PAUL SCHERRER INSTITUT

PSI

Thomas Schmidt :: Paul Scherrer Institut

Apple-X undulator for SwissFEL Athos and EU-XFEL (SASE 3)

8th Hard X-ray FEL Collaboration Meeting

PAUL SCHERRER INSTITUT

PSI

SwissFEL
Ethos

250eV - 1900eV @ 3 +- 0.25 GeV

for Kz, Kx, circular

APPLE type

UE38

K = 1 … 3.5

SmCo

vacuum chamber: dia 5mm

Hall - probe: 3mm

Chicane:

PM / Dispersion / offset

EU-XFEL
SASE 3 Afterburner

0.4 - 1.6nm @ 15 GeV

3.1keV - 775 eV

Linear 0 - 90°, circular

UE90

K = 3.6 … 7.7

NdFeB

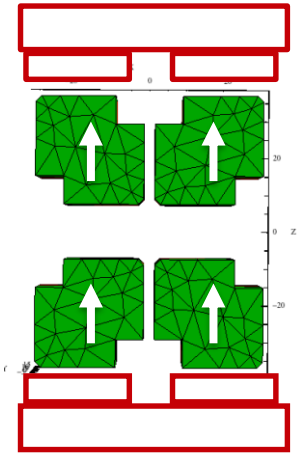
vacuum chamber: dia 5mm

Hall - probe: 3mm

Chicane:

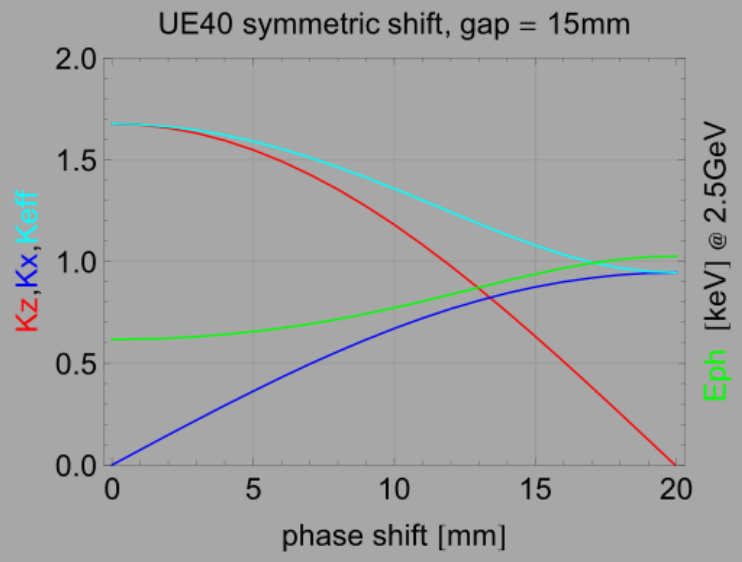
PM

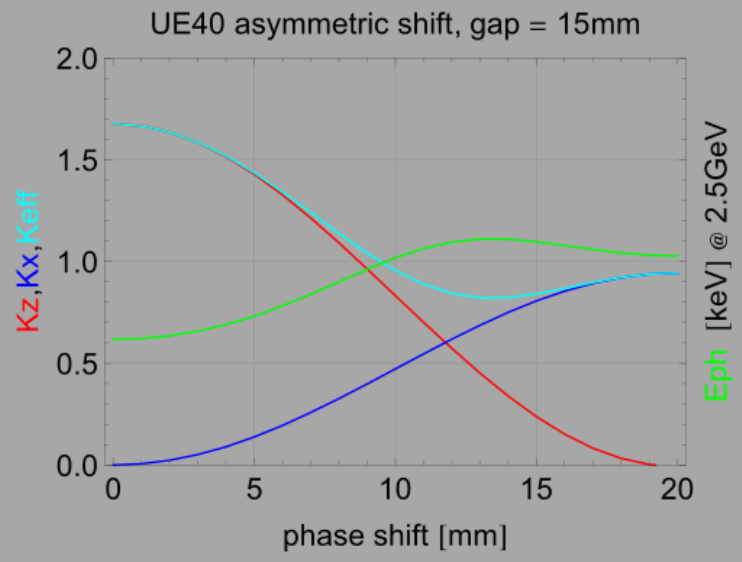
APPLE II - work horse in storage rings



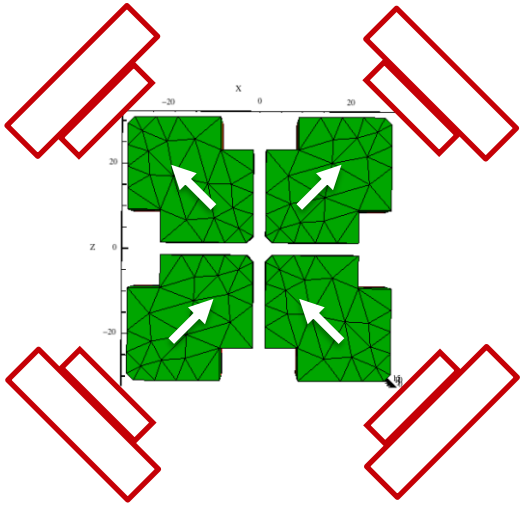
K_z > K_circ > K_x > K_45°

gap and shift drive, coupled





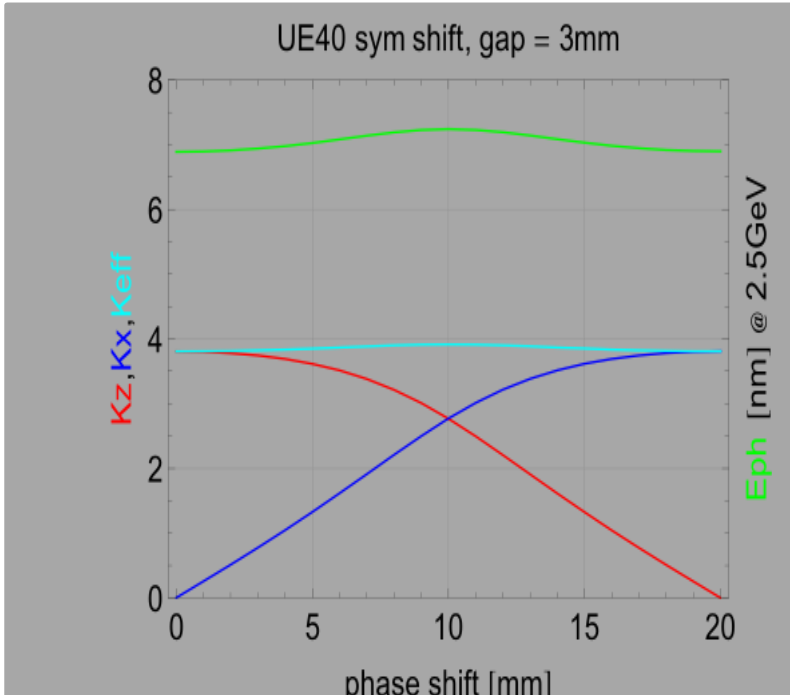
APPLE - X

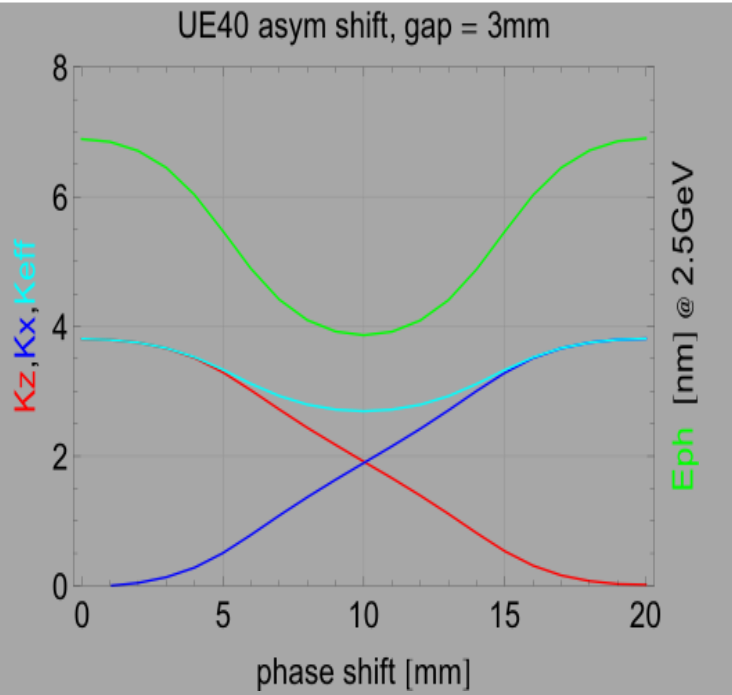


K_z = K_circ = K_x > K_45°

gap = slit for all gaps

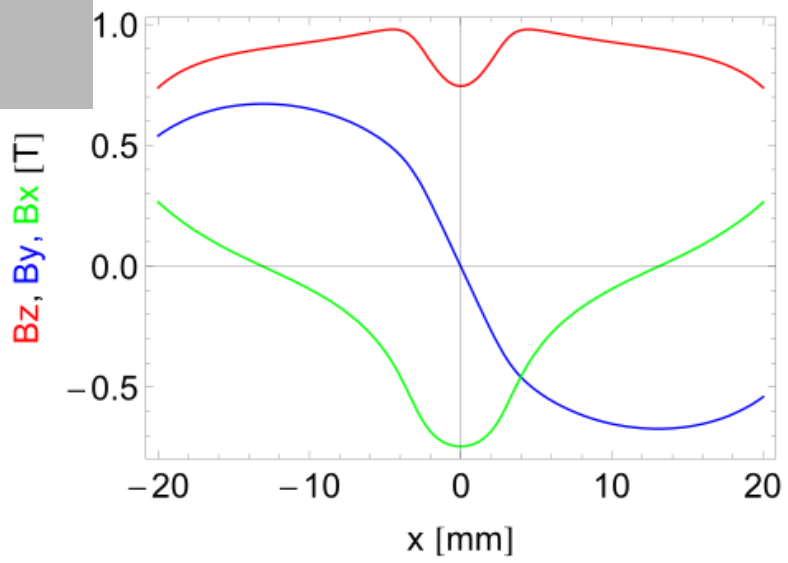
full symmetric design





why not fixed gap operation

variable gap mode: circular

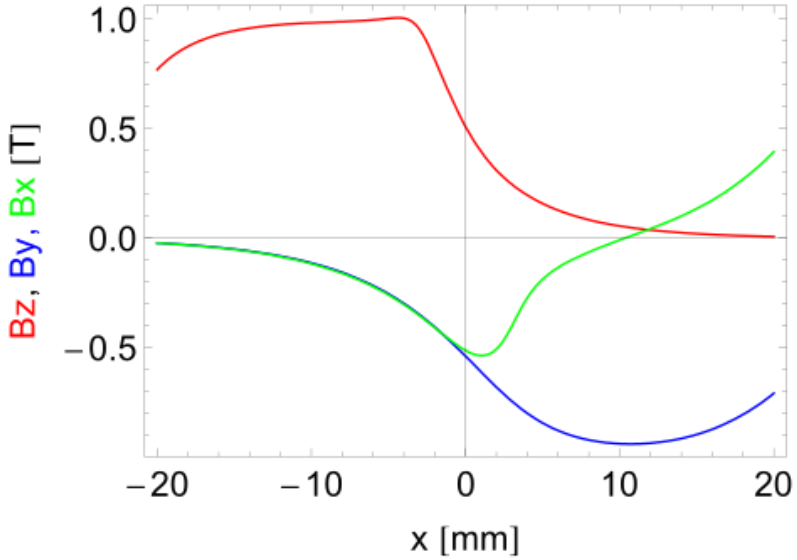


pros: good field region +- 60µm
no longitudinal field on axis

cons: gap and shift dependent

benefit: adjustable linear taper
with gradient and yaw angle

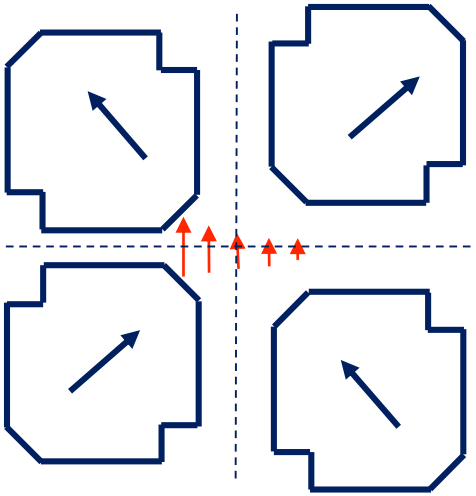
fixed gap mode: circular



pros: costs
1-dim operation

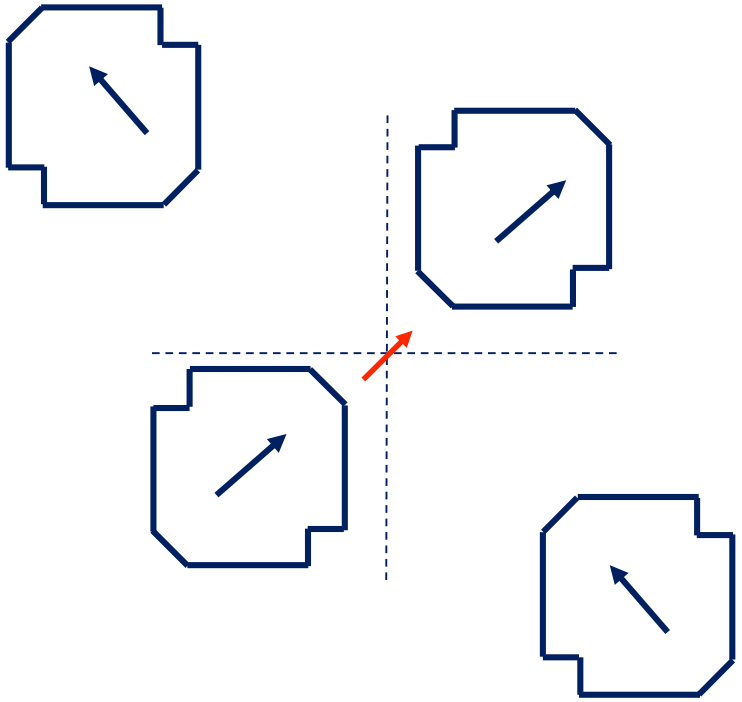
cons: strong gradients in Bz / Bx and By on axis
no good field region
dE/E = 1E-4: 1µm !!!

