# $\mu$E4 secondary beam line

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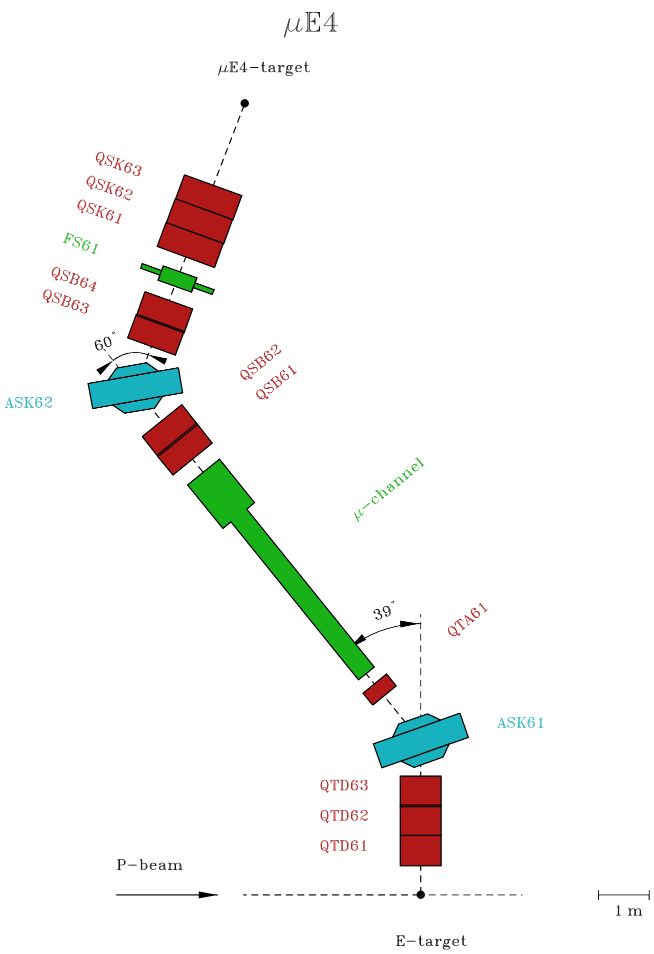


