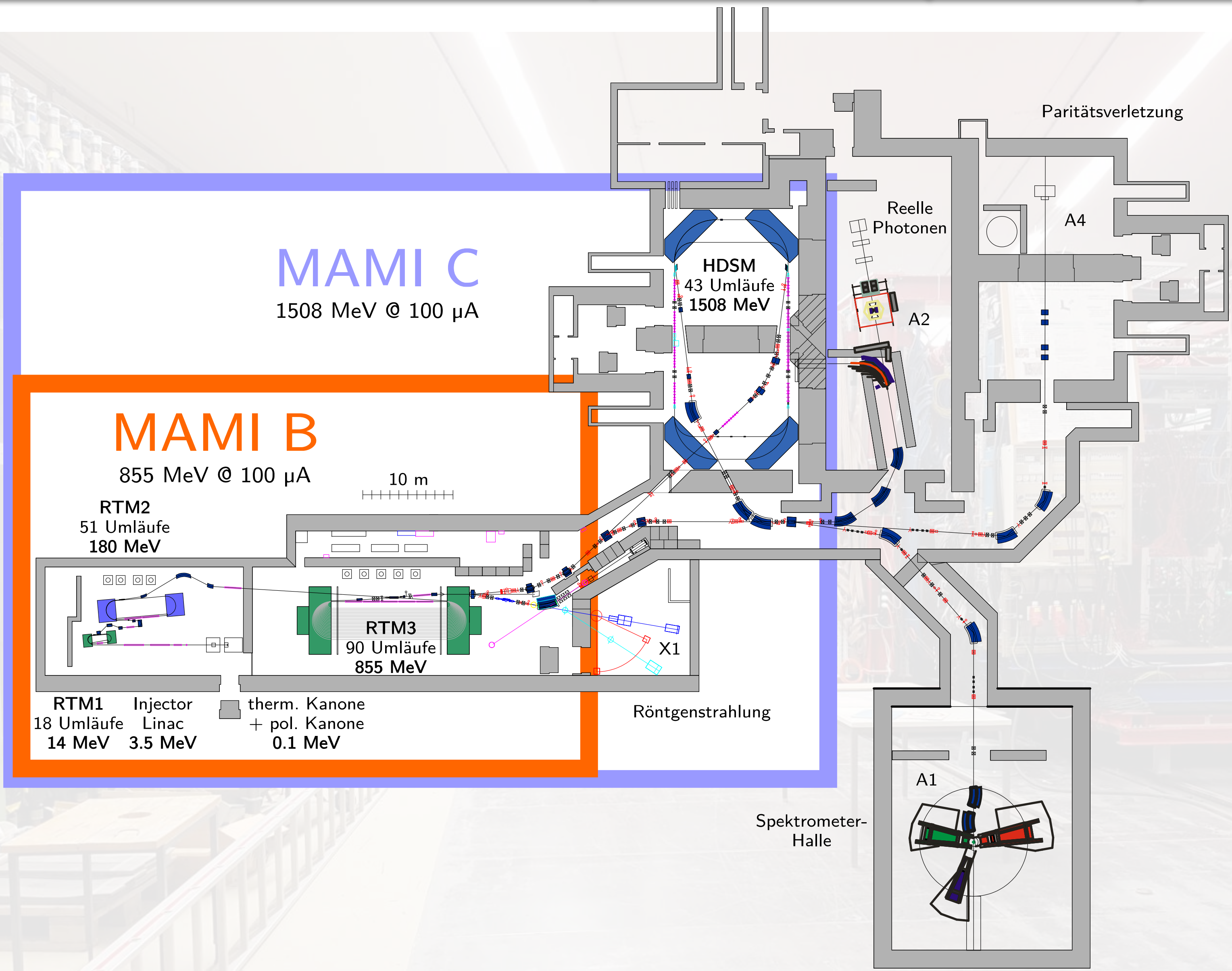
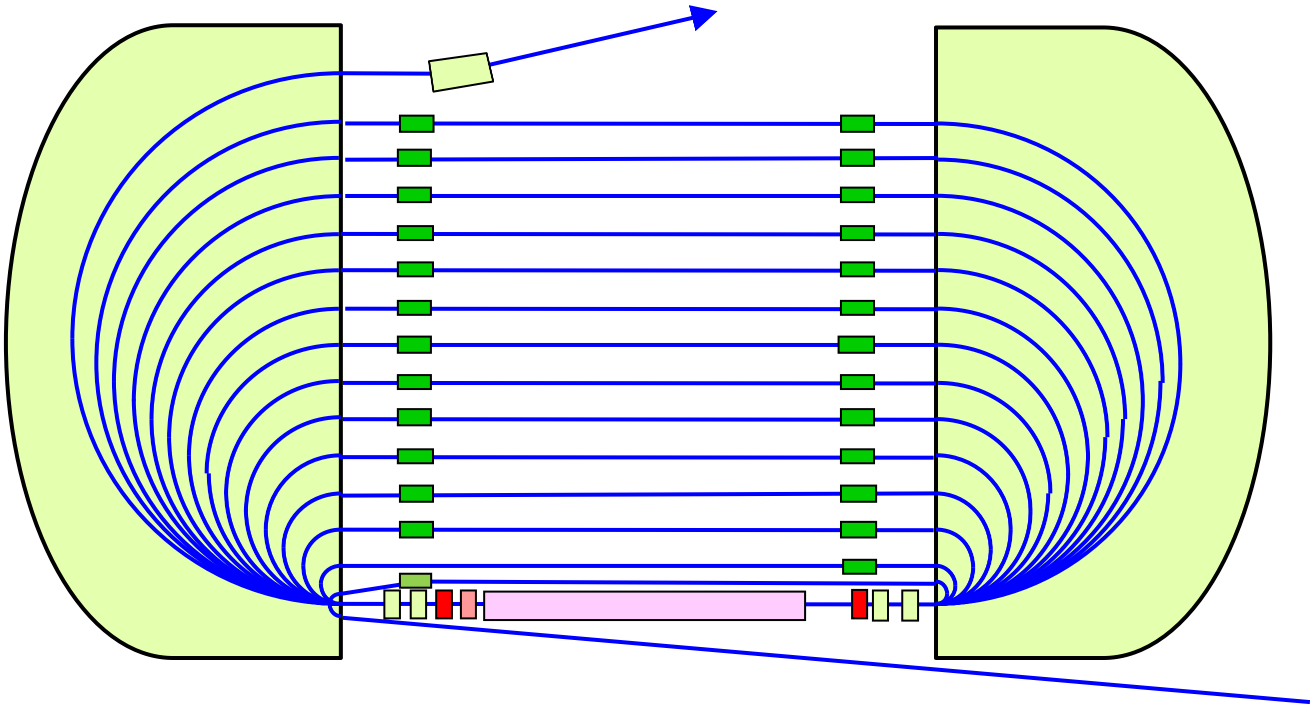
Construction of a new electron beamline in the A2 Hall