APPLE X highlights



highest flexibility
-> gradients for
ultra high bandwith mode

(PSI)

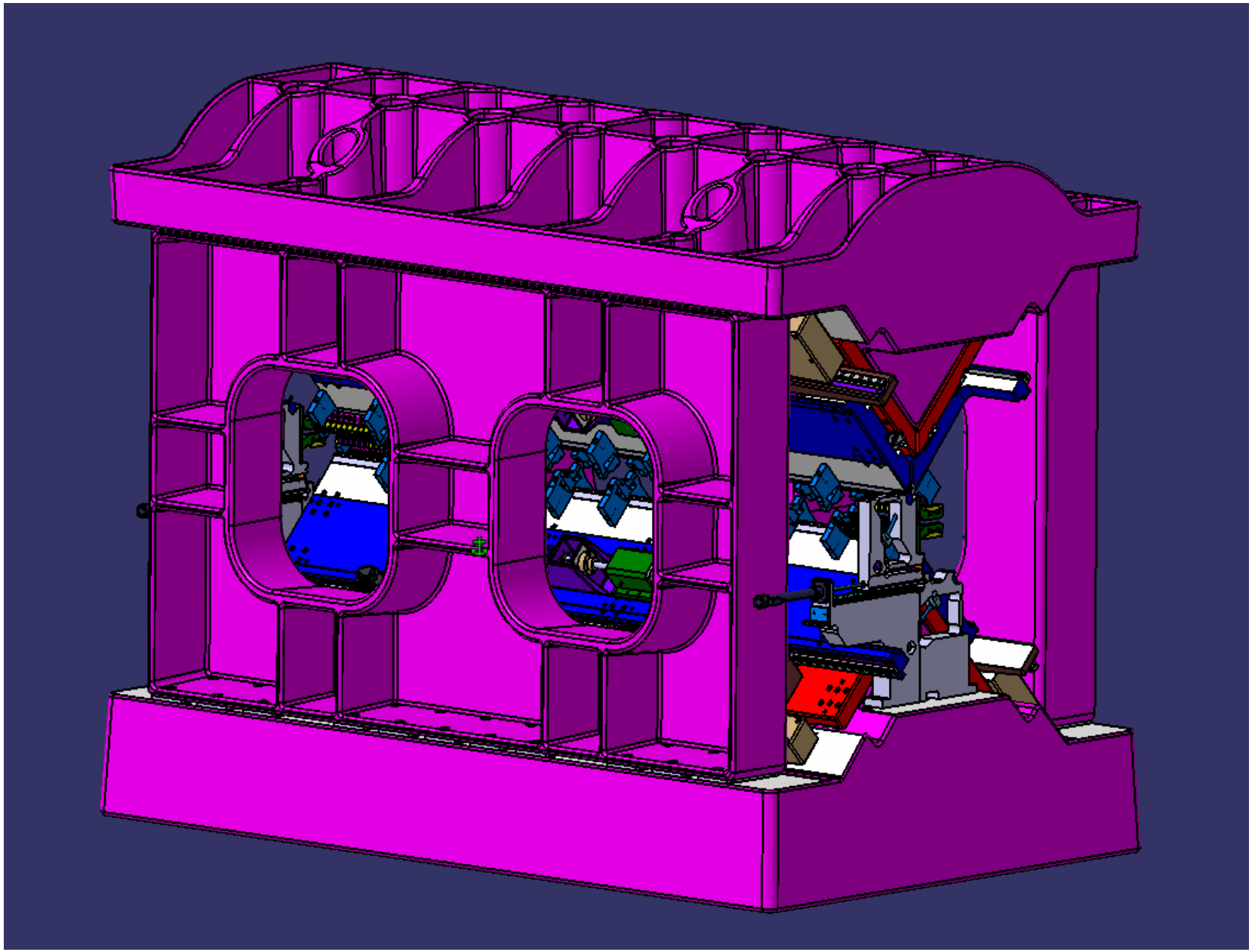


highest flexibility
-> 45°
without longitudinal forces

(EUXFEL)

