BPIX Cooling with CO2

Assuming 3 or 4 Layers

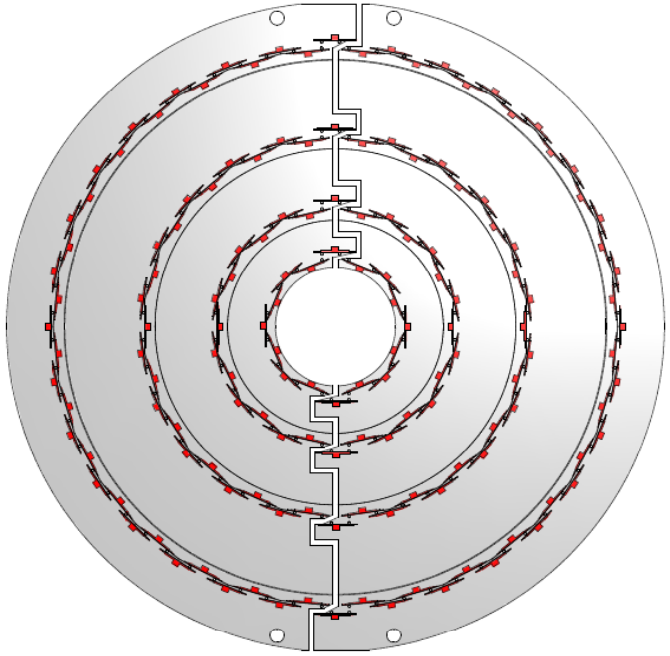
Design Goals for BPIX Upgrade

4 Layers instead of 3

Avoid “half” modules

Closer to beam pipe

(more see in Streuli’s talk)



Layer	# faces	mod/face	# pipes
L1	16 (16+4)	8 (8)	20 (18)
L2	28 (28+4)	8 (8)	32 (30)
L3	44 (40+4)	8 (8)	48 (42)
L4	64 (-------)	10 (-)	68 (--)

Layers placed at

R1 = 39 mm (now 44)

R2 = 68 mm (73)

R3 = 109 mm (104)

R4 = 160 mm (--)

Power Dissipation

Assumptions: full SLHC luminosity $10^{35}\ cm^{-2}\ s^{-1}$

max. irradiation of ALL layers

(Numbers based on H.C. Kaestli's calculations)

Power dissipation: (only for detector layers, supply tube NOT included)

Layer	ROC-current [mA]	ROC-Power [μW/pix]	Sensor-Power [μW/pix]	Layer-Power [W]	Power/pipe [W]
L1	274	174	45	1880	94
L2	127	86	45	1973	62
L3	77	56	45	2404	50
L4	55	43	45	3807	56

CO2-Cooling (layers only!)

Assumptions:

CO2 @ T = - 20 ºC, P = 20 bar

pipe inner diameter d = 1.5 mm

allow evaporation of 20% (40%)

→ $\Delta H = 56$ Ws/g (112)

Required:

dP/P small for stable operation

CO2 parameters:

	liquid	gas	
Density:	1.032	0.052	g cm^{-3}
Viscosity:	1.38E-3	1.33E-4	poise
Enthalpy:	458	740	J/g

($\Delta H = 282$ J/g)

Pressure Drop

$$\Delta P = \zeta \frac{l}{d} \frac{\rho w^2}{2}$$

$$\mathrm{Re} = \frac{w \rho d}{\eta}$$

$$\zeta = \frac{64}{\mathrm{Re}} \qquad \text{laminar (Re<2320)}$$

$$\zeta = \frac{0.3164}{\mathrm{Re}^{0.25}} \qquad \text{turbulent (Re<1E5)}$$

$$\zeta = 0.00540 + \frac{0.3964}{\mathrm{Re}} \qquad \text{turbulent (Re<2E6)}$$

P pressure

l pipe length

d pipe diameter

ρ density

w velocity

Re Reynolds number

Some Results (@max. load)

Two examples: liquid → gas at 20% (40%)

Scenario 1: all pipes parallel loaded, supply/return at different z (like now)

Layer	mass flow [g/s]	velocity [cm/s]	ΔP [bar]
L1	1.67 (0.83)	101 (56)	0.053 (0.017)
L2	1.10 (0.55)	67 (37)	0.025 (0.008)
L3	0.89 (0.44)	54 (30)	0.017 (0.006)
L4	0.99 (0.50)	60 (34)	0.026 (0.009)

Scenario 2: 4 pipes serial, supply/return at same z (like FPIX now)

L1	6.67 (3.33)	404 (226)	2.46 (0.80)
L2	4.40 (2.20)	266 (149)	1.20 (0.39)
L3	3.55 (1.77)	215 (120)	0.82 (0.26)
L4	3.97 (2.0)	241 (134)	1.23 (0.40)

Supply pipes: d=10mm → both scenarios: 2 loops/layer sufficient → 2 spare loops

Conclusion

2-phase CO2 cooling with detector pipes as small as 1.5mm diameter should work for BPIX even at max. luminosity 10^{35} cm^{-2} s^{-1}

4 detector pipes in serial seems to be upper limit of serialization

2 serial pipes look save

Supply pipes from balcony to PP0: existing pipes should be ok (20 bar ?)

CO2 properties: p-H diagram