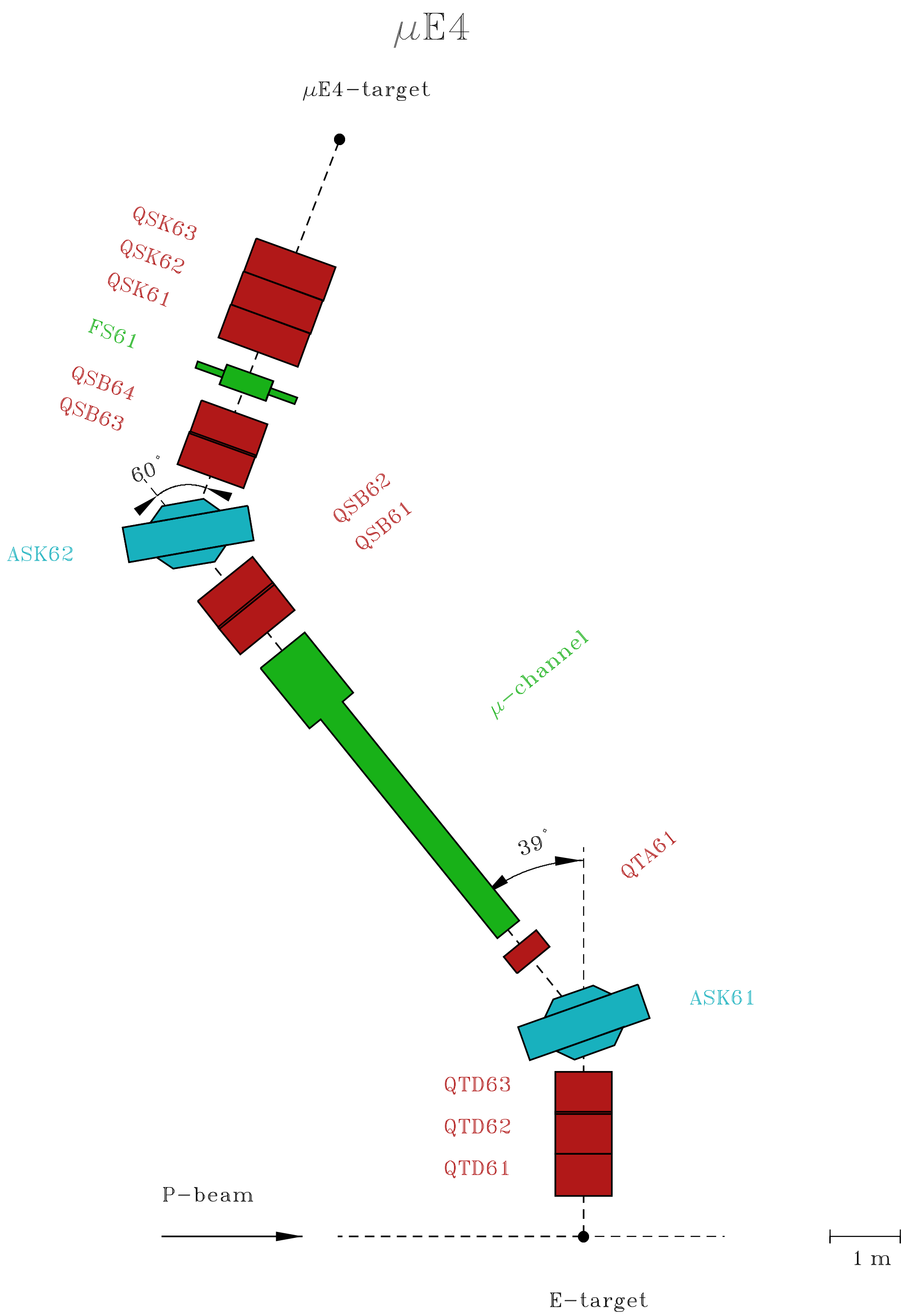



Figure 1: $\mu$E4 beam line

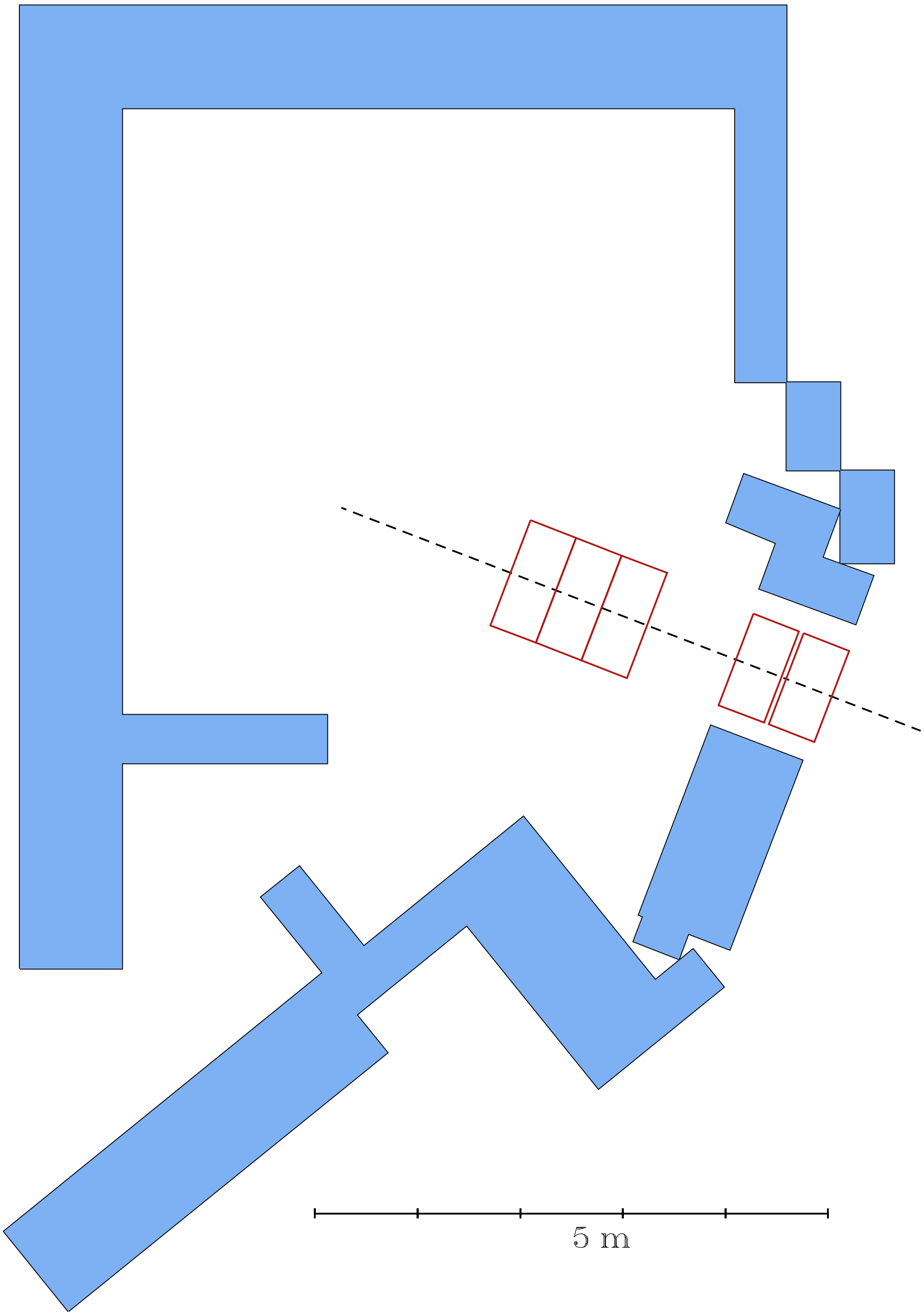



Figure 2: Lyout of the $\mu$E4 area

## 1 $\mu$E4 beam line

The second muon channel at PSI is essentially a copy of the first one. The extraction angle is however $90^0$. The system has been addapted to the 6 cm length of the carbon production target. The present area $\mu$E4 is shown in fig 2 and the beam line in fig 1.