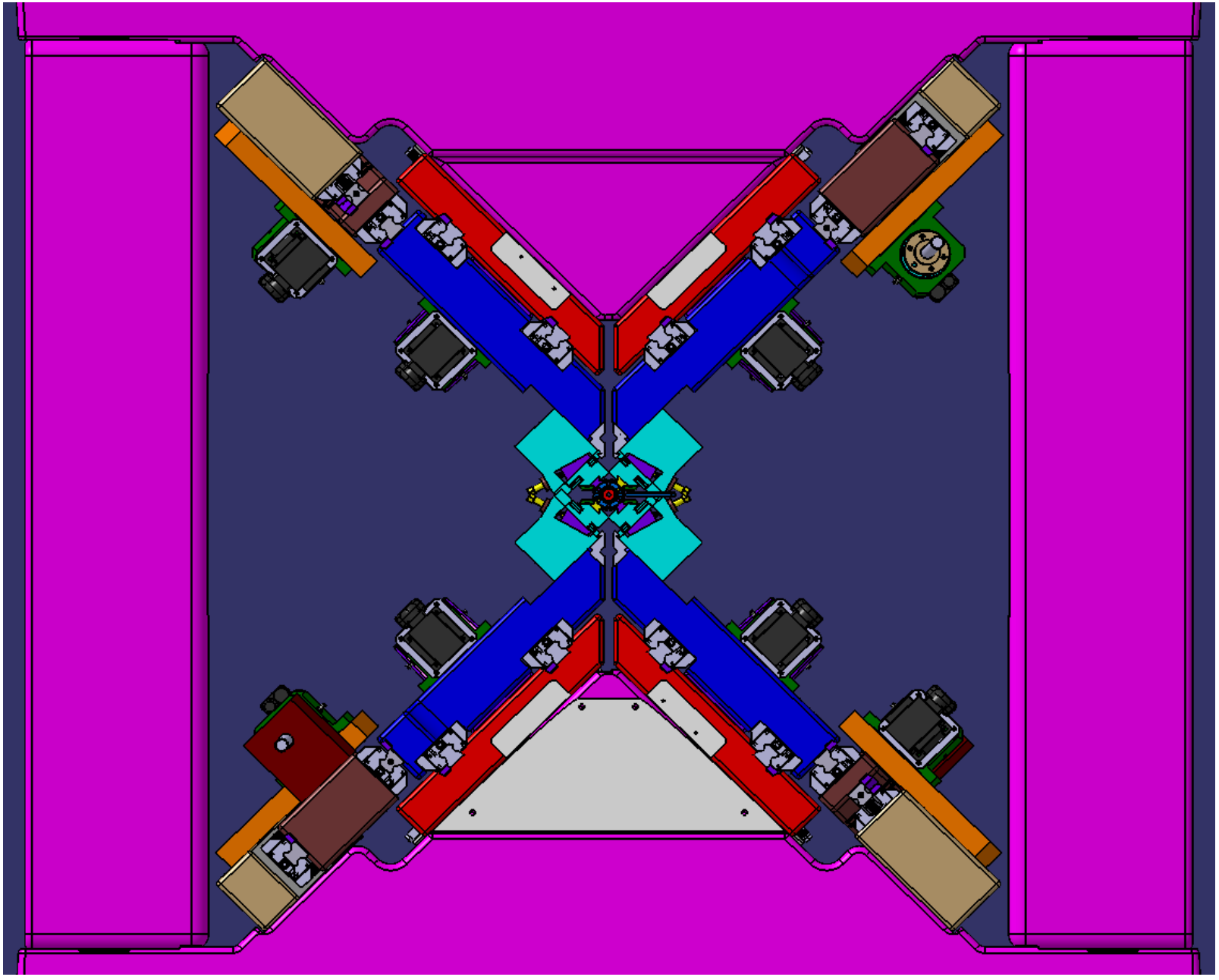
PAUL SCHERRER INSTITUT

APPLE - X design study



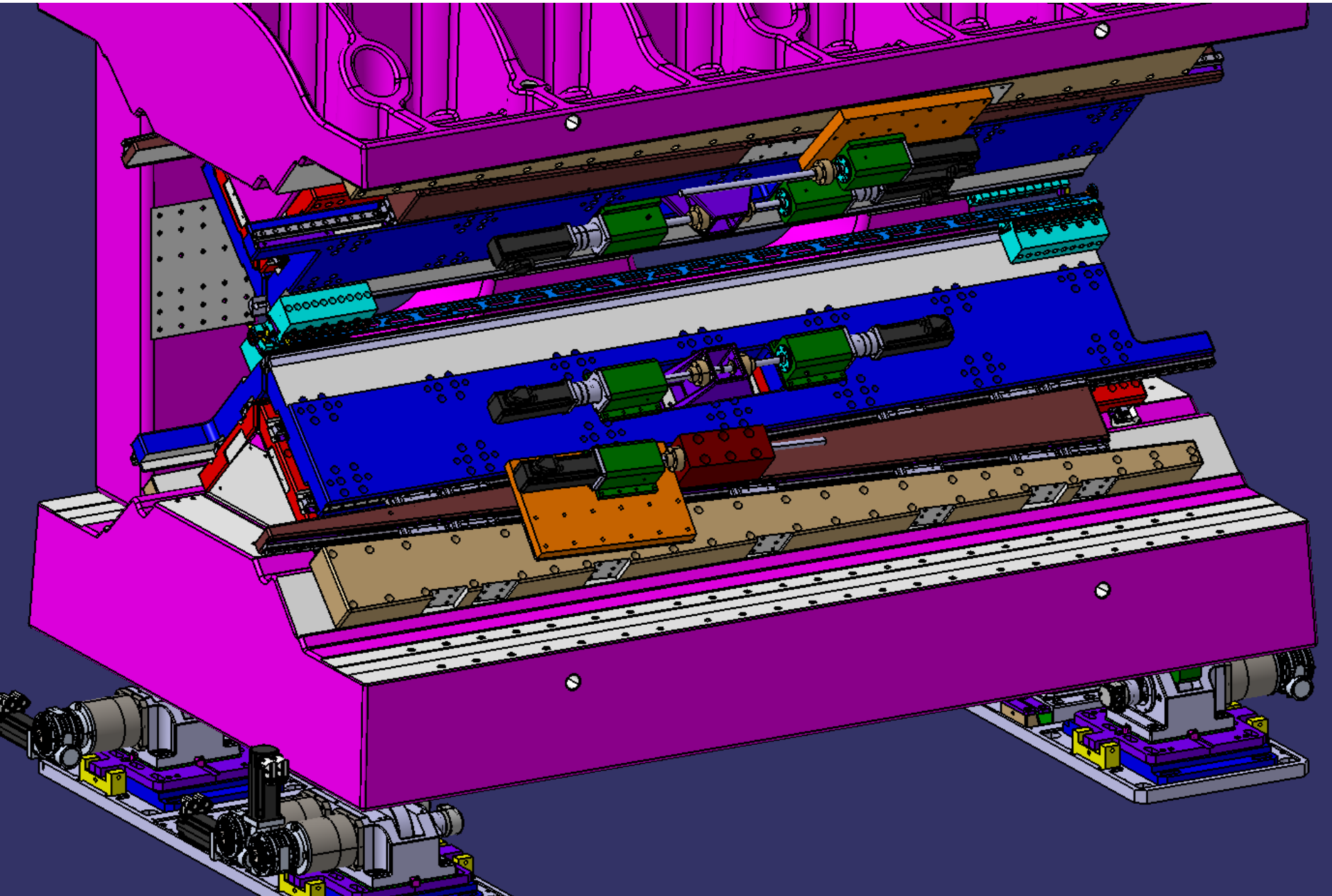
PAUL SCHERRER INSTITUT

APPLE - X design study



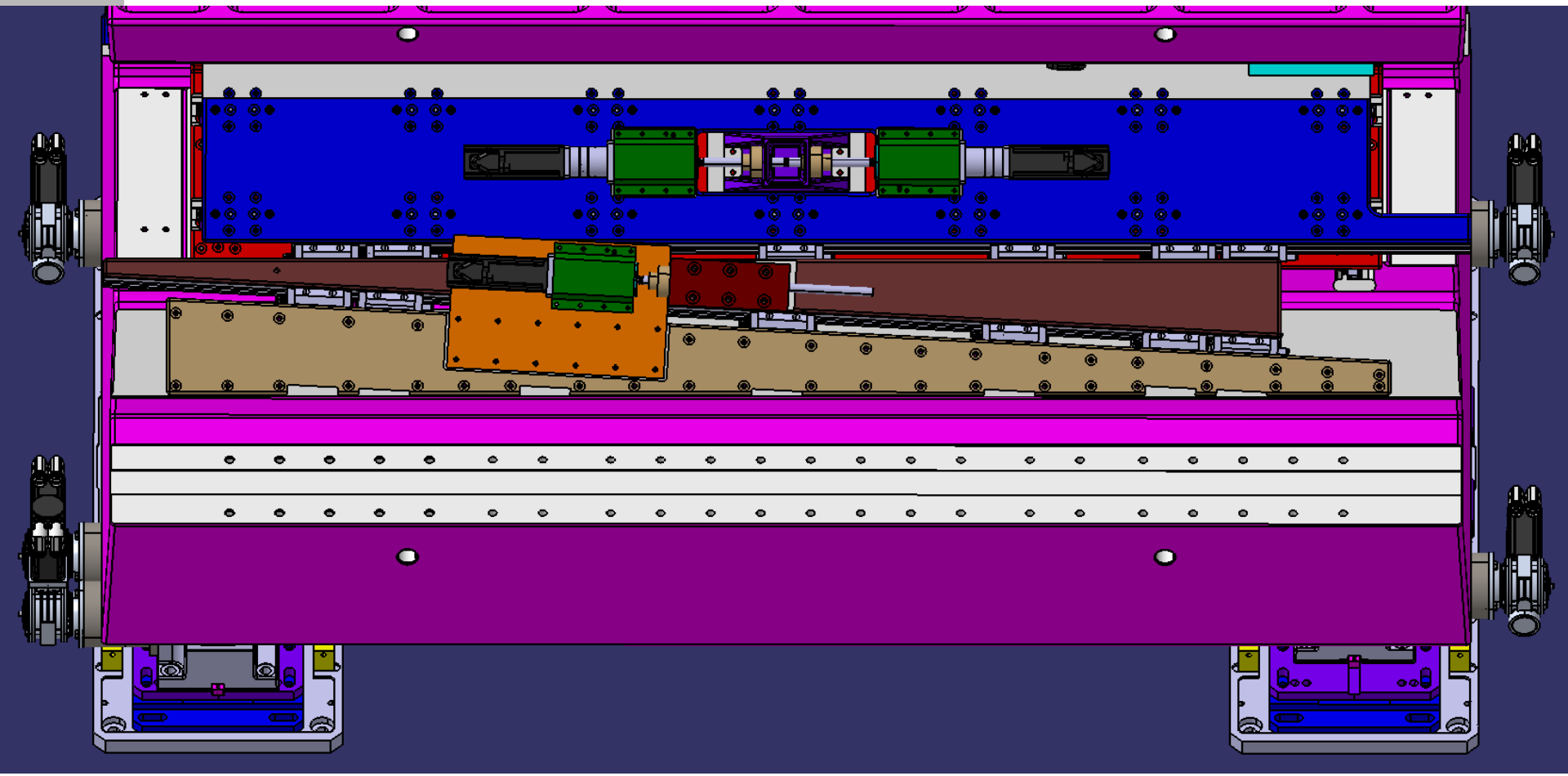
PAUL SCHERRER INSTITUT

APPLE - X design study



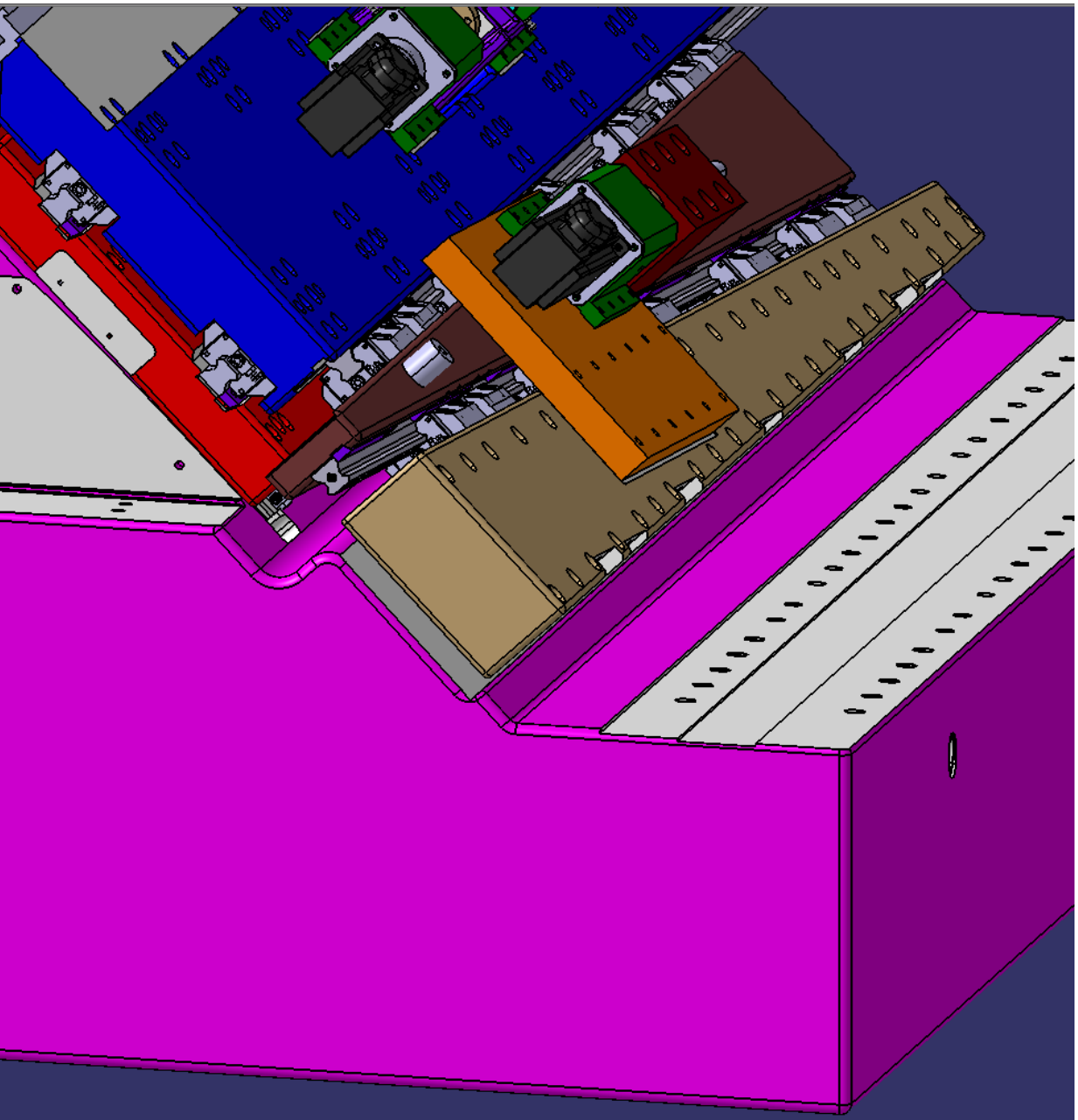
APPLE - X design study

shift drive with 2 servos and satellite roller screw (<= 0.5mm pitch)
position control and moment control to minimize backlash



wedge based radial drive for high accuracy (< Aramis U15)
servo - differential satellite roller screw - wedge: minimum backlash

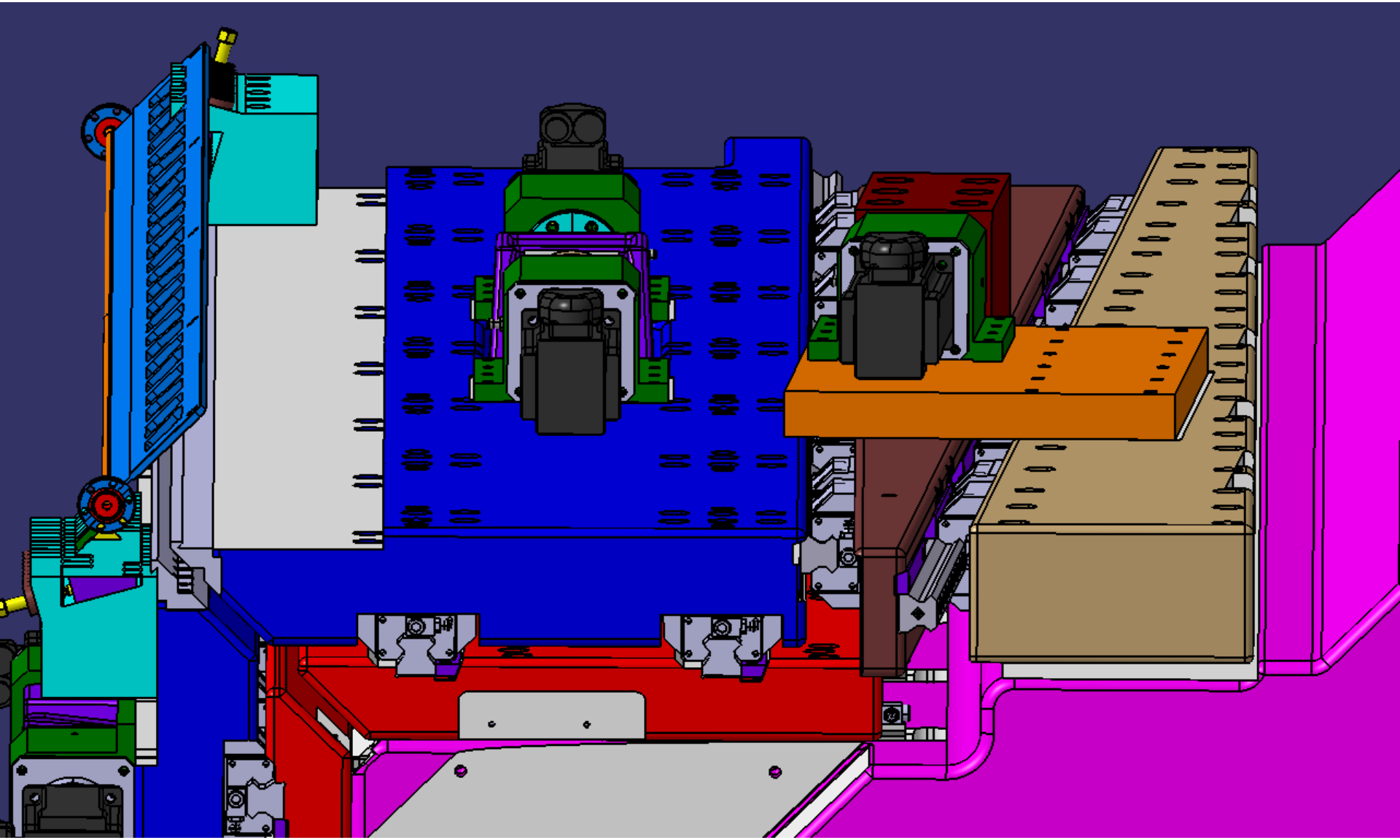
APPLE - X design study



support: cast iron

wedges and main plates:
stainless steel

APPLE - X design study



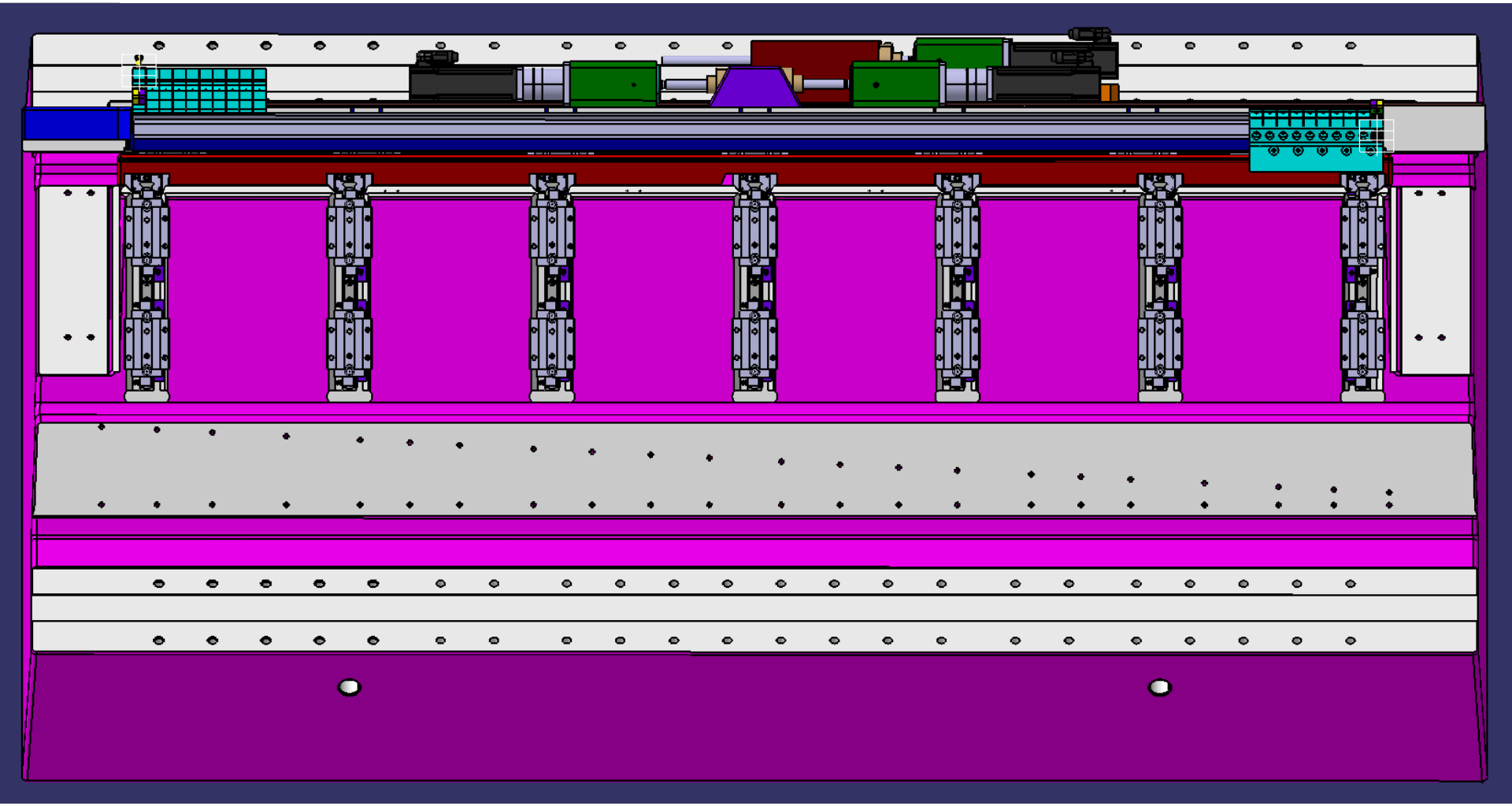
blue: shift plate, keeper interface machined after assembly

