188	20.49891
115	3.20349117	0.000553	6.515098	0.023559	20.87106	33786.81	2.850537693	19.99623
120	3.27239133	0.000542	6.531264	0.023443	21.37285	34599.13	2.919071772	19.52676
125	3.33987042	0.000533	6.546729	0.023332	21.86523	35396.2	2.986319647	19.08704
130	3.40601289	0.000524	6.561549	0.023227	22.34872	36178.9	3.052354582	18.67411
135	3.47089515	0.000515	6.575774	0.023126	22.82382	36948.01	3.117243207	18.28539
140	3.53458662	0.000507	6.589448	0.02303	23.29097	37704.26	3.181046081	17.91863
145	3.59715053	0.0005	6.60261	0.022939	23.75058	38448.28	3.243818563	17.57188
150	3.65864473	0.000492	6.615296	0.022851	24.20362	39180.7	3.305611396	17.24341

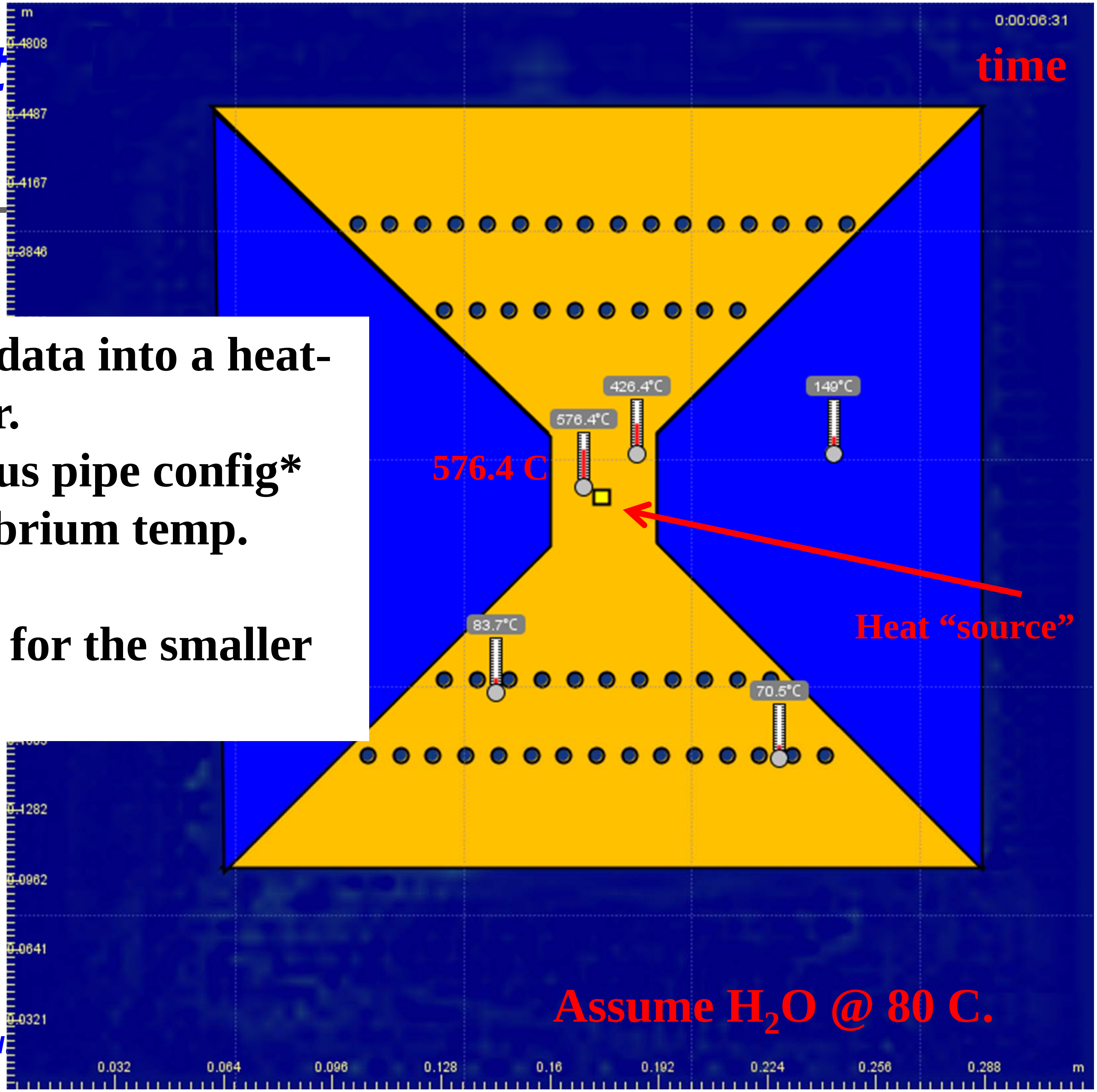
- **Manageable H_20 flow and ΔT.**

typical pressure → 100

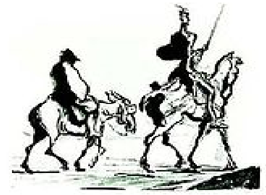
Heat

- Input the PD data into a heat-flow simulator.
- Assume various pipe config*
- Record equilibrium temp.

- NOTE: this is for the smaller bore magnet.



Quo Vadis?



- **Two magnet options explored. Also two diff. pos. for the radiator. Several shielding thicknesses.**
- **With enough W + PolyB the HCPS behaves (rad.-wise) as the 1.5m W sphere from last time.**
- **Beam spot small, suitable for WACS (other exp.) work.**
- **Power deposition in CP mapped in great detail.**
- **Heat flow/coolant flow calculations/simulations carried out.**
- **CP temperature stabilizes at an acceptable value.**

- **Finish simulation of shielding options & rad. position. Fluka.**
- **Heat calculation for larger bore magnet.**

- ***THANK YOU!***