The extraction system can be run in two distinct modes :

- **Achromatic** mode yielding the higher muon fluxes
- **Chromatic** mode (or **analyzing** mode) yielding four times smaller range widths at a corresponding cost of intensity

Figure 3 shows the measured muon fluxes and range curve versus momentum. Table I list the main characteristics of the $\mu$E4 beam line.
The flux of positive muons is higher by a factor of four.

| Pion collection system | | | | |
|---|---|---|---|---|
| Effective length | 4.75 | m | | |
| Visible target length | 6 | cm | | |
| $\Omega_\pi^{acc}$ (average over target length) | 47 | msr | | |
| $\Delta_\pi^{acc}/p_\pi$ (average over target length) | 16 % | FWHM | | |
| $\pi$ flux acc. by sol. $p\pi$ = 160 MeV/c | 1.2 $10^{10}$ | $\pi^-$/sec | | |
| ( $I_p$ = 1 mA ) $p_\pi$ = 110 MeV/c | 6.0 $10^9$ | $\pi^-$/sec | | |
| Pion decay section | | | | |
| Solenoid length | 5. | m | | |
| Longitudinal field | 5. | T | | |
| Inner free diameter | 12. | cm | | |
| Muon extraction system | | | | |
| Effective length | 7. | m | | |
| Accepted phase space at solenoid end FWHM | $\Delta x$ >50mm | $\Delta x'$ 100mrad | $\Delta y$ 35mm | $\Delta y'$ 500mrad |
| $\Delta p_\mu/p_\mu$ (chromatic/achromatic mode) | 3 % / 15% | FWHM | | |
| Measured .$CH_2$ range width at (for chromatic/achromatic modes) | 88.5 MeV/c<br>50.0 MeV/c | 0.55/2.0<br>0.10/0.3 | g/$cm^2$<br>g/$cm^2$ | |
| Measeared $\mu$ beam spot size FWHM | 60×40 | $mm^2$ | | |
| Mean muon beam polarization | 75 % | | | |

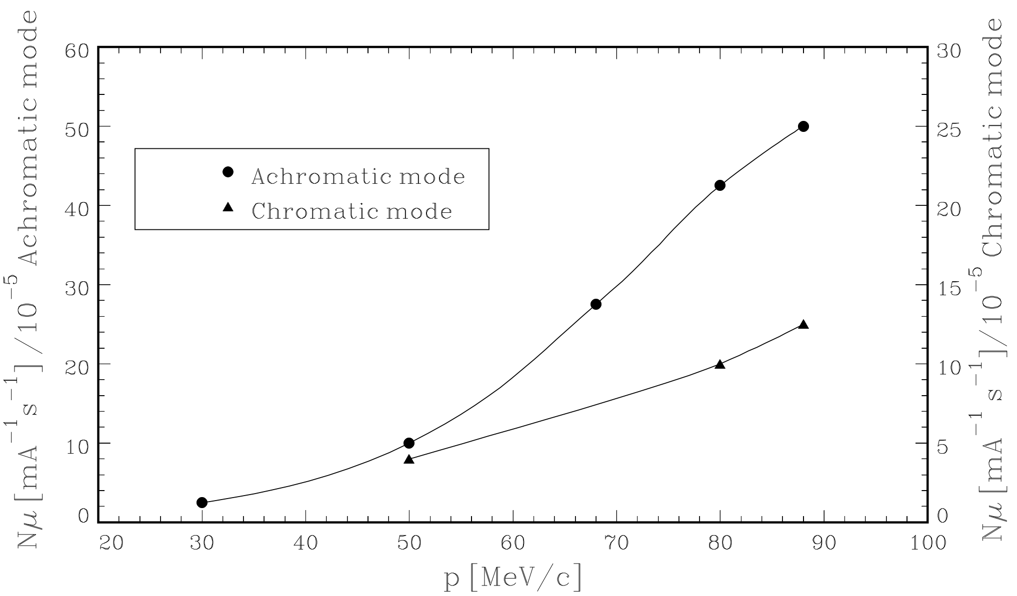



Figure 3: Flux of negative muons of the $\mu$E4 beam line

The muon channel II system has the following advantages over the muon channel I :

- **Flux flexibility** in the sign, range and momentum of the muons, which is important for optimal adjustement to experiments and for tests of the system.
- Ideal operations for experiments requiring **low momentum** and/or **small range widths**. Typical range widths from 20 mg/cm$^2$ to 2 g/cm$^2$ have been obtain by tunning the muon analyzing system from 30 MeV/c to 90 MeV/c. In principle it is possible to tune even lower muons momenta and to obtain correspondingly smaller range widths by degrading the pion in front of the channel.
- **Low neutron background** arising from the use of a $90^0$ pion production angle. Since the muon area $\mu$E4 looks at backward angles at the E target and the beam dump, very few high energy ($<$ 100 MeV) neutrons reach the area from these sources ( $< 10^{-3}$ HE n/cm$^2$·sec). The main source of fast neutrons of 1 to 100 MeV is therefore the pion dump after the last bending magnet, which is well shielded. A second source of neutrons (in the case of $\mu^-$ operation) is the slit system where waste muons are dumped.