and some background information:

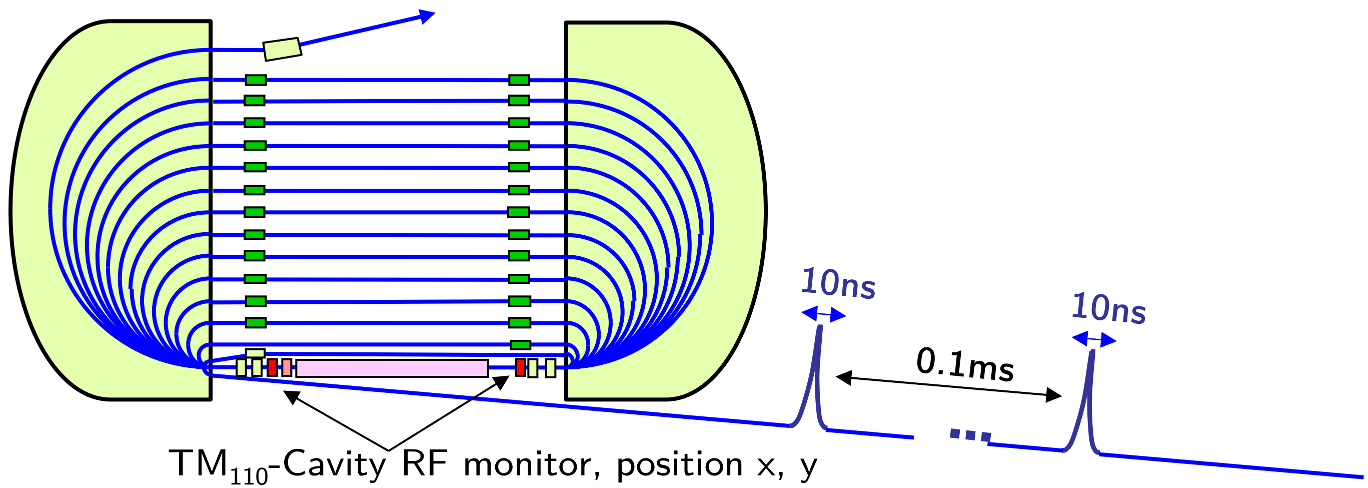
What makes the MAMI accelerator unique for high precision measurements?

Mainzer Mikrotron and experimental areas (as of 2012)

