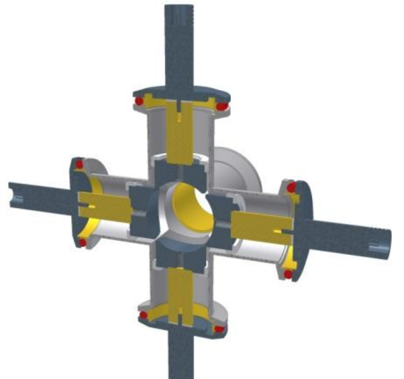
FETS Meeting @ RHUL

BPM Design

By Juergen Pozimski & Peter Savage

14th November 2012



Diameter 24mm button BPM

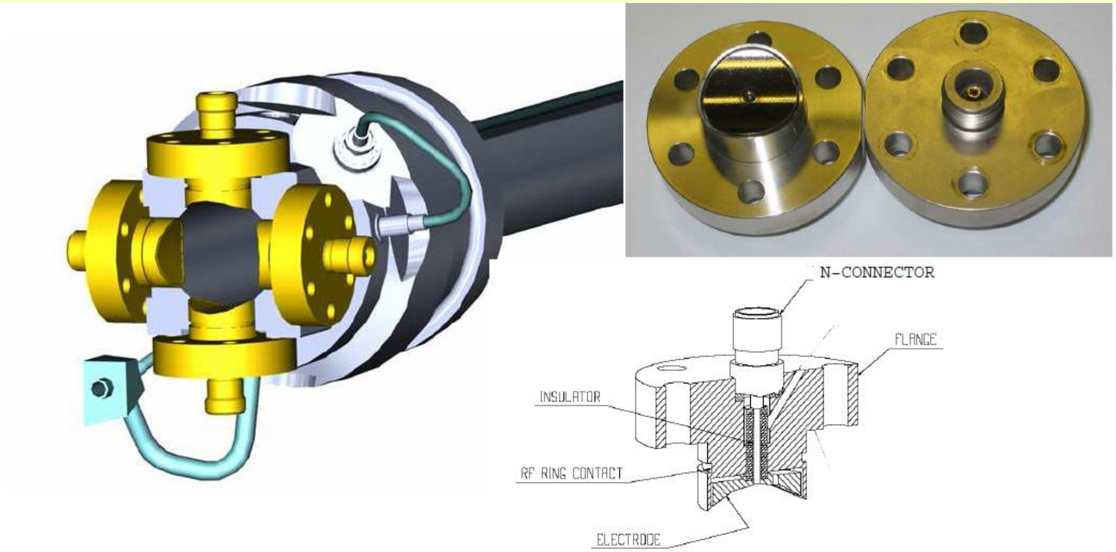


Fig. 18: Left: The installation of the curved Ø 24 mm button BPMs at the LHC beam pipe of Ø 50 mm, from [18]. Right: Photo of a BPM used at LHC, the air side is equipped with a N-connector as well as a technical drawing for this type.

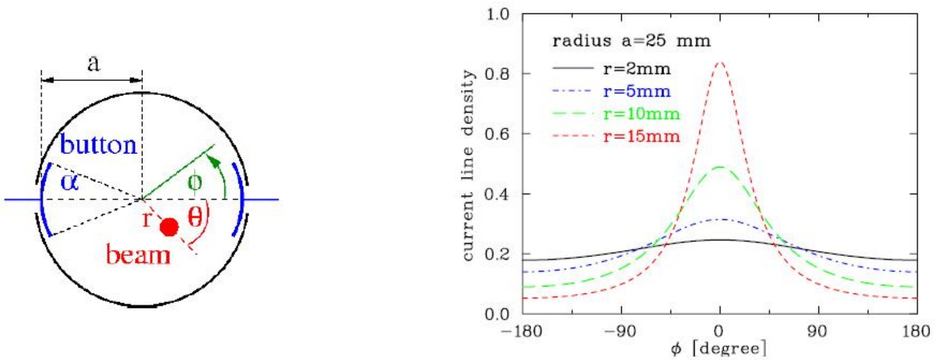


Fig. 19: Schematics for a button BPM and the image current density generated by a 'pencil' beam at different displacements r for an azimuth $\theta = 0$.