red: radial plate radial bearings to support

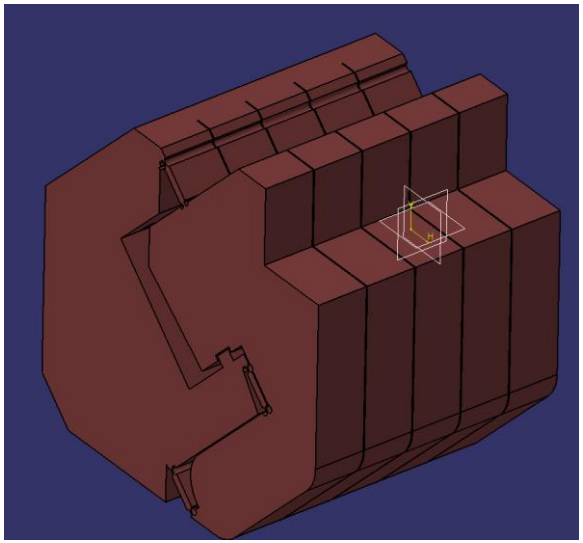
APPLE - X design study

7 radial shifts located on top of support structure ribs

FEM: 10 slightly better but higher friction

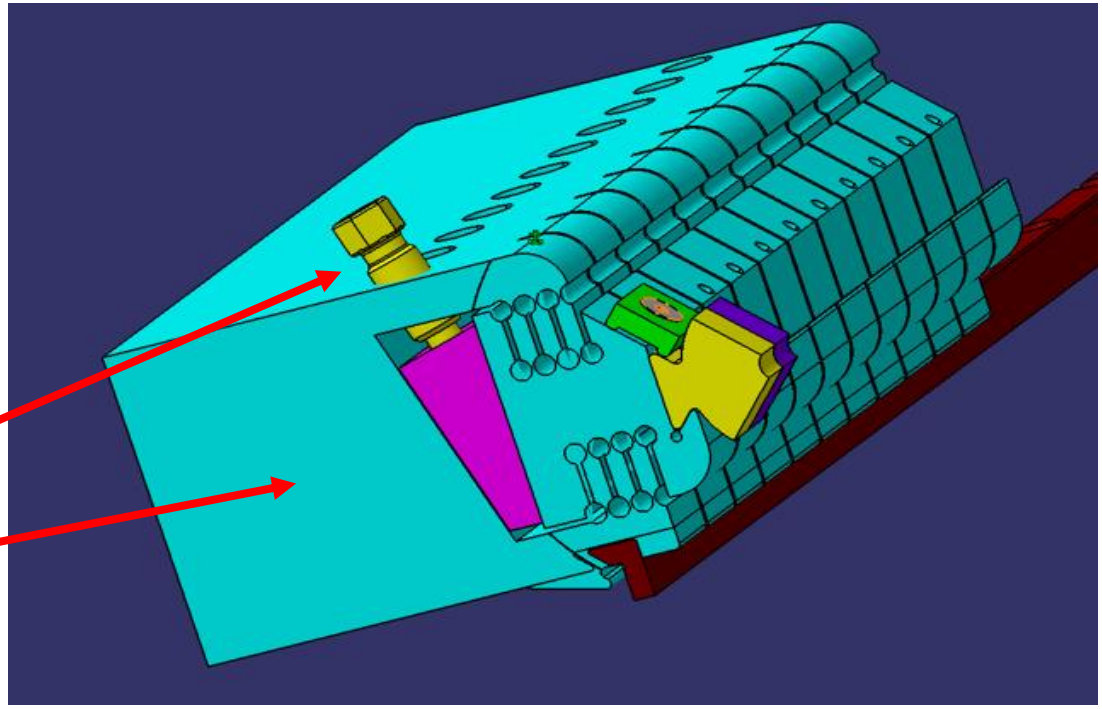


Keeper Optimization



Design favorite after workshop August 2015

simplified “better” design January 2016



differential screw for wedge

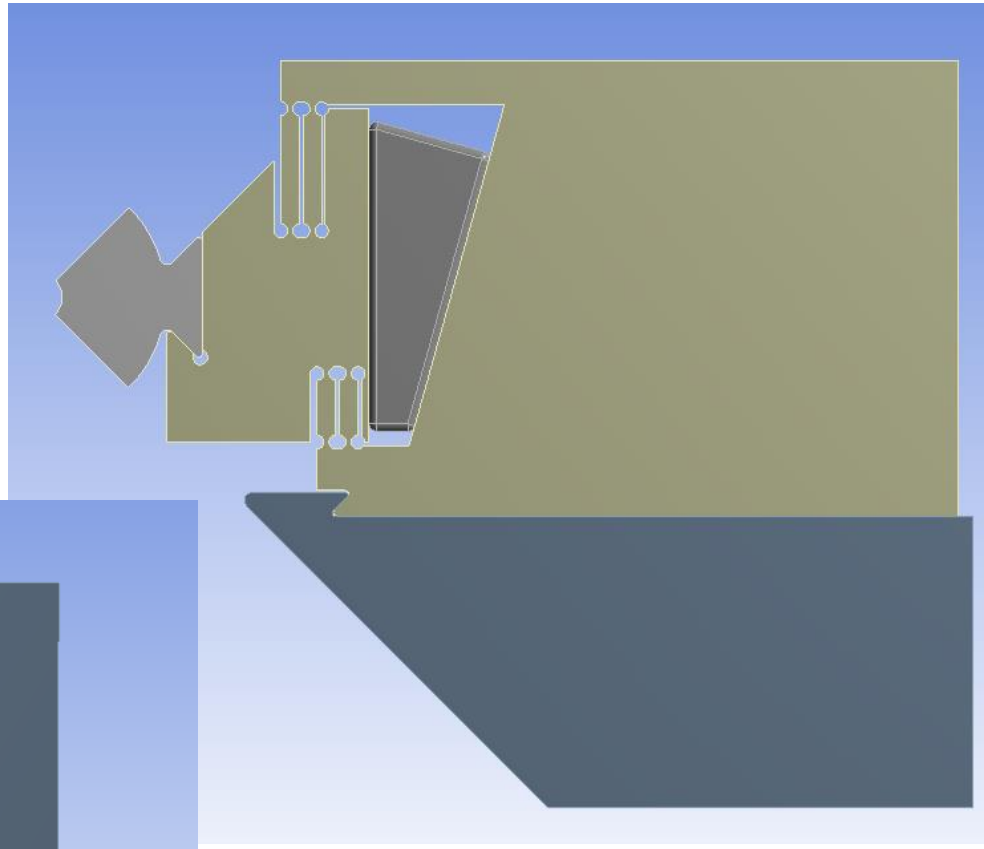
separated preload adjustment range:

+/- 60 µm

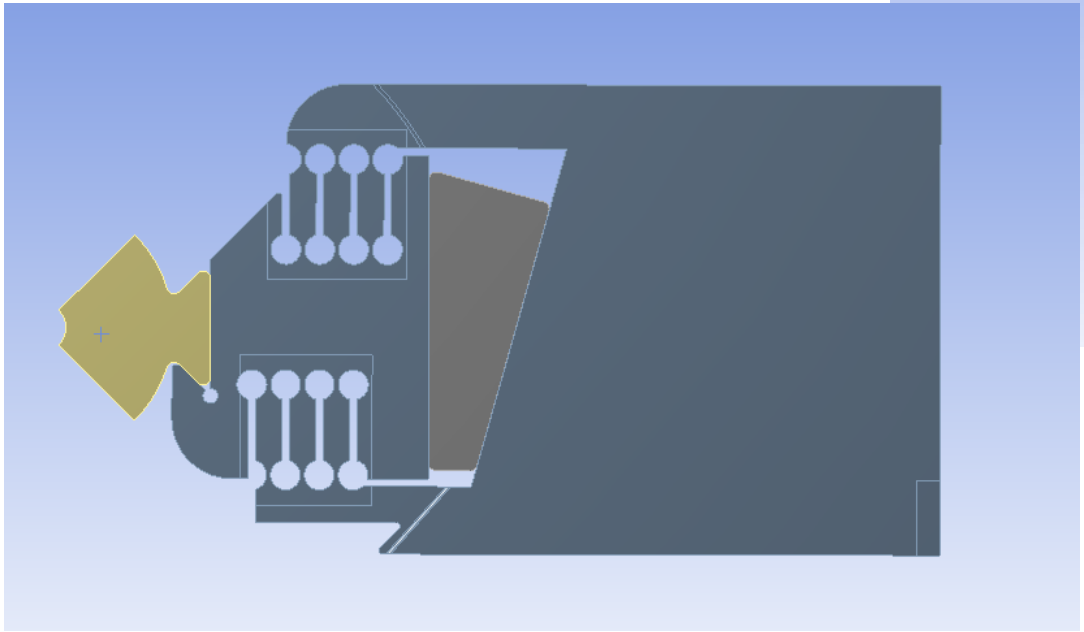
Keeper Optimization

Parametric software optimization

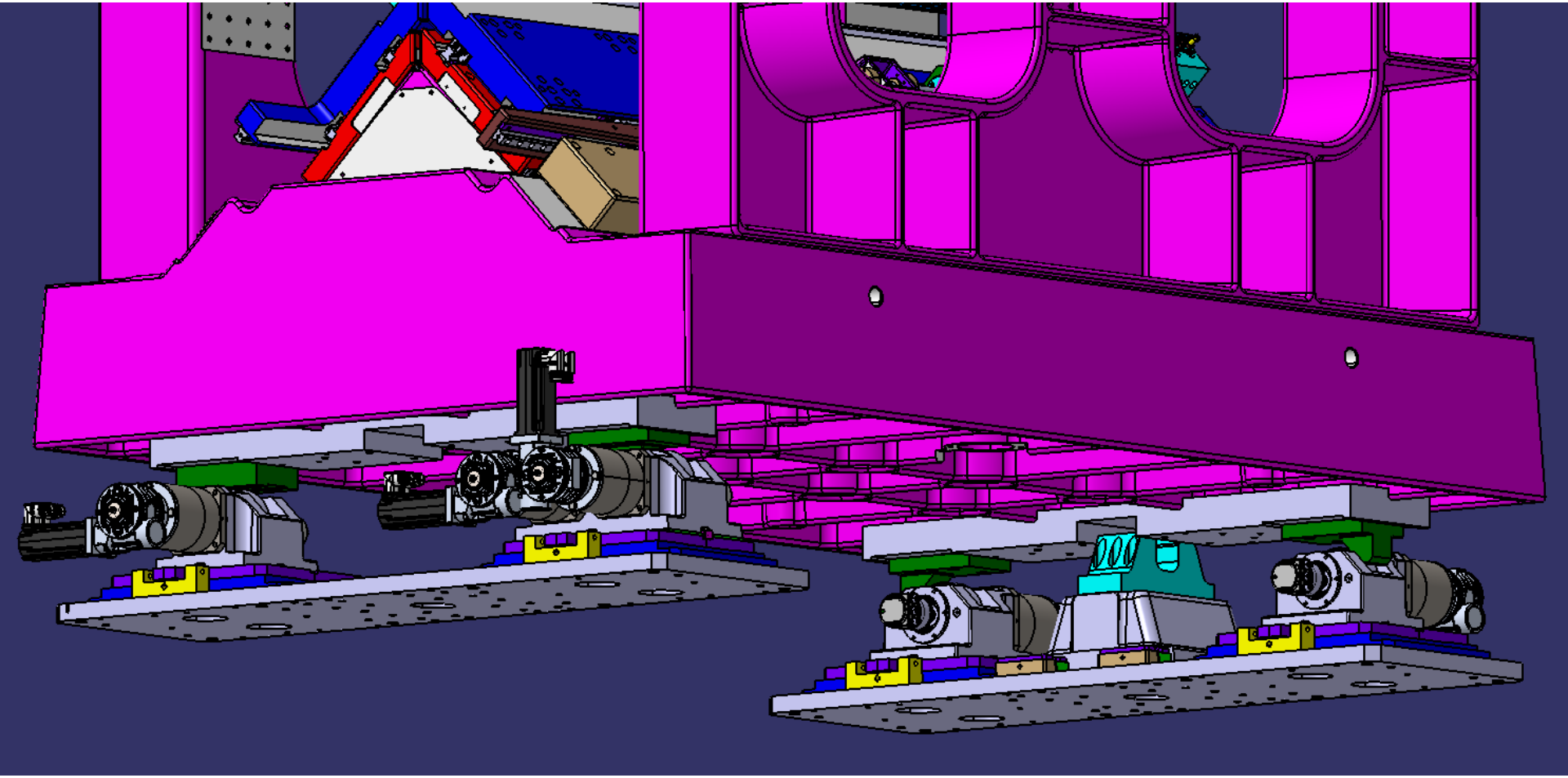
ANSYS / OptiSlang



Prototype already existing

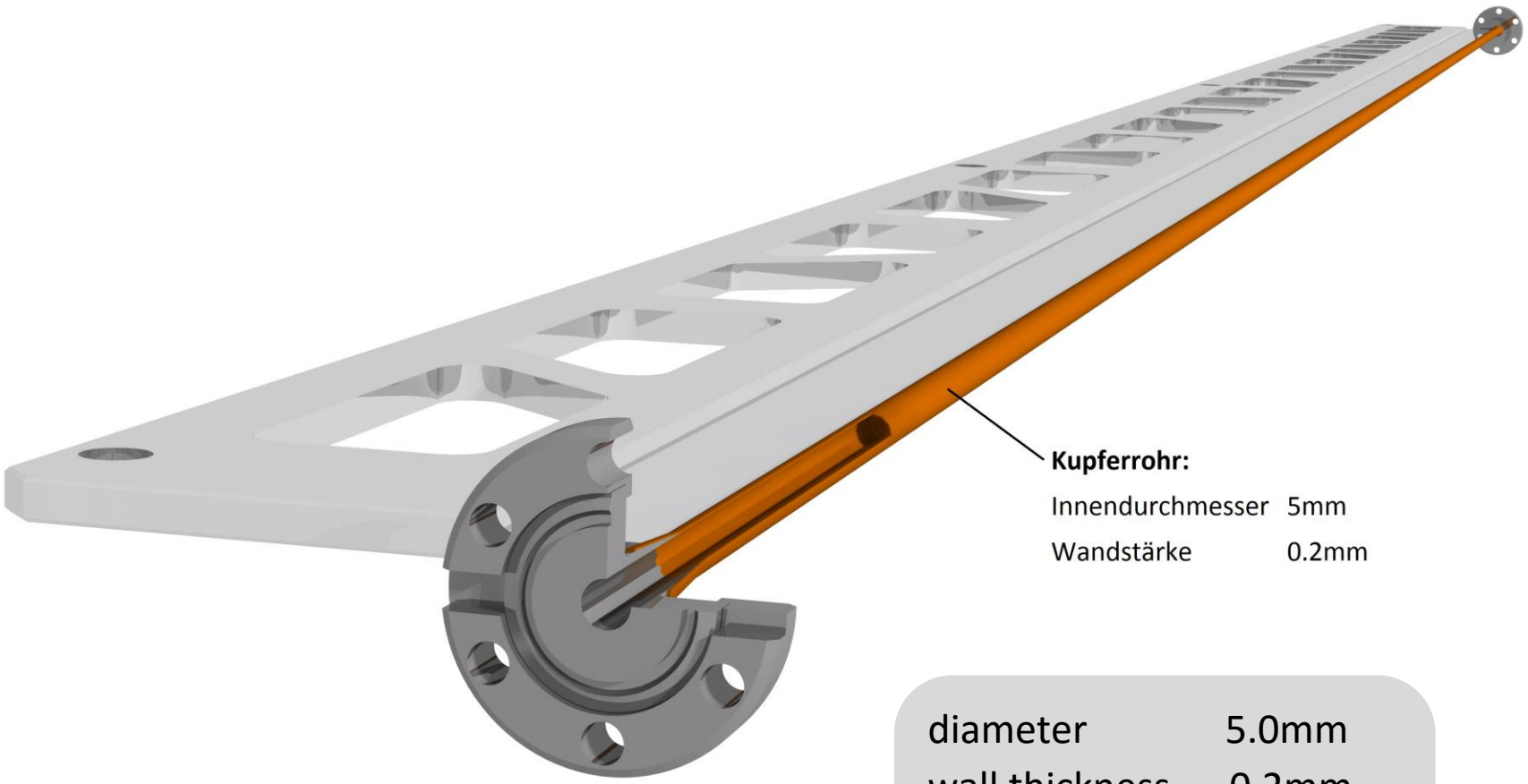


APPLE - X design study



5-axis cam-shaft mover 5-axis (SLAC, PSI: SLS, SwissFEL)
alignment in x and y, pitch, yaw and roll
longitudinal taper with gradients and pitch for CHIC modes

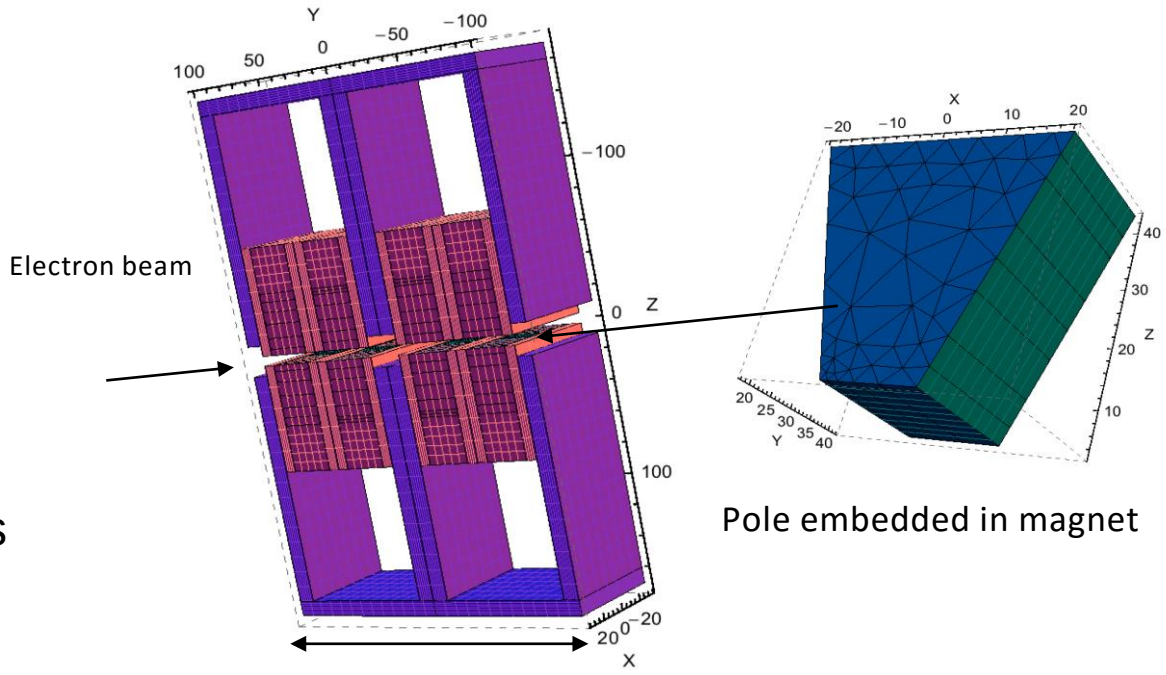
Vacuumchamber



Cu chamber
galvanic on silicon hose

diameter	5.0mm
wall thickness	0.2mm
magnet aperture	6.5mm
minimum gap	3.0mm

Chicane



Pole embedded in magnet

based on

EUXFEL design

higher hfield and 2 motors

to meet CHIC demand

Chicane length: 200 mm

Maximum delay: 5 fs (1.5 um)