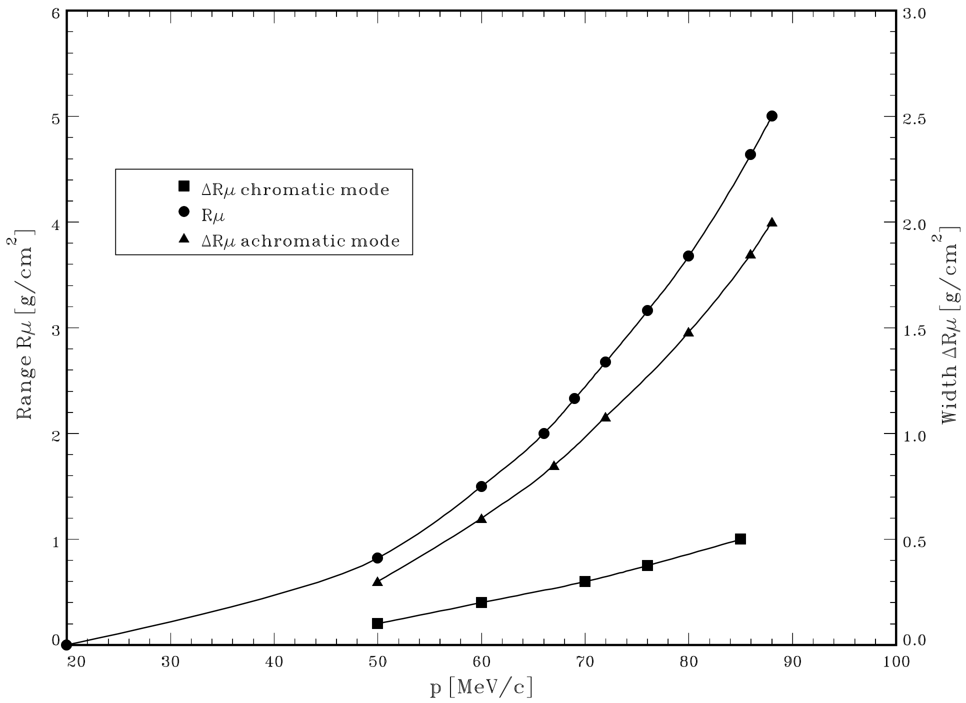



Figure 4: Muon range and width in $CH_2$ in the $\mu$E4 beam line

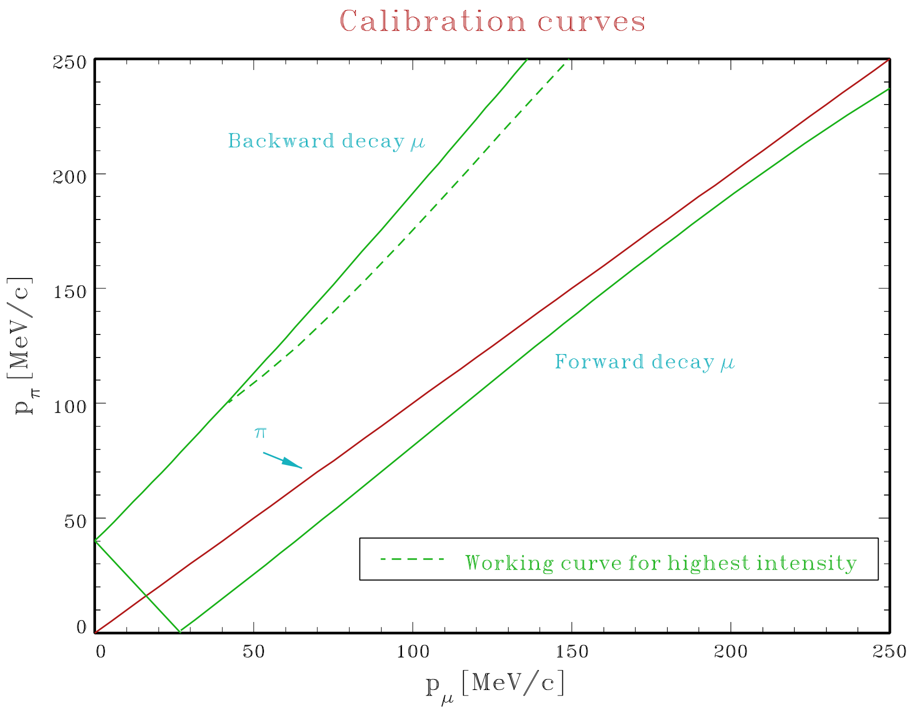



Figure 5: Decay kinematics for selecting the proper $\pi/\mu$ momentum