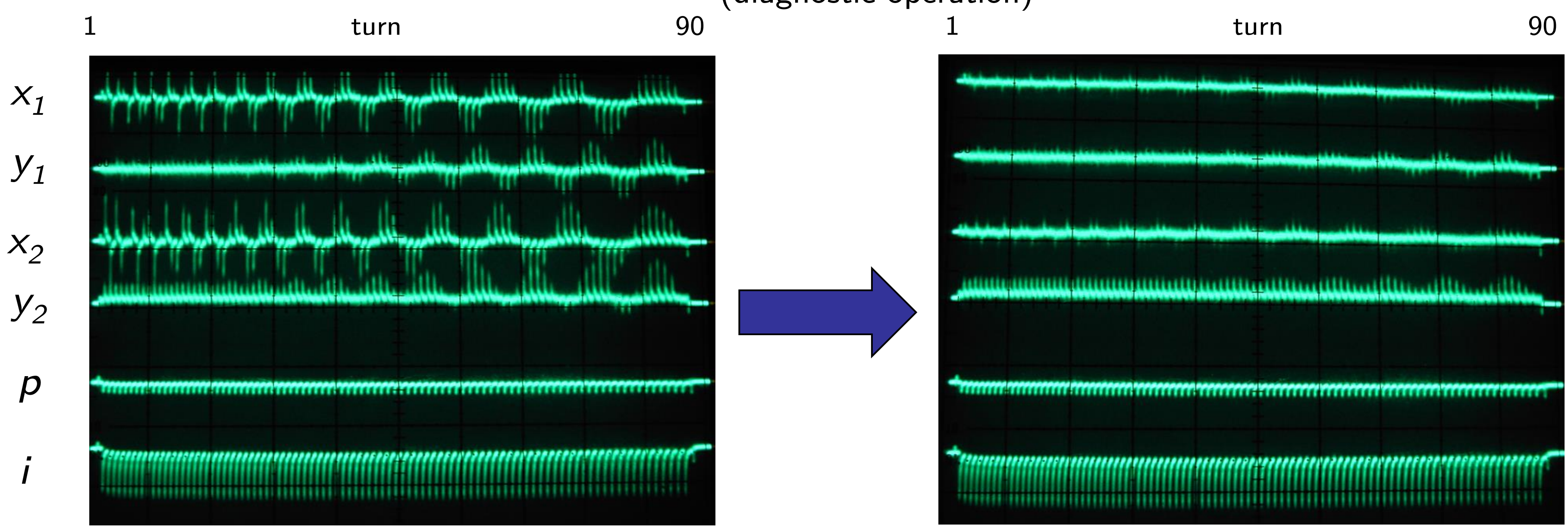


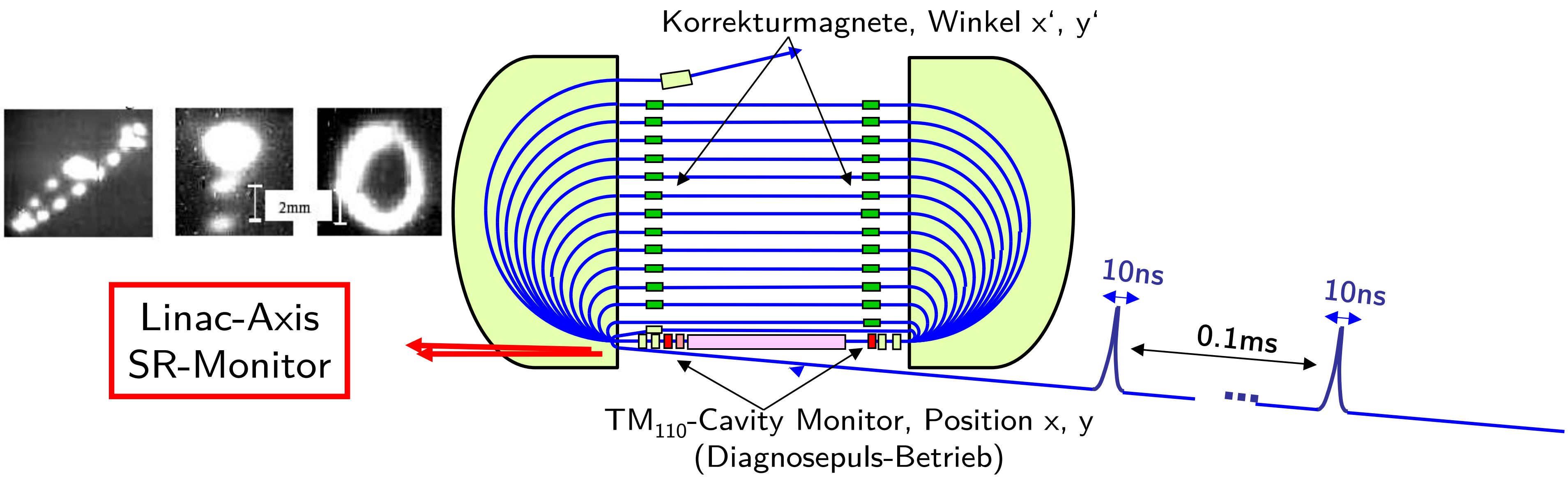


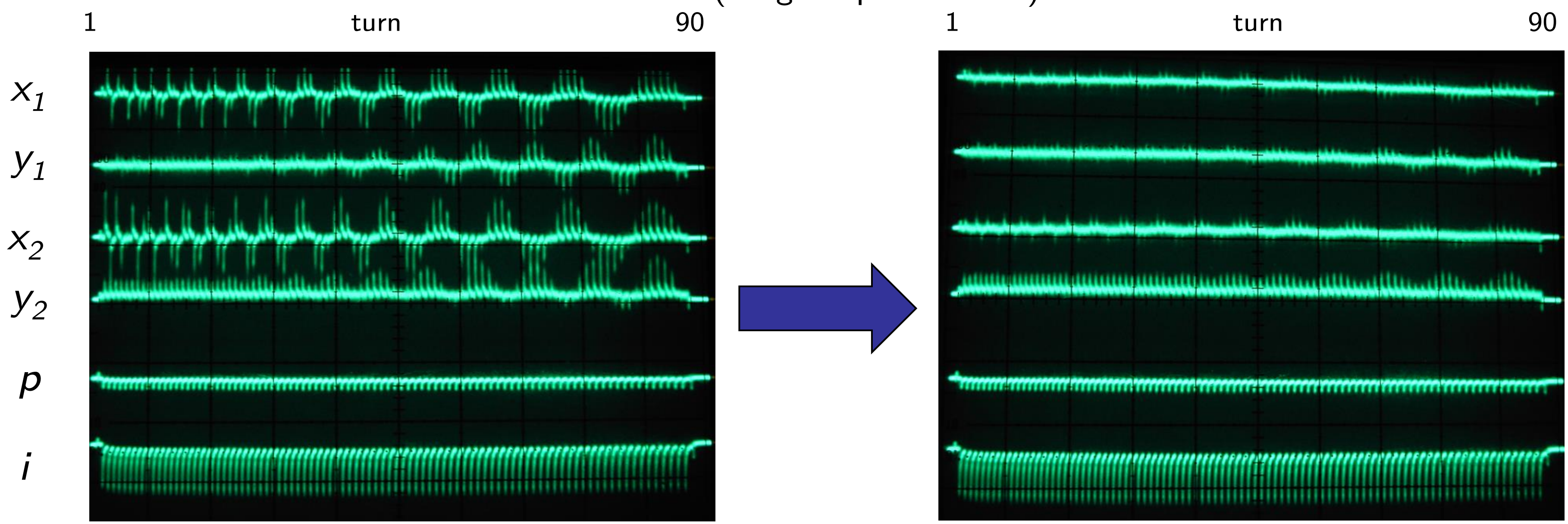
	RF Linac (~1MV/m, eg. 7.5MeV RTM3)
	RF cavity monitors (position x,y and time)
	quadrupole magnets (focussing)
	corrector magnets (h/v, “steerer“)