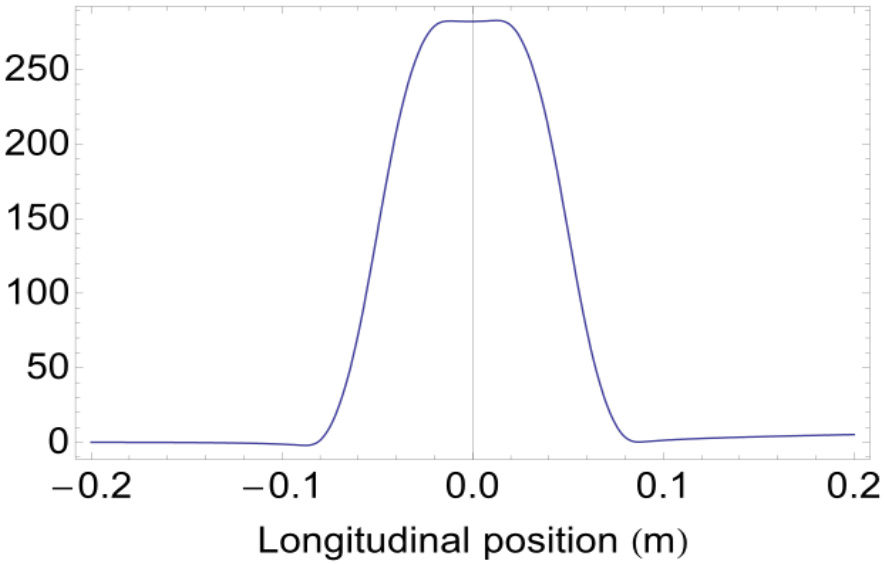
Maximum hor. shift: 280 μm

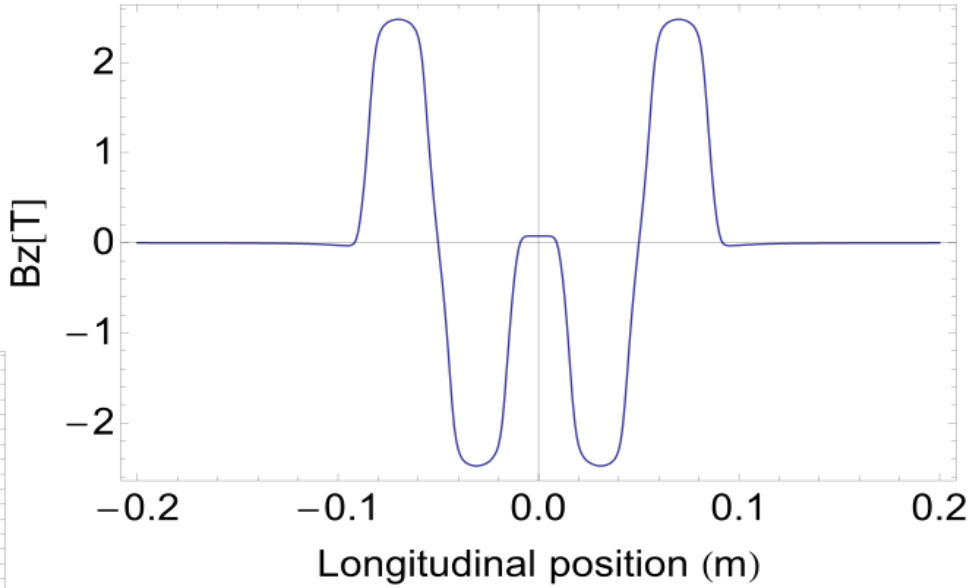
and you know Phase shifter for EUXFel

is Optical klystron for SwissFEL

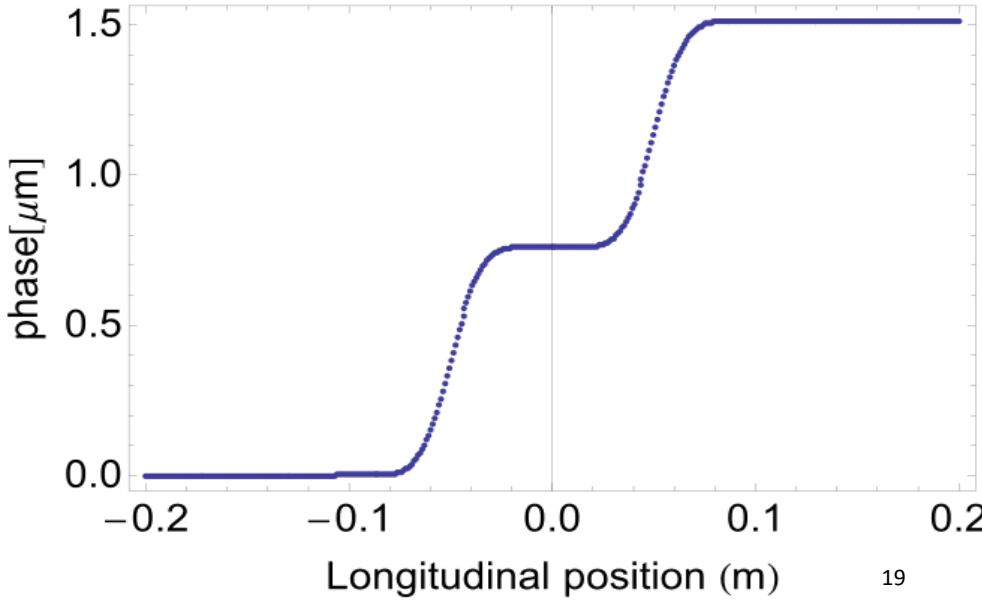
Chicane Design

Trajectory at 6.5 mm gap

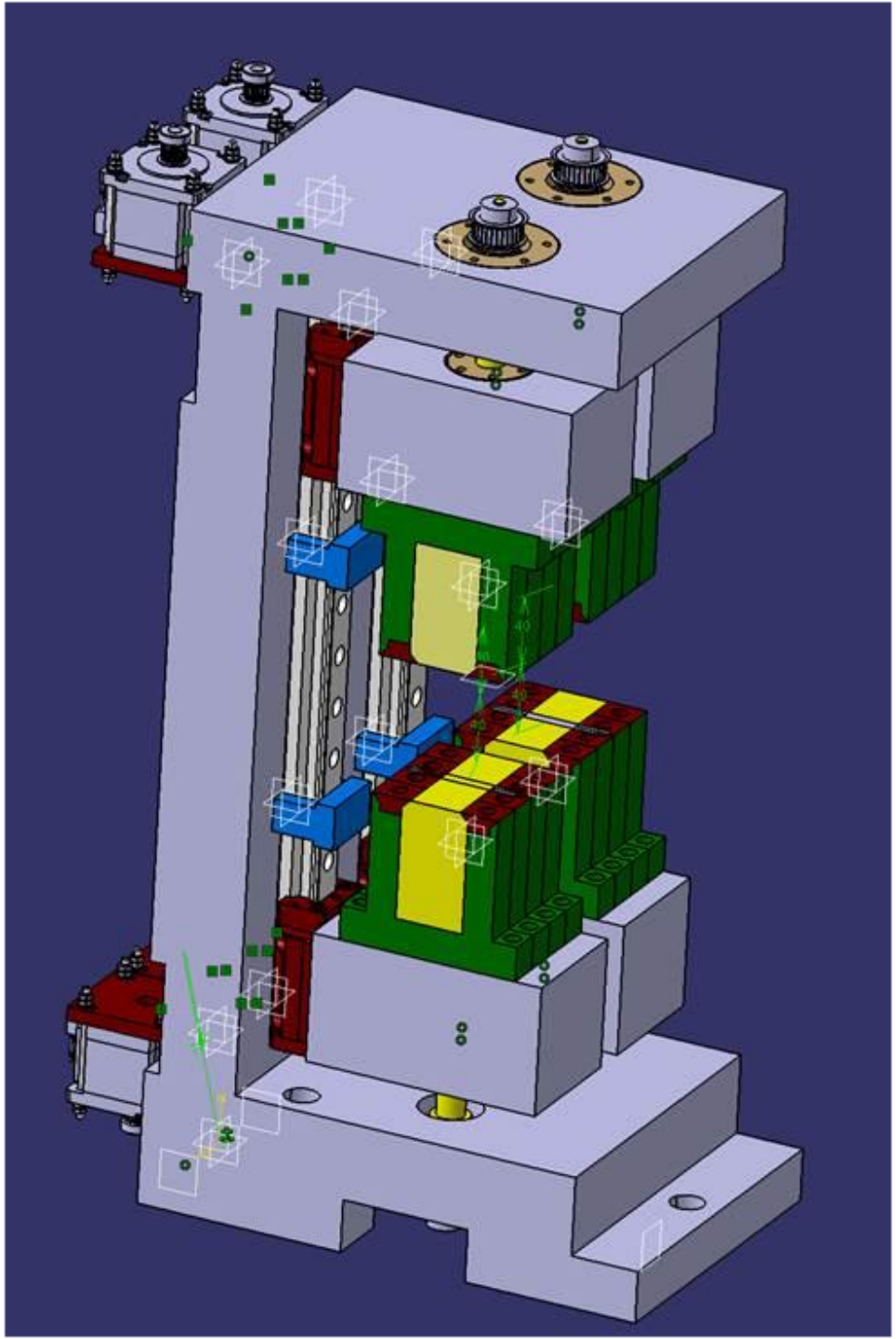




Phase Delay at 6.5 mm gap



PAUL SCHERRER INSTITUT



Concluding Remarks

APPLE X / DELTA II

is a strong design

dedicated to single pass machines

PSI undulator design to be used for EUXFEL

EUXFEL Chicane design used by PSI with 4 motors

LCLS DELTA II design more compact but limited access

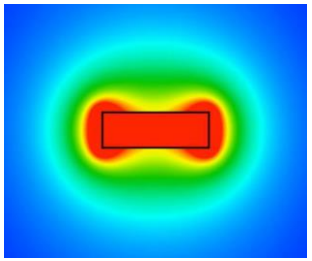
PSI APPLE X allows use of automated optimization

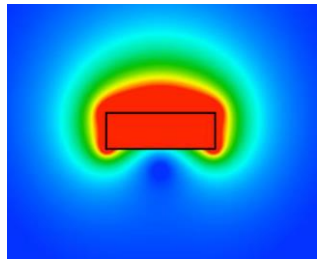
PAUL SCHERRER INSTITUT

PSI

thanks for listening

UE38 Magnet Design





- shaped field design
  with local manufacturer Arnold Magnetics
  supported by CTI

  inhomogenious magnetization to concentrate on axis flux

  + 5% field – 30% forces

  works for Sm2Co17
  to be extended for SmCo5

	remanence	permeability
SmCo5	0.95 T	1.01 / 1.04
Sm2Co17	1.1 T	1.06 / 1,15

field integral changes
due to shift
up to 4 x reduced

	SmCo5		SmCo17		
LH	0	0	0	0	Gcm
C+	-0,824	7,16	0,89	29	
C-	0,824	-7,16	-0,88	-29	
LV circ	4,68	18	74,3	20,4	
LV lin	0	0	0	0	
45°	0	0	0	0	

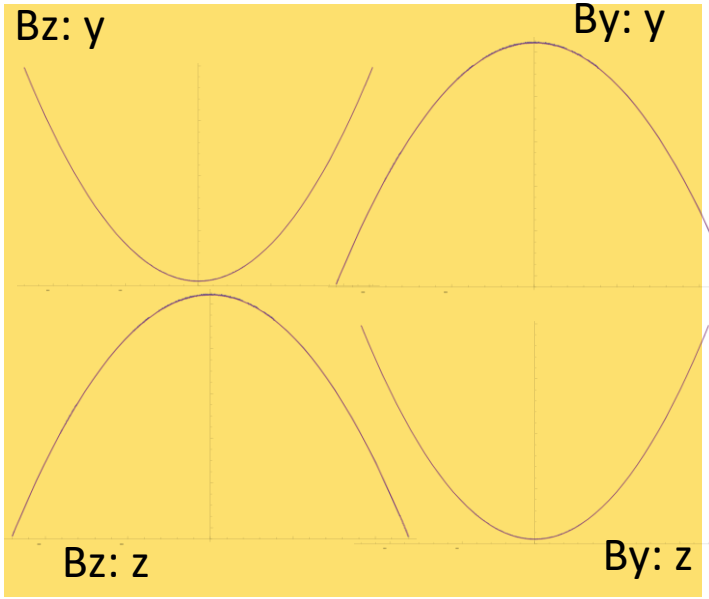
Tolerance Studies

good field region shaped field:

mode	y-dir	z-dir	
LH	+- 47	+- 52	
circ	+- 45	+- 60	$1*10^{-4}$
	+- 78	+- 78	$3*10^{-4}$
	+- 101	+- 135	$5*10^{-4}$

good field standard magnets:

circ	+- 47	+- 67	
	+- 80	+- 116	
	+- 104	+- 150	

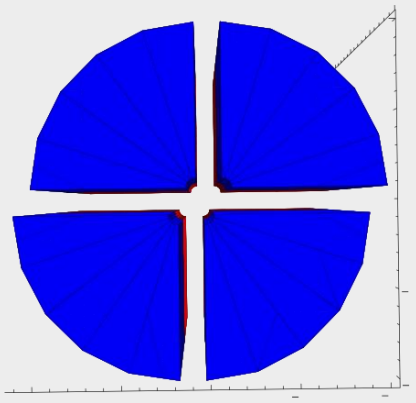


assembly error by 0.1mm upper vs lower half:

center moves by 0.05

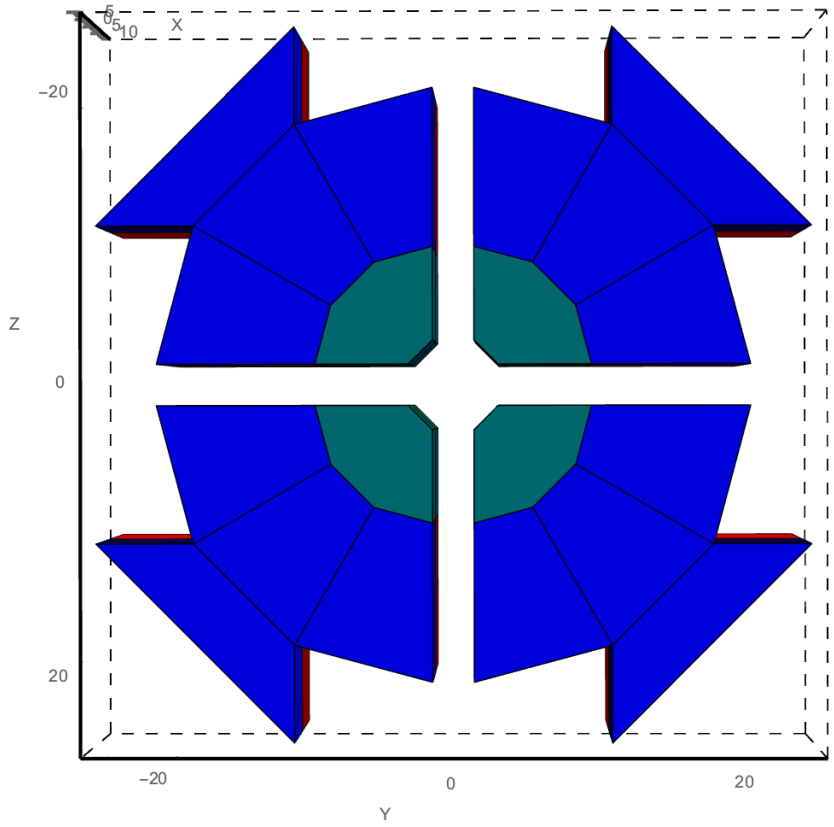
$\Delta Kz/Kz = 1.9\ 10^{-4}$

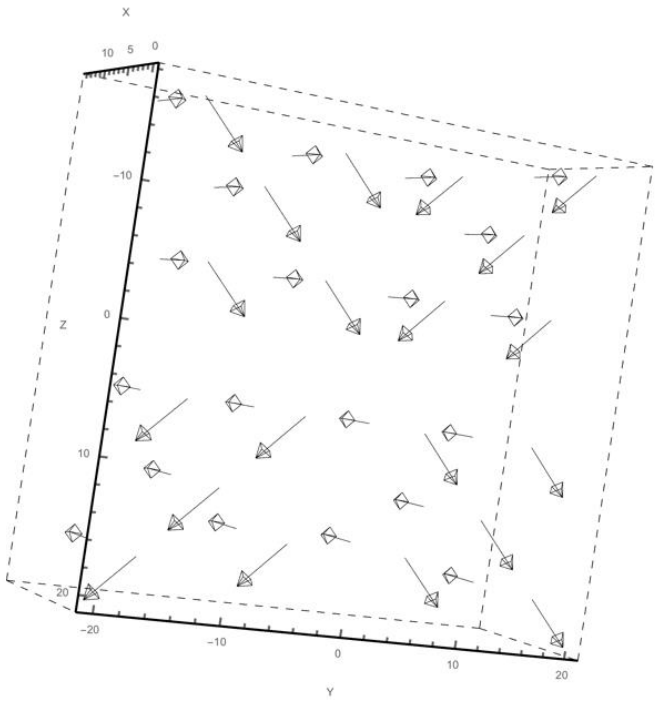
$\Delta Ky/Ky = 7\ 10^{-6}$



Radia Model

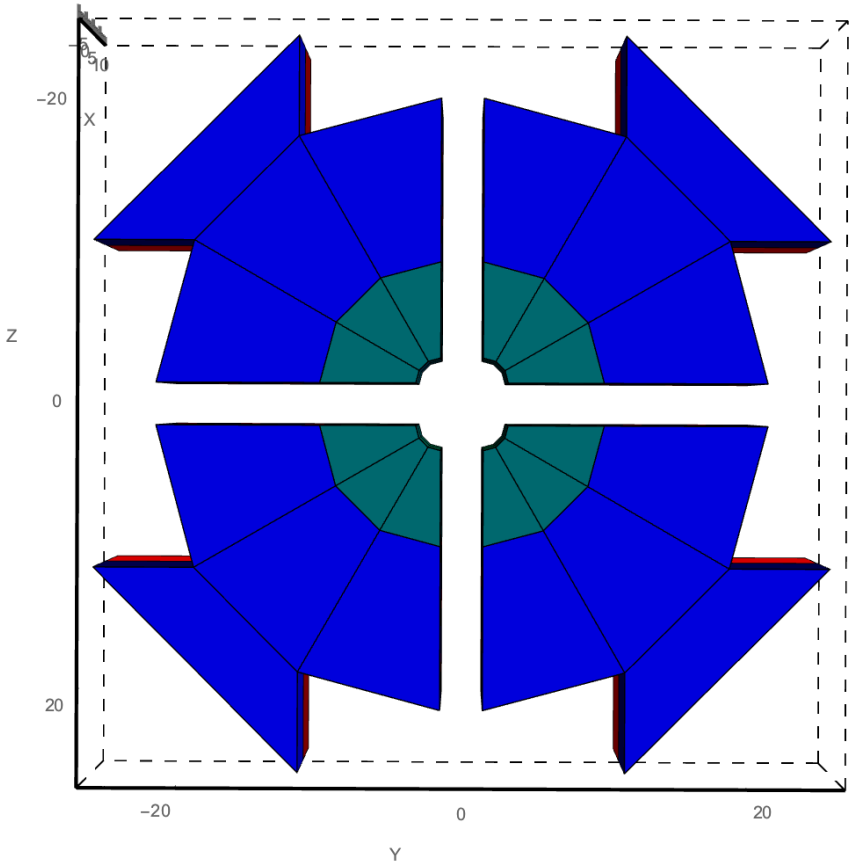
- n = 1

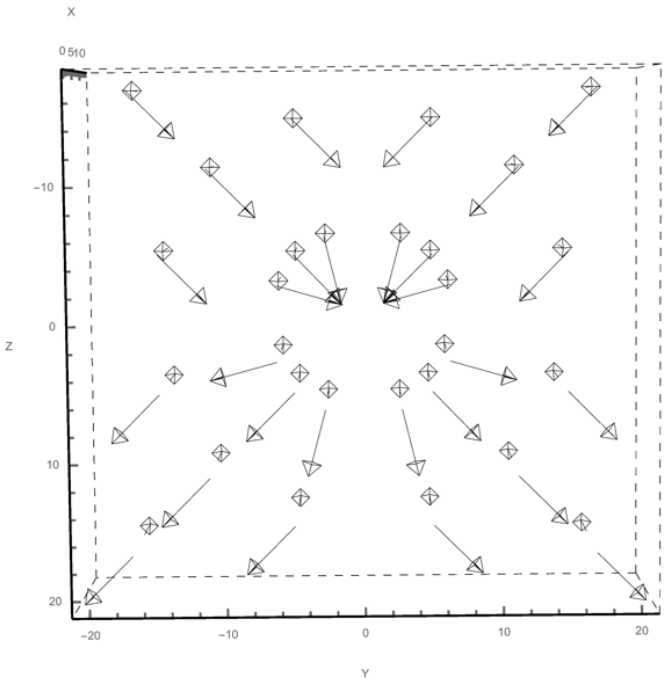




Radia Model

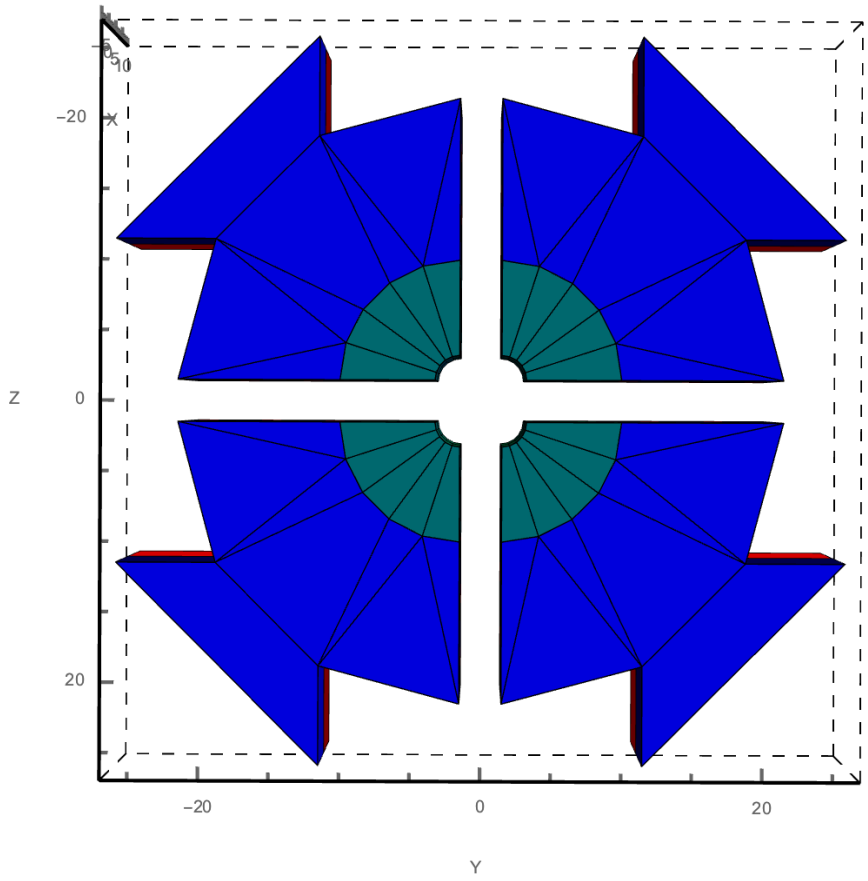
- n = 3

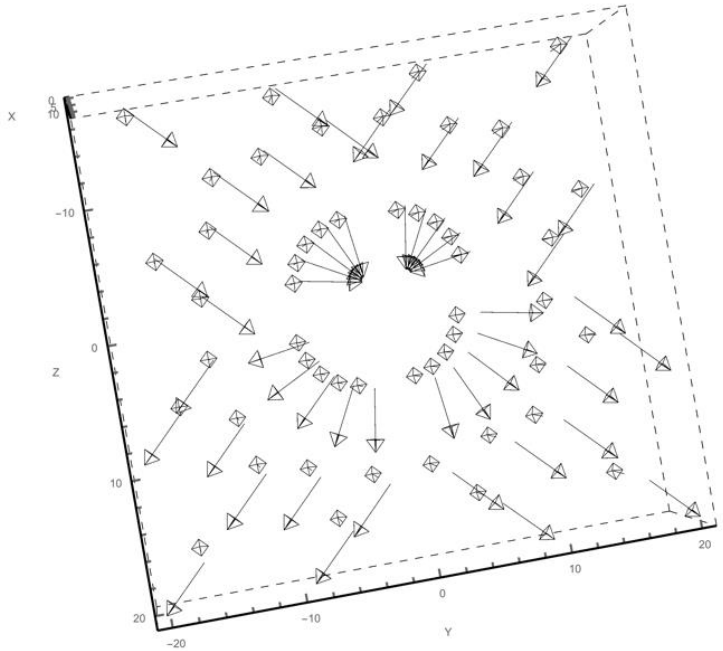




Radia Model

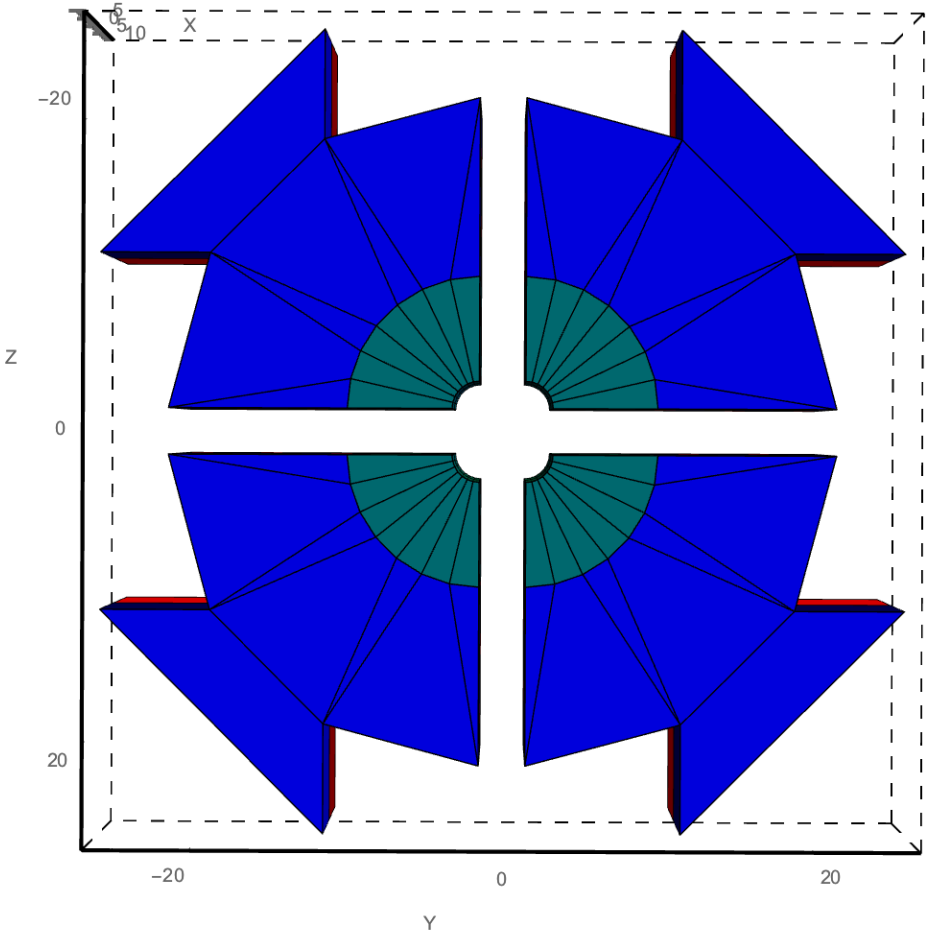
- n = 5

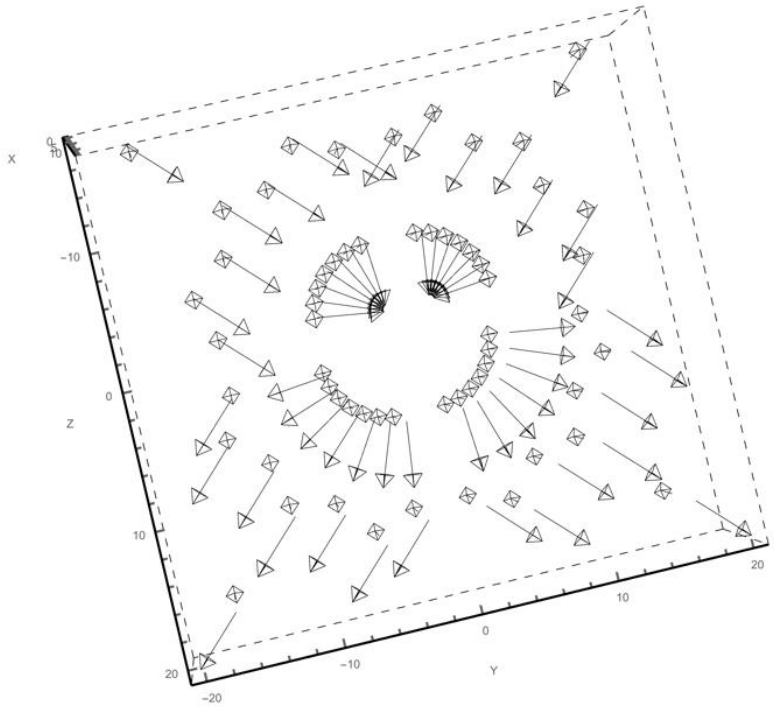




Radia Model

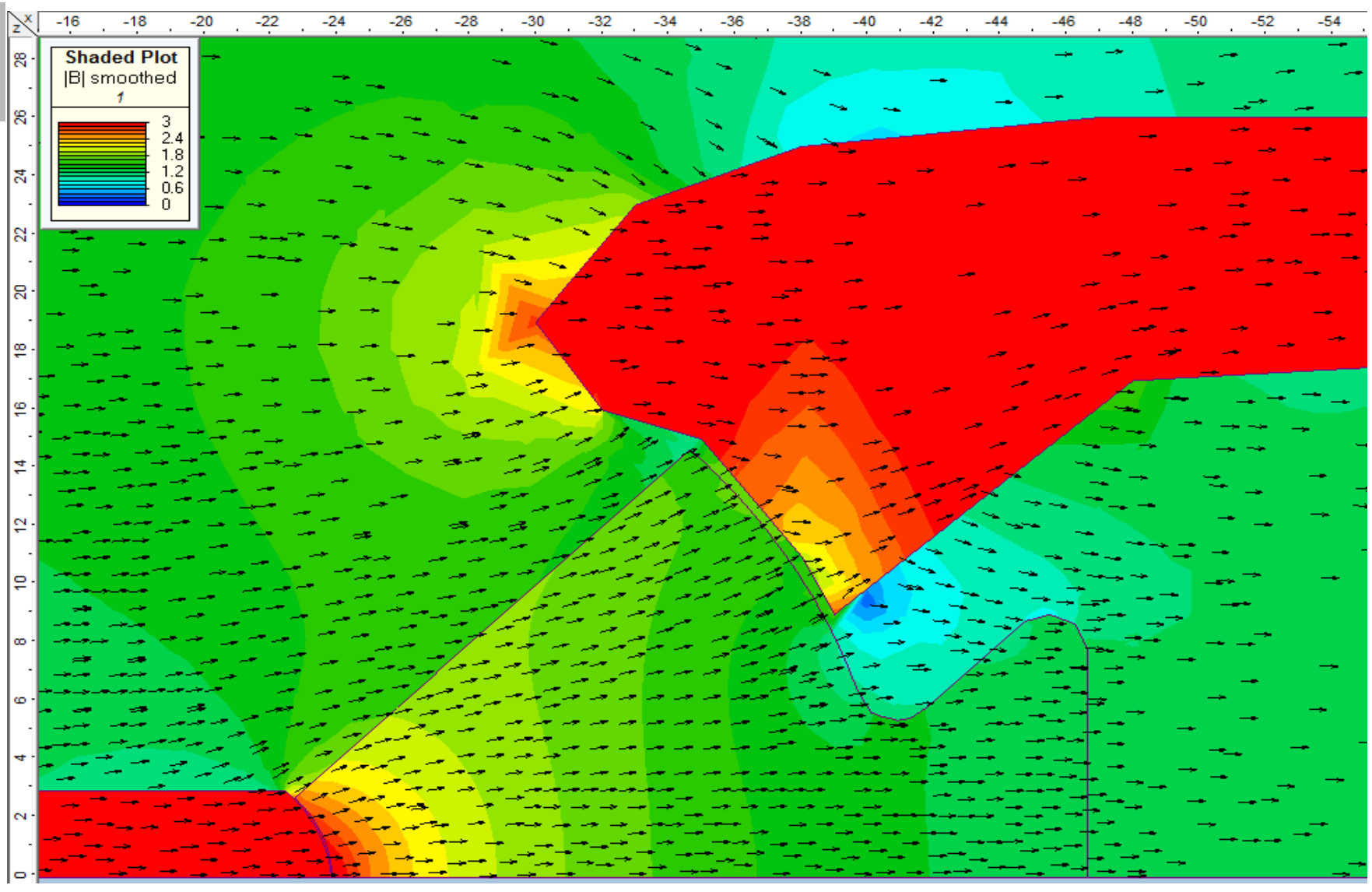
- n = 5

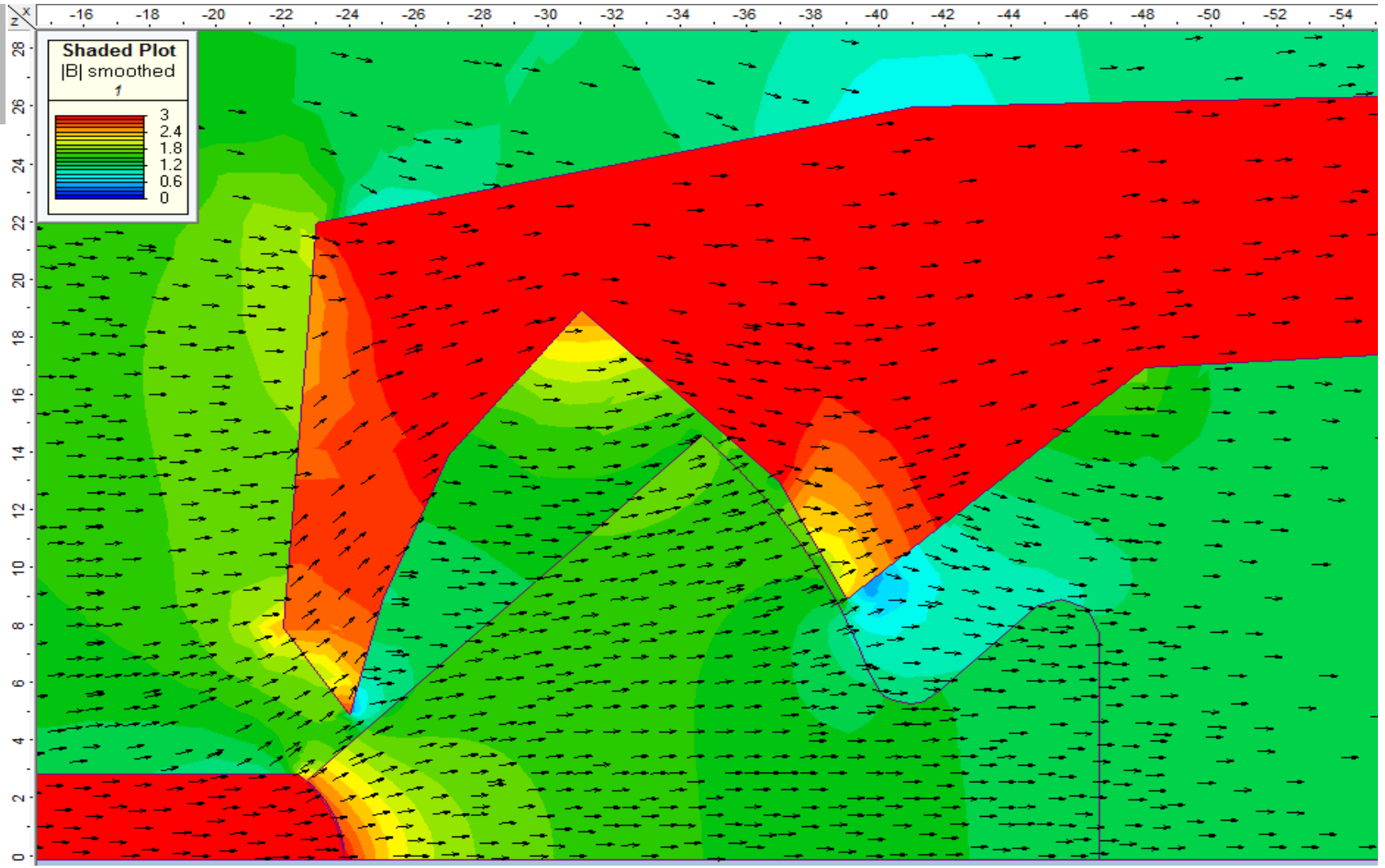




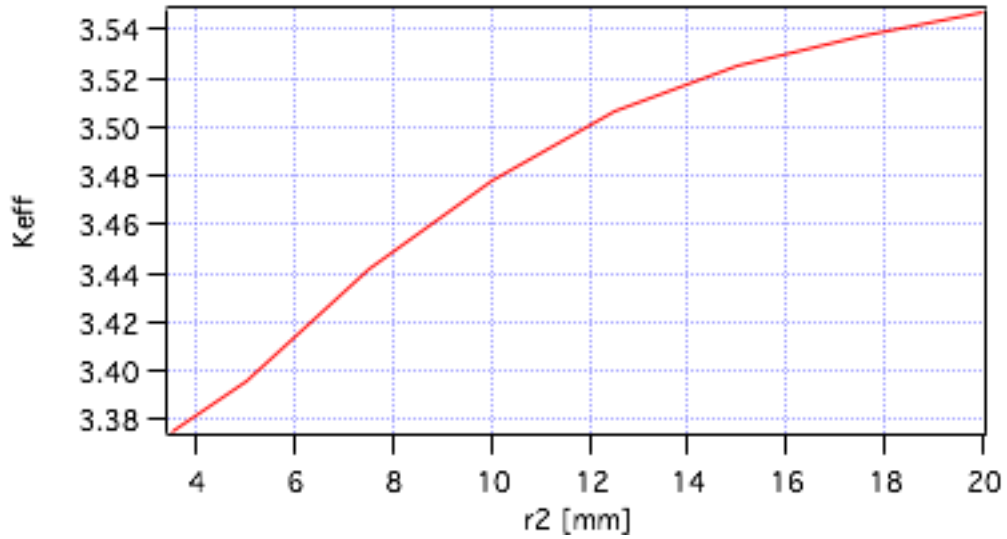
PAUL SCHERRER INSTITUT

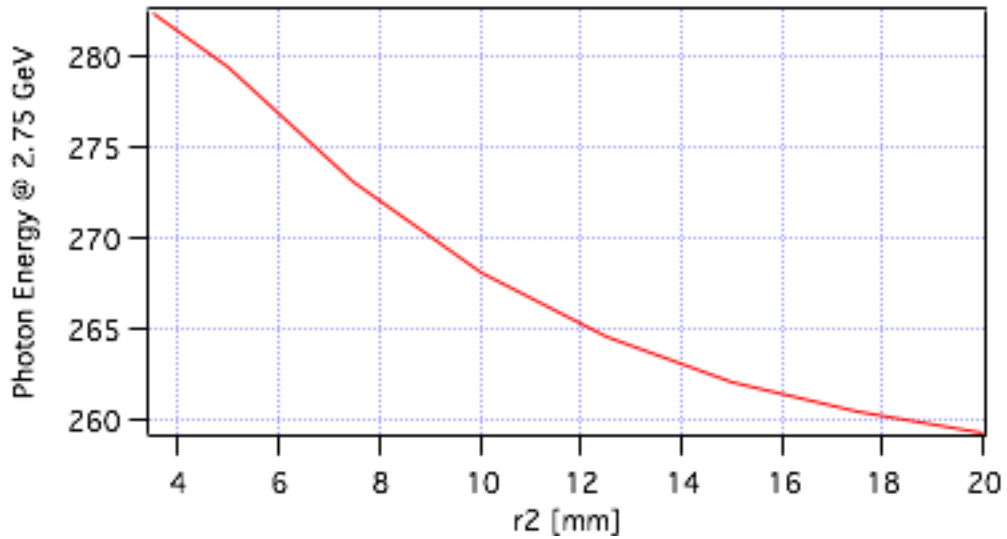
PSI




Shaded Plot
|B| smoothed
1
3
2.4
1.8
1.2
0.6
0
-16
-18
-20
-22
-24
-26
-28
-30
-32
-34
-36
-38
-40
-42
-44
-46
-48
-50
-52
-54
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0

shaped field: effectivity





UE38

SmCo5

r1 = 3.25

r3 = 21.5

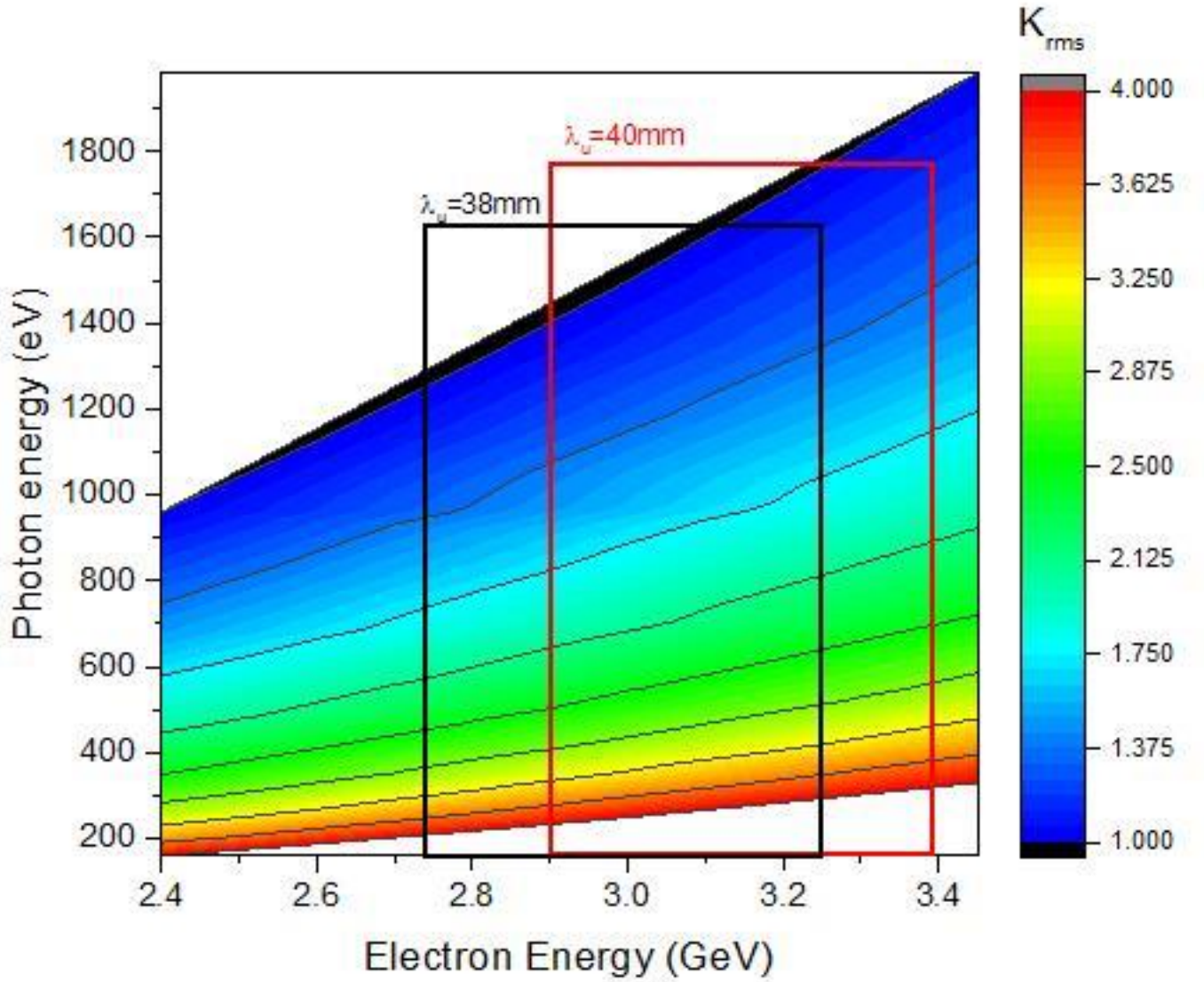
slit = 3

radial segments: 5

r2 is the radius up to which the angle change works

total increase:

Athos extraction energy



APPLE X

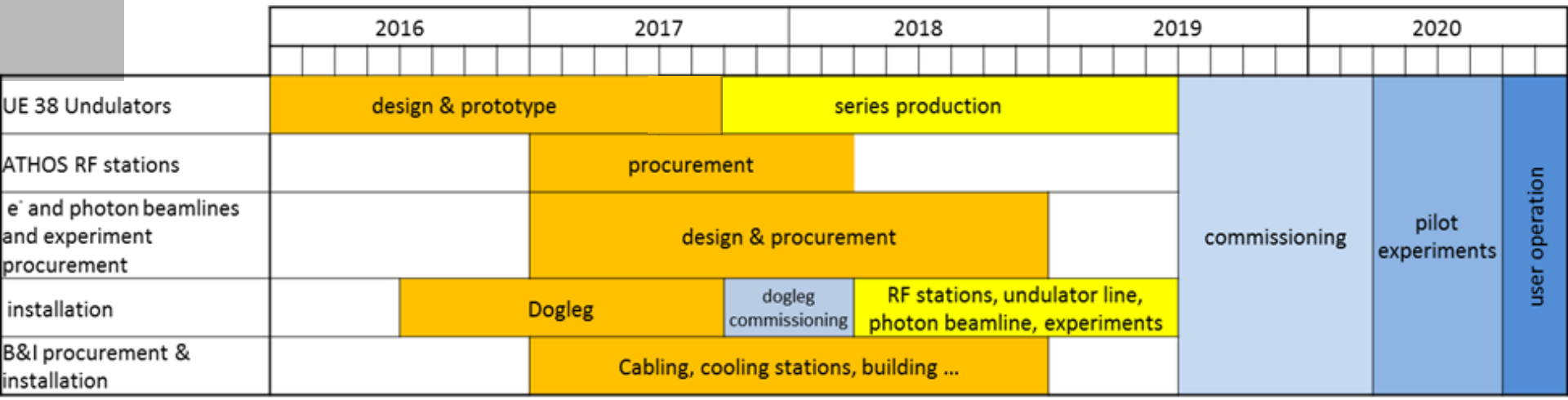
- full symmetric mode
-

- design for SwissFEL and EUXFEL
- use of EUXFEL phase shifter design

- but with 2 motors allows all flexibility needed for CHIC modes
- Chicanes for high power and improved coherence

- gradient field scheme (important for that is the mover concept
- (SLAC, PSI, ..)
- because of small vacuum chamber technology this can be brought also in hard x-ray wall thickness 160mu galvanic copper (surface roughness?) check in old FLAC meeting
- again: gradients to be handled - but not the baseline
- maximum tilt angles required reasonable length of bellows as vacuum chamber is supported by the undulatory

what's next Athos?



calculations done till mid of September:

Review (best with LCLS team, ...) LCLS: APPLE X with alternative concept

drawings: end of the year

prototype manufacturing: Jan – June 2016 (Daetwlyer)

parallel magnet fabrication (Arnold)

parallel construction of modified measurement bench

undulator field measurements summer 2017

ready for series production end Q3 2017