Peter Forck

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Simplified comparison

Table 1: Simplified comparison between linear-cut and button BPM

	Linear-cut BPM	**Button BPM**
Precaution	bunches longer than BPM	bunches comparable to BPM
BPM length (typical)	10 to 20 cm per plane	Ø 0.5 to 5 cm
Shape	rectangular or cutted cylinder	orthogonal or planar orientation
Mechanical realization	complex	simple
Coupling	1 MΩ or $\sim$ 1 kΩ via transformer	50 Ω
Capacitance (typical)	30 - 100 pF	3 - 10 pF
Cut-off frequency (typical)	1 kHz for $R = 1\text{M}\Omega$ or 1 MHz for $R = 1\text{k}\Omega$	0.3 to 3 GHz for $R = 50\Omega$
Usable bandwidth (typical)	0.1 to 100 MHz	0.1 to 5 GHz
Linearity	very linear, no x-y coupling	non-linear, x-y coupling
Position sensitivity	good required: min. plate cross talk	good required: 50 Ω signal matching
Usage	at proton synchrotron, $f_{acc} < 10$ MHz	proton Linac, all electron acc. $f_{acc} > 100$ MHz

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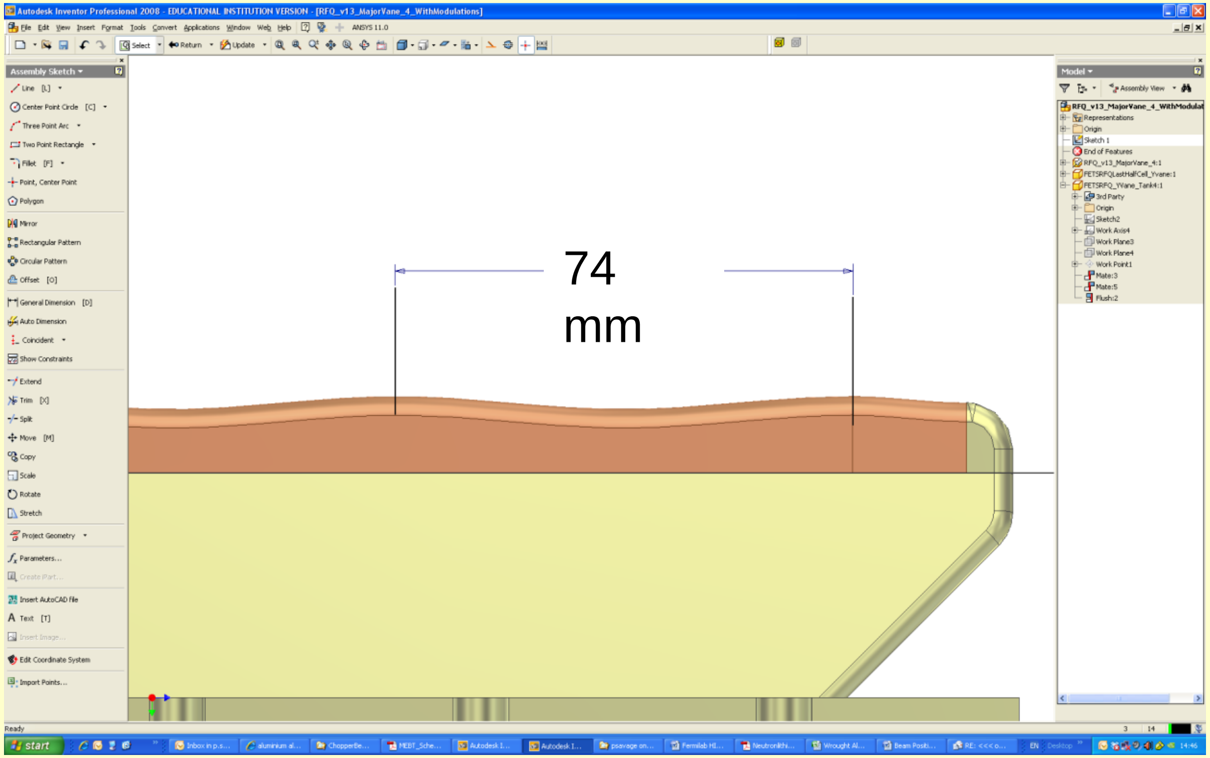
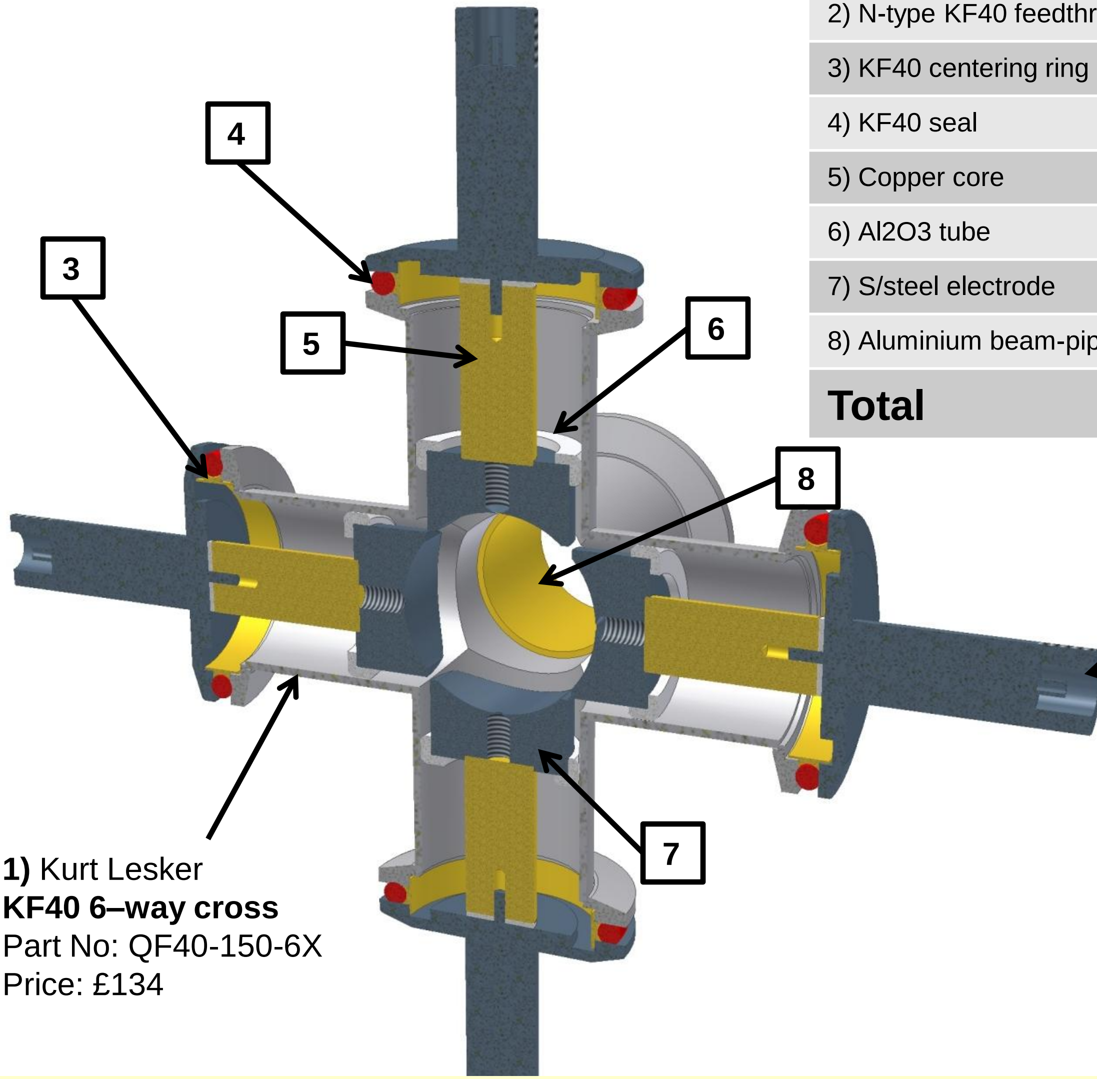
BPM Diameter