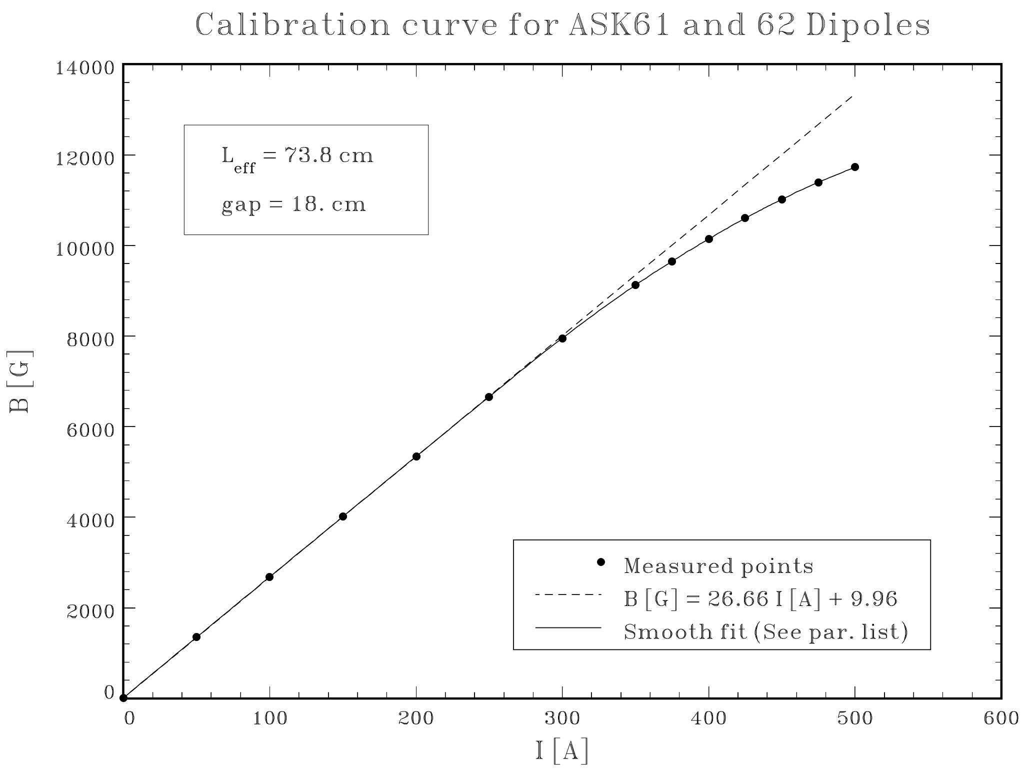
For a setting up do the following :

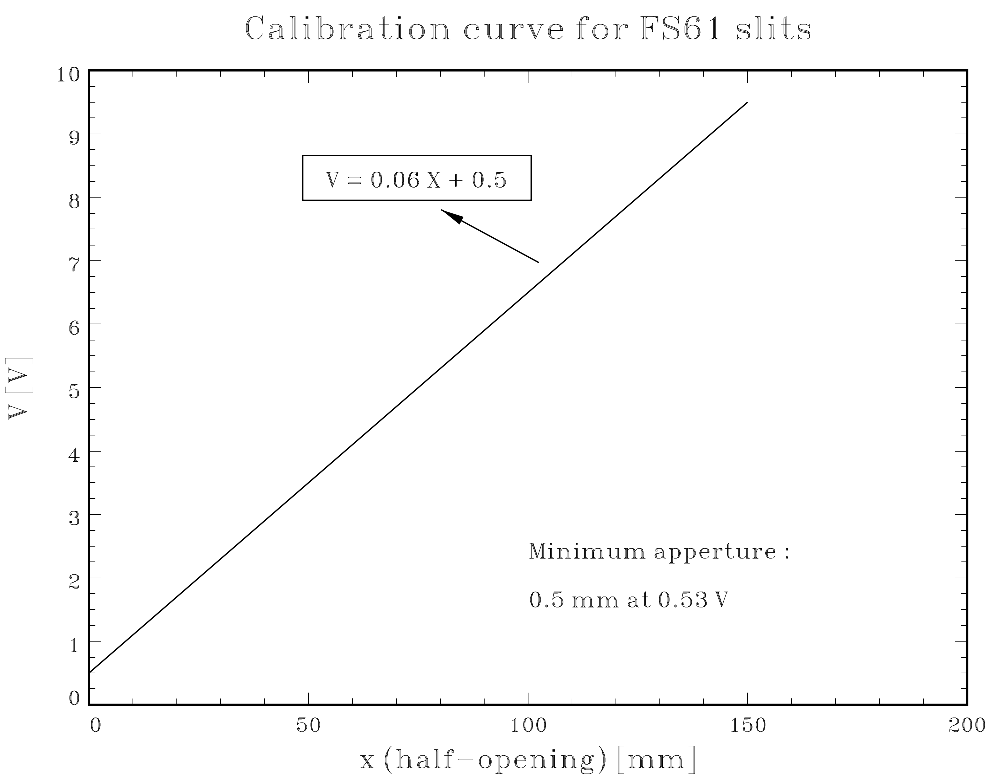
1) Select $\mu$ momentum $p_\mu$ and extraction mode according to desired flux-range properties (fig. 3-4)