TM$_{110}$-Cavity RF monitor, position x, y
(diagnostic operation)

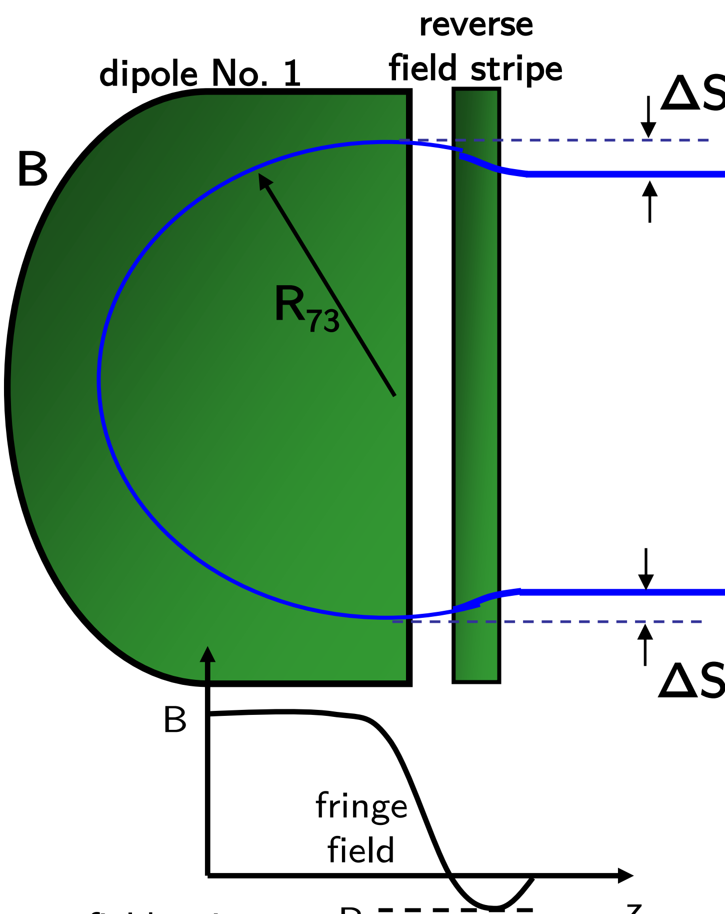



Korrekturmagnete, Winkel x‘, y‘
2mm
Linac-Axis
SR-Monitor
10ns
10ns
0.1ms
TM$_{110}$-Cavity Monitor, Position x, y
(Diagnosepuls-Betrieb)