The BPM diameter can be estimated from the bunch length:
Distance between last 2 peaks in RFQ / 4 = 74 /4 = 18.5mm
(length<90 degree of RF)
Therefore, DN25CF should be sufficient.



Imperial College could produce a prototype for ~£1000

Item	Quantity	Unit Cost (£)	Total Cost (£)
1) KF40 6-way cross	1	134	134
2) N-type KF40 feedthrough	4	127	508
3) KF40 centering ring	4	2	8
4) KF40 seal	4	3	12
5) Copper core	4	10	40
6) Al2O3 tube	4	15	60
7) S/steel electrode	4	10	40
8) Aluminium beam-pipe liner	4	5	20
Total	**29**		**822**

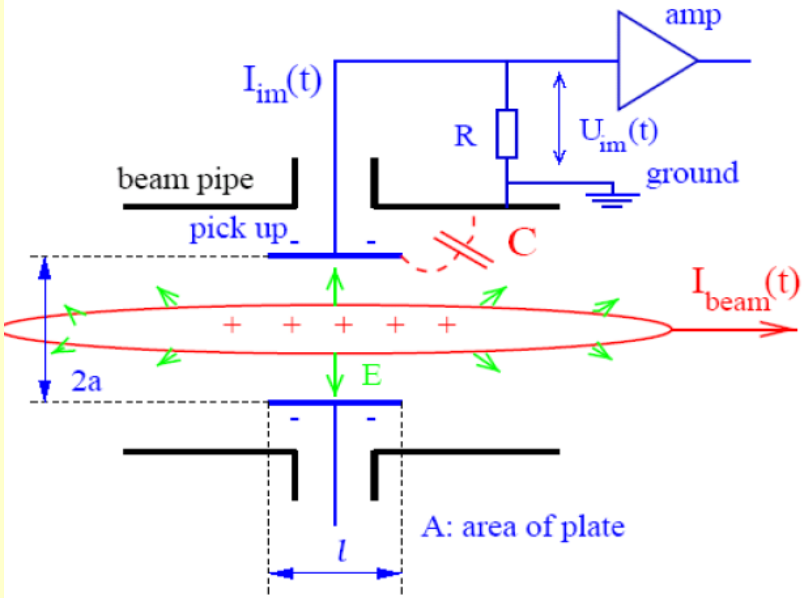


2) Kurt Lesker
N-type KF40 feedthrough
Part No: IFTNG011038B
Price: £127

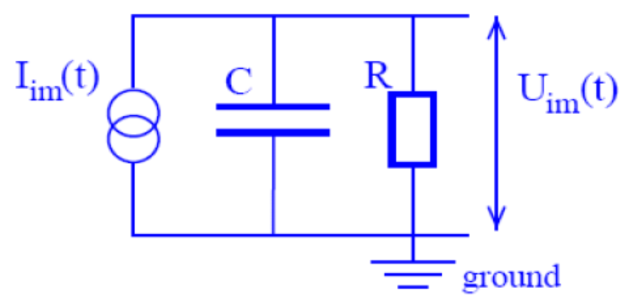
1) Kurt Lesker
KF40 6–way cross
Part No: QF40-150-6X
Price: £134

Sensitivity

Kapazitiver Strahlpositionsmonitor



equivalent circuit



$$\frac{1}{Z} = \frac{1}{R} + i\omega C \rightarrow Z = \frac{R}{1 + i\omega RC}$$

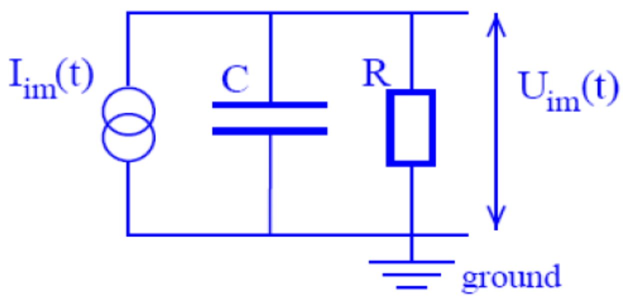
Flächenverhältnis
Pick up / Rohr mit Radius a, Länge l

$$Q_{beam}(t) = I_{beam}(t) \cdot \frac{l}{\beta c}$$

$$I_{im}(t) = \frac{dQ_{im}(t)}{dt} = \frac{A}{2\pi a l} \cdot \frac{dQ_{beam}(t)}{dt} = \frac{A}{2\pi a} \cdot \frac{1}{\beta c} \cdot \frac{dI_{beam}(t)}{dt}$$

Frequency Response 1

equivalent circuit



In Frequenzdarstellung:

$$U_{im}(\omega) = Z(\omega) \cdot I_{im}(\omega)$$

komplexes Übertragungsverhalten des BPM.

Wir setzen ein und erhalten

$$U_{im}(\omega) = \frac{R}{1+i\omega RC} I_{im}(\omega)$$

$$= \frac{A}{2\pi a} \cdot \frac{1}{\beta c} \cdot \frac{R}{1+i\omega RC} \frac{dI_{beam}(\omega)}{dt}$$

$$= \frac{A}{2\pi a C} \cdot \frac{1}{\beta c} \cdot \frac{i\omega RC}{1+i\omega RC} \cdot I_{beam}(\omega)$$

$$= Z_t(\omega, \beta) \cdot I_{beam}(\omega)$$

also

$$Z_t(\omega, \beta) = \frac{A}{2\pi a} \cdot \frac{1}{\beta c} \cdot \frac{1}{C} \cdot \frac{i\omega RC}{1+i\omega RC}$$

Transferimpedanz des BPM

Hochpass

mit

$$|Z_t(\omega, \beta)| = \frac{A}{2\pi a} \cdot \frac{1}{\beta c} \cdot \frac{1}{C} \cdot \frac{\omega/\omega_C}{\sqrt{1+\omega^2/\omega_C^2}}$$

$$\varphi(\omega) = \arctan\left(\frac{1}{\omega RC}\right) = \arctan\left(\frac{\omega_C}{\omega}\right)$$

$$\omega_C = {}^{1}\!/_{RC}$$

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Frequency Response 2

Auswirkungen auf Signalstärke und -form

Hochfrequente Signale: $\omega \gg \omega_C$ $\quad Z_t(\omega,\beta) \propto \dfrac{i\omega/\omega_C}{1+i\omega/\omega_C} \to 1$

$$U_{im}(\omega) = \frac{A}{2\pi a C}\cdot\frac{1}{\beta c}\cdot I_{beam}(\omega) \quad \to \quad U_{im}(t) \propto I_{beam}(t)$$

Signalform = Bunchform

$Z_t(\omega,\beta) \propto \dfrac{A}{C}$ ⇨ *(fast) unabhängig von Länge der Pickups*

Niederfrequente Signale: $\omega \ll \omega_C$ $\quad Z_t(\omega,\beta) \propto \dfrac{i\omega/\omega_C}{1+i\omega/\omega_C} \to i\omega/\omega_C$

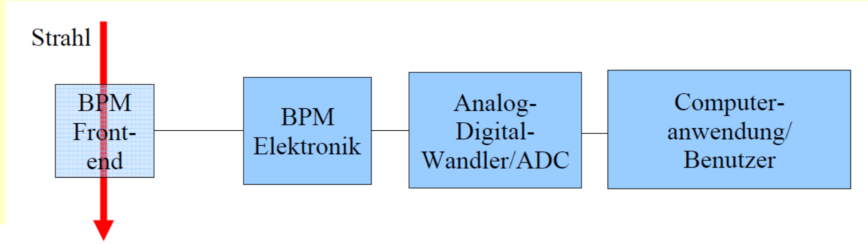
$$U_{im}(\omega) = R\cdot\frac{A}{2\pi a}\cdot\frac{1}{\beta c}\cdot i\omega I_{beam}(\omega) = R\cdot\frac{A}{2\pi a}\cdot\frac{1}{\beta c}\cdot\frac{d}{dt}I_{beam}(\omega)$$

$$\to \quad U_{im}(t) \propto \frac{d}{dt}I_{beam}(t)$$

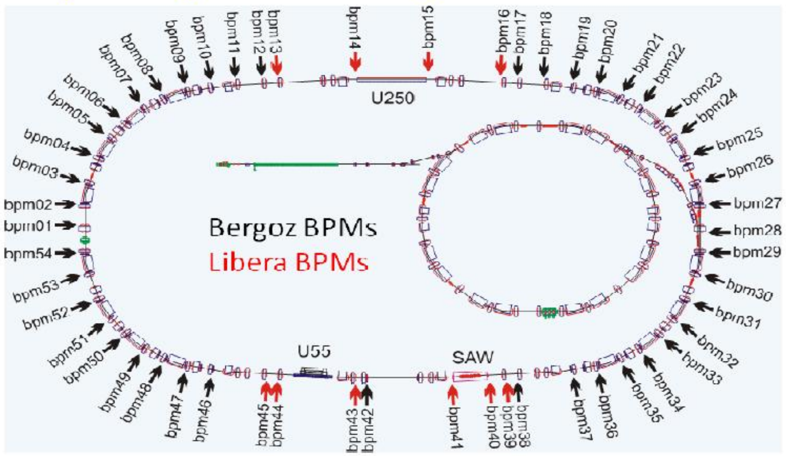
Signalform = Ableitung der Bunchform.

$Z_t(\omega,\beta) \propto A$ ⇨ *(fast) unabhängig von Kapazität der Pickups*

Electronics



Erfassung der Strahllagedaten / DELTA



ältere Elektroniken analog:

Fa. Bergoz f < 10 Hz
üblicherweise für langsame Orbitkorrektur

Datenrate bis 10 kHz nutzbar.

Digital: *Libera*

Fa. Intrumentation Technologies f < 3 MHz
sehr große Verbreitung an Lichtquellen

Next steps...

1. The mechanical design seems no major problem , the relevant physical behaviour is know analytically or can swiftly be simulated. Available designs might be used if suitable.

2. This is also true for the manufacturing of the BPM and no major cost driver is expected there as well.

3. A development of the electronics seems too much effort in the light of available electronics on the market. What is CERN/Linac4 using ?

4. Are we able to define what we need and purchase the required electronics now ?