2) Determine optimum $\pi$ momentum $p_\pi$ according to $\pi - \mu$ decay kinematics (fig.5)

Setting of the magnets (Decimal settings : DAC, $p_\pi$ and $p_\mu$ in MeV/c).
The focus is 52 cm from QSK63.

| $\pi^+$ injection | | $\mu^+$ extraction | | |
|---|---|---|---|---|
| | | | Chromatic mode | Achromatic mode |
| Element | DAC | Element | DAC | DAC |
| QTD61 | $-11.3\,p_\pi$ | QSB61 | $-18.7\,p_\mu$ | $-22.0\,p_\mu$ |
| QTD62 | $+18.9\,p_\pi$ | QSB62 | $+10.3\,p_\mu$ | $+20.4\,p_\mu$ |
| QTD63 | $-5.4\,p_\pi$ | ASK62 | $+14.9\,p_\mu$ | $-14.9\,p_\mu$ |
| ASK61 | $-15.0\,p_\pi$ | QSB63 | $+8.9\,p_\mu$ | $+17.2\,p_\mu$ |
| QTA61 | $+14.8\,p_\pi$ | QSB64 | $-15.1\,p_\mu$ | $-18.0\,p_\mu$ |
| | | QSK61 | $-16.4\,p_\mu$ | $-16.4\,p_\mu$ |
| | | QSK62 | $+17.1\,p_\mu$ | $+17.1\,p_\mu$ |
| | | QSK63 | $-14.5\,p_\mu$ | $+14.5\,p_\mu$ |


Calibration curve for ASK61 and 62 Dipoles
$L_{eff}$ = 73.8 cm
gap = 18. cm
Measured points
B [G] = 26.66 I [A] + 9.96
Smooth fit (See par. list)
B [G]
I [A]
0
2000
4000
6000
8000
10000
12000
14000
0
100
200
300
400
500
600


Calibration curve for FS61 slits
V = 0.06 X + 0.5
Minimum apperture :
0.5 mm at 0.53 V
V [V]
x (half−opening) [mm]
0
1
2
3
4
5
6
7
8
9
10
0
50
100
150
200

### 1.1 Some other informations

- The beam's higt is 150.5 cm
- If an end beam window is needed, it is of Mylar and has usually 150 $\mu$m
- The standard beam pipe diameter is 320 mm
- The DAC values for the slits run from 0 to 600

In case of problems contact :

- for **electricity** : A Widmer , M Horvat
- for **cooling water** : Markus Koller
- for **beam setting** : U Rohrer
- for **vacuum system** : U Kalt
- for **muon channel** : W Gloor
- for **Experimental hall** : H Vetterli
- for **SU** : W Wittwer

## 1.2 On beam setting

There are **two** PC available for $\mu$E4 beam line :

- PC 565 located in the $\mu$E4 barracq
- PC 451 located on the gallery in a CAMAC crate

You work with the PC 565, using mainly the **SETPOINT** facility.
The corresponding CAMAC address and magnet identification are in the :
**device.lis** file (in OPTIMA).If you change the device.lis, start SETPOINT again.
You might have setting saved in a**.set** file (in SETPOINT) , which can be loaded, or created.

However :

| If you have to change the **device.lis** file, you have to do it **in** the **PC451** |
|---|

More information are to be found in :

http://www.psi.ch/~Rohrer/secblctl.html

For this go into the PSI home page : http://www.psi.ch and click on Departments and Projects , and then on Experimental Facilities (AEA) and finally on Control system for secondary beam lines.

To convert from DAC value to Field value you can use the **Itune** programme. There is a manual for the **Tune** , **Itune** , **DAC_to_B** and **B_to_DAC** programme by F Foroughi.

Examples are given at the end.

The structure of the **device.lis** file is :

| Device name | DAC-special | ROAD add | CAMAC station Nb | DAC min | DAC max | DAC-type | ADC-parameter | ROAD add | CAMAC ADC-CRCI | ADC-channel | Range | ADC-type | Scale (normal=1.0) | Precision DAC-ADC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| QTD61 | 0 | 3 | 3 | -4095 | 4095 | 7 | 0 | 3 | 3 | 0 | 0 | 7 | 1.000 | 0.150 |
| QTD62 | 0 | 5 | 3 | -4095 | 4095 | 7 | 0 | 5 | 3 | 0 | 0 | 7 | 1.000 | 0.150 |
| QTD63 | 0 | 1 | 3 | -4095 | 4095 | 7 | 0 | 1 | 3 | 0 | 0 | 7 | 1.000 | 0.150 |
| ASK61 | 1 | 13 | 3 | -4095 | 4095 | 7 | 1 | 13 | 3 | 0 | 0 | 7 | 1.000 | 0.150 |
| QTA61 | 1 | 7 | 3 | -4095 | 4095 | 7 | 1 | 7 | 3 | 0 | 0 | 7 | 1.000 | 0.150 |
| QSB61 | 1 | 2 | 3 | -4095 | 4095 | 7 | 1 | 2 | 3 | 0 | 0 | 7 | 1.000 | 0.150 |
| QSB62 | 1 | 3 | 3 | -4095 | 4095 | 7 | 1 | 3 | 3 | 0 | 0 | 7 | 1.000 | 0.150 |
| ASK62 | 1 | 6 | 3 | -4095 | 4095 | 7 | 1 | 6 | 5 | 0 | 0 | 7 | 1.000 | 0.150 |
| QSB63 | 1 | 4 | 3 | -4095 | 4095 | 7 | 1 | 4 | 3 | 0 | 0 | 7 | 1.000 | 0.150 |
| QSB64 | 1 | 5 | 3 | -4095 | 4095 | 7 | 1 | 5 | 3 | 0 | 0 | 7 | 1.000 | 0.150 |
| QSK61 | 1 | 9 | 3 | -4095 | 4095 | 7 | 1 | 9 | 3 | 0 | 0 | 7 | 1.000 | 0.150 |
| QSK62 | 1 | 10 | 3 | -4089 | 4095 | 7 | 1 | 10 | 3 | 0 | 0 | 7 | 1.000 | 0.150 |
| QSK63 | 1 | 11 | 3 | -4089 | 4095 | 7 | 1 | 11 | 3 | 0 | 0 | 7 | 1.000 | 0.150 |
| * | | | | | | | | | | | | | | |
| FS61-O | 0 | 0 | 9 | 0 | 1000 | 9 | 1 | 0 | 9 | 0 | 0 | 9 | 4.095 | 0.050 |
| FS61-U | 0 | 1 | 9 | 0 | 1000 | 9 | 1 | 1 | 9 | 0 | 0 | 9 | 4.095 | 0.050 |
| FS61-L | 0 | 0 | 10 | 0 | 1000 | 9 | 1 | 0 | 10 | 0 | 0 | 9 | 4.095 | 0.050 |
| FS61-R | 0 | 1 | 10 | 0 | 1000 | 9 | 1 | 1 | 10 | 0 | 0 | 9 | 4.095 | 0.050 |

A * means newpage.

For more informations see the corresponding WWW pages !

**FS61**

Reduces beam **intensity**

Located between QSB64 and QSK61 ( see fig 1)

Maximal opening $\pm 10$ cm (i.e, 20 cm )

Calibration :

$$x \text{ or } y = \pm 10 \times \frac{\text{DAC} - 50}{600} \; cm$$

The four jaws move indepentently .

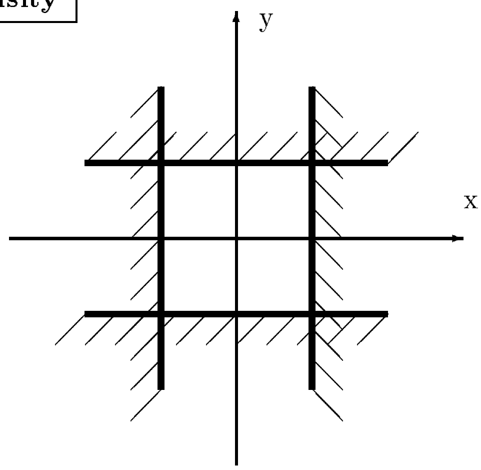


Table I. Coefficients for the calibration of magnetic elements

$B = a_0 + a_1 I + a_2 I^2 + a_3 I^3 + a_4 I^4$ [B] = G ; [I] = A

| | Coefficients | | | | |
|---|---|---|---|---|---|
| Element | $a_0$ | $a_1$ | $a_2$ | $a_3$ | $a_4$ |
| QTA | 12.00 | 25.113 | $-.2946\ 10^{-1}$ | $+.182\ 10^{-3}$ | $-.36\ 10^{-6}$ |
| QTB | 1.933 | 16.011 | $-.7186\ 10^{-2}$ | $+.432\ 10^{-4}$ | $-.63\ 10^{-7}$ |
| QTD | 1.933 | 16.011 | $-.7186\ 10^{-2}$ | $+.432\ 10^{-4}$ | $-.63\ 10^{-7}$ |
| QTH | 7.647 | 18.10 | $-.4520\ 10^{-2}$ | $+.333\ 10^{-4}$ | $-.61\ 10^{-7}$ |
| QSB | 0. | 17.066 | $+.9412\ 10^{-2}$ | $-.361\ 10^{-4}$ | $+.10\ 10^{-7}$ |
| QSE | .1541 | 14.125 | $+.4991\ 10^{-2}$ | $-.132\ 10^{-4}$ | |
| QSF | .8402 | 9.1893 | $-.3735\ 10^{-2}$ | $+.254\ 10^{-4}$ | $-.32\ 10^{-7}$ |
| QSL | 0. | 18.092 | $+.4228\ 10^{-3}$ | | |
| QSK | 7.135 | 18.2460 | $-.9022\ 10^{-2}$ | $+.528\ 10^{-4}$ | $-.79\ 10^{-7}$ |
| HSA | 13.47 | 62.384 | $-.2505\ 10^{+0}$ | $-.225\ 10^{-2}$ | |
| HSB | 13.47 | 62.384 | $-.2505\ 10^{+0}$ | $-.225\ 10^{-2}$ | |
| HSC | 1.145 | 9.2268 | | | |
| HSD | 12.33 | 9.6336 | $+.4849\ 10^{-1}$ | $-.279\ 10^{-3}$ | $+.37\ 10^{-6}$ |
| ASK* | 10.02 | 25.722 | $+.1256\ 10^{-1}$ | $-.341\ 10^{-4}$ | |
| ASK** | 7.51 | 19.291 | $+.9420\ 10^{-2}$ | $-.256\ 10^{-4}$ | |
| ASL | 0. | 32.256 | $-.3116\ 10^{-2}$ | | |
| ASM | 7.31 | 25.967 | | | |
| ADT | 1.83 | 12.445 | | | |
| ASX | 3.91 | 21.382 | $+.1040\ 10^{-1}$ | $-.223\ 10^{-4}$ | |
| ASY | 20.8 | 23.974 | $-.1655\ 10^{-2}$ | | |
| ASZ | 7.31 | 25.967 | | | |

* ASK 61,62,71,72,81 and 82 ; ** ASK 31 and 32

# Setting for $\mu$E4

$P$ = 88. MeV/c Particle : $\boldsymbol{\mu^-}$ Mode : **Achromatic**

| Elements | B [KG] | I [A] | DAC | $\frac{I}{Imax} \cdot \frac{100}{r}$ | r Range factor | Imax [A] |
|---|---|---|---|---|---|---|
| QTD 61 | 3.4469 | 217.34 | 1780 | 0.435 | 100 | 500 |
| QTD 62 | -5.7764 | -358.93 | -2940 | 0.718 | 100 | 500 |
| QTD 63 | 1.6296 | 103.78 | 850 | 0.208 | 100 | 500 |
| ASK 61 | 7.6194 | 286.91 | 2350 | 0.574 | 100 | 500 |
| QTA 61 | -6.8378 | -299.15 | -2450 | 0.598 | 100 | 500 |
| QSB 61 | 3.9098 | 224.35 | 1837 | 0.449 | 100 | 500 |
| QSB 62 | -3.6378 | -208.43 | -1707 | 0.417 | 100 | 500 |
| ASK 62 | -4.1652 | -155.73 | -1275 | 0.311 | 100 | 500 |
| QSB 63 | -3.1722 | -181.3 | -1485 | 0.363 | 100 | 500 |
| QSB 64 | 3.276 | 187.35 | 1534 | 0.375 | 100 | 500 |
| QSK 61 | 3.4698 | 193.93 | 1588 | 0.388 | 100 | 500 |
| QSK 62 | -3.1618 | -176.75 | -1448 | 0.353 | 100 | 500 |
| QSK 63 | 2.0857 | 116.35 | 953 | 0.233 | 100 | 500 |

Example for QTD 61 : $\frac{I}{Imax} \frac{100}{r} = \frac{217.34}{500} \times \frac{100}{100} = 0.435$

$\frac{217.34}{500} \times \frac{100}{100} = 0.4347 \rightarrow \text{DAC} = 0.4347 \times 4095 = 1780$

26-JUN-97

## Setting for $\mu$E4

$P$ = 50.5 MeV/c Particle : $\mu^-$ Mode : **Chromatic**

| Elements | B [KG] | I [A] | DAC | $\frac{I}{Imax} \cdot \frac{100}{Dr}$ | r Range factor | Imax [A] |
|---|---|---|---|---|---|---|
| QTD 61 | 2.4892 | 158.24 | 1296 | 0.316 | 100 | 500 |
| QTD 62 | -4.2075 | -263.49 | -2158 | 0.527 | 100 | 500 |
| QTD 63 | 1.2283 | 78.15 | 640 | 0.156 | 100 | 500 |
| ASK 61 | 5.4435 | 203.91 | 1670 | 0.408 | 100 | 500 |
| QTA 61 | -5.3919 | -228.93 | -1875 | 0.458 | 100 | 500 |
| QSB 61 | 1.9893 | 112.98 | 925 | 0.226 | 100 | 500 |
| QSB 62 | -1.092 | -61.75 | -506 | 0.124 | 100 | 500 |
| ASK 62 | -2.3666 | -88.14 | -722 | 0.176 | 100 | 500 |
| QSB 63 | -1.0639 | -60.15 | -493 | 0.12 | 100 | 500 |
| QSB 64 | 1.9159 | 108.78 | 891 | 0.218 | 100 | 500 |
| QSK 61 | 1.7735 | 98.82 | 809 | 0.198 | 100 | 500 |
| QSK 62 | -1.6378 | -91.24 | -747 | 0.182 | 100 | 500 |
| QSK 63 | 0.7566 | 41.99 | 344 | 0.084 | 100 | 500 |

Example for QTD 61 : $\frac{I}{Imax}\frac{100}{r} = \frac{158.24}{500} \times \frac{100}{100} = 0.316$

$\frac{158.24}{500} \times \frac{100}{100}, = 0.3165 \rightarrow \text{DAC} = 0.3165 \times 4095 = 1296$