1
turn
90
1
turn
90
x_1
y_1
x_2
y_2
p
i

Absolute beam energy measurement

i) Determining E_{73} (all simulation data are based on the standard 855MeV PTRACE file)

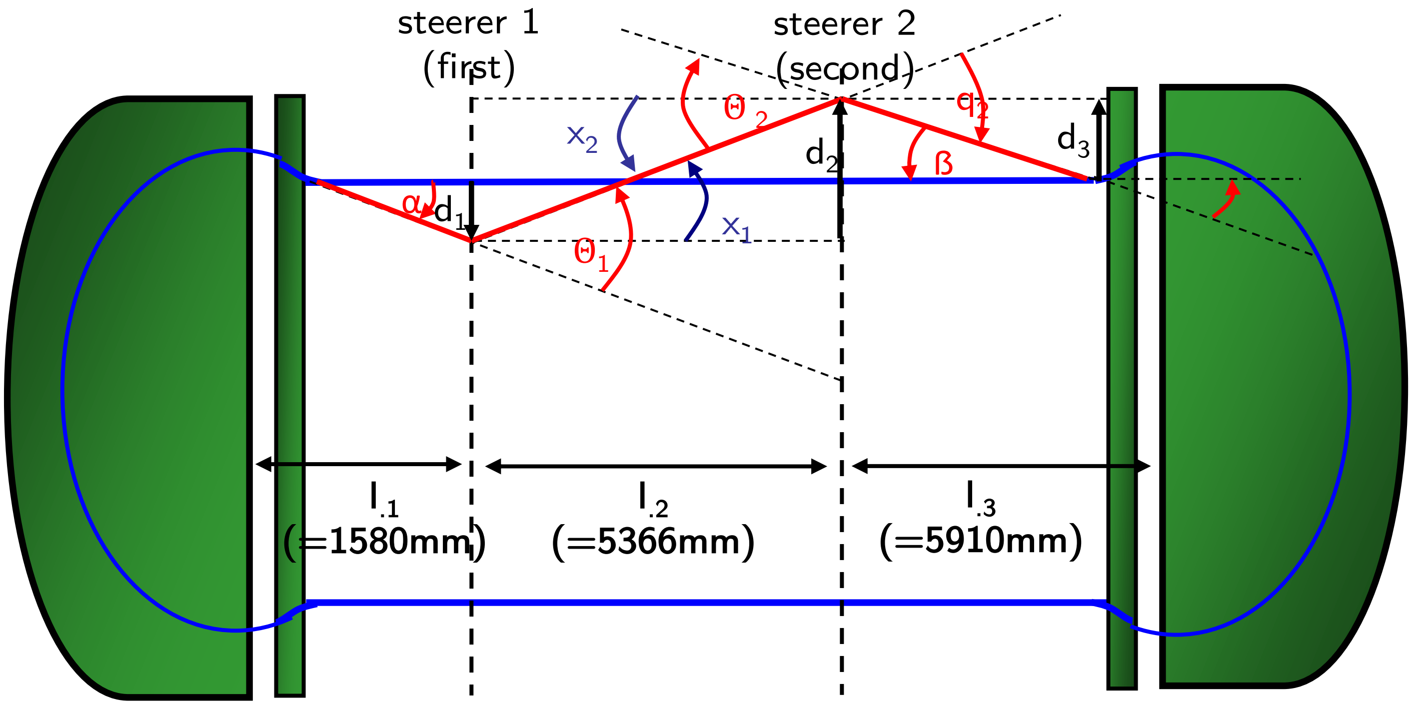


The reverse field stripe allows to adjust the vertical focussing properties of the dipoles.

B_{rev}/B=-0.18510
(for the standard 855MeV configuration)

$$\boxed{R_{73} = \frac{\beta}{e \cdot c} \cdot \frac{E_{73}}{B} \Leftrightarrow E_{73} = \frac{e \cdot c}{\underbrace{\cancel{\beta}}_{=1}} \cdot B \cdot R_{73}}$$

iv) Determining E_{73}

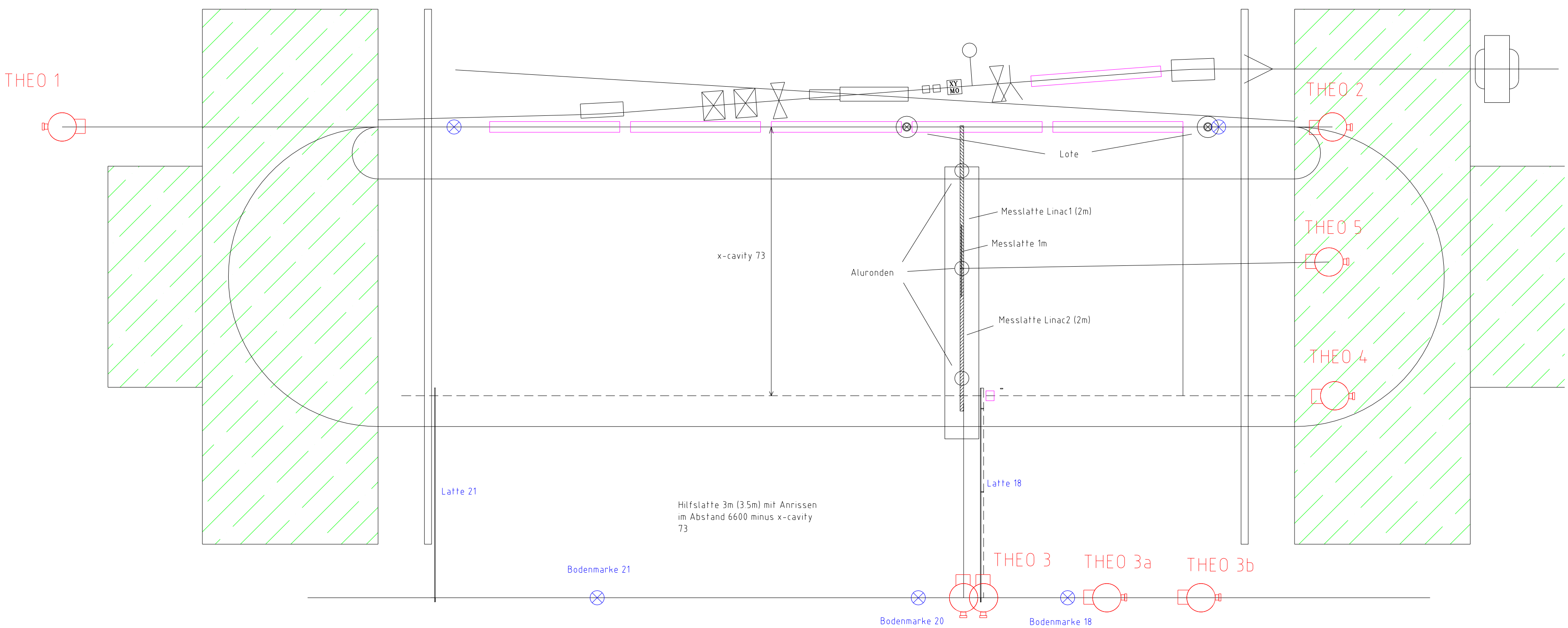


This shows, schematically, the situation in turn 73 after reduction of all betatron oscillations (centring the beam on the linac axis by help of the XYMOs there, at the entrance and exit of the 12m long linac). From this setup it is possible to calculate the bending angle errors **α** and **ß** of the dipoles from the known steerer angles Θ_1 and Θ_2. In the next step **α** is needed to calculate D.

The prerequisites are:
1) The bending radii in dipole No.1 and No.2 are identical.
2) The bending field inaccuracy of 10^{-4} leads only to individual bending errors **α** and **ß** and not to noticeable differences in the bending radii (this is checked up to the 0.1mm level !).

03.-06.03.2008: Check of distance of XYMO73 to the linac axis (direct measurement)

Sketch of the geodetic measurement setup



i) Error estimation for E_{73}

$$E_{73} \sim B \cdot \left(\frac{D}{2} + \Delta S\right) \sigma$$

a) B: $\sigma B = 0.000128T$, because
$\sigma B_{rel} = 10^{-4}$ (measured field flatness of RTM3 dipole)

b) ΔS: $\sigma \Delta S = 0.1mm$ (estimated from PTRACE calculations)

c) D: $D = D_M \overbrace{-(l_1 + l_M)\alpha - l_M \Theta_M}^{\delta D}$

$\sigma D_M = 0.4mm$ (geodetic measurement error, $D_M = 3768.6mm$)

$\sigma \delta D = 0.17mm$ $(= \sqrt{0.14^2 + 0.10^2}\ \mathrm{mm})$

length error for l_1, l_2, l_3, l_M (longitudinal positions on return path): ~5mm
($l_1 + l_M = 4821mm$ and $l_M = 3241mm$)
angle error for Θ_1, Θ_2, Θ_M: 0.03mrad
(we estimate the calibration errors of the steerers to be around 10%;
typical steerer values during this measurement are ~0.3mrad)
conclusion: the angle errors are dominant compared to the rel. length error of 0.1% for the error estimation of δD !

$\sigma D = 0.43mm$ $(= \sqrt{0.40^2 + 0.17^2}\ \mathrm{mm})$

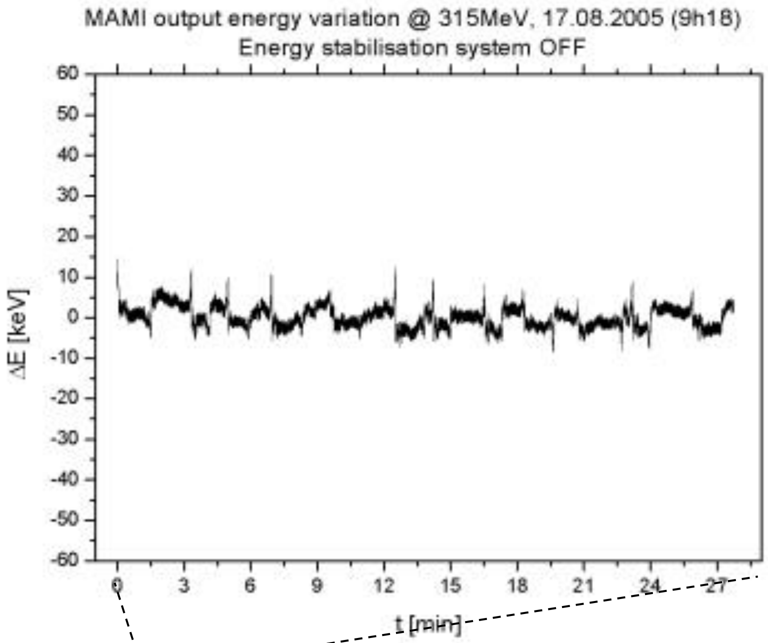
Therefore the total error of E_{73} (~727MeV) can be estimated to be:

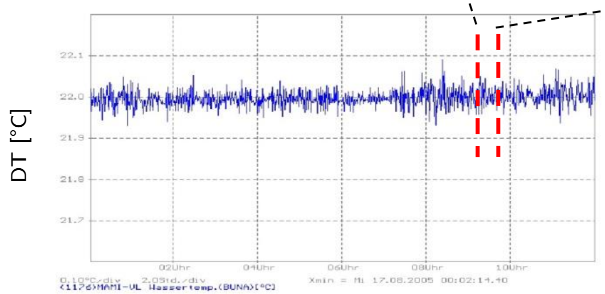
$$\sigma E_{73,rel} = 1.6 \cdot 10^{-4} \quad \text{resp.} \quad \sigma E_{73} = 120keV$$

Absolute beam energy measurement

iii) What affects the output energy of MAMI:

From the energy measurements for the A4 collaboration we know, that the variation of the MAMI energy without energy regulation is, thanks to the excellent cooling water stability of less then ±0.1°, in the order of typical < **±10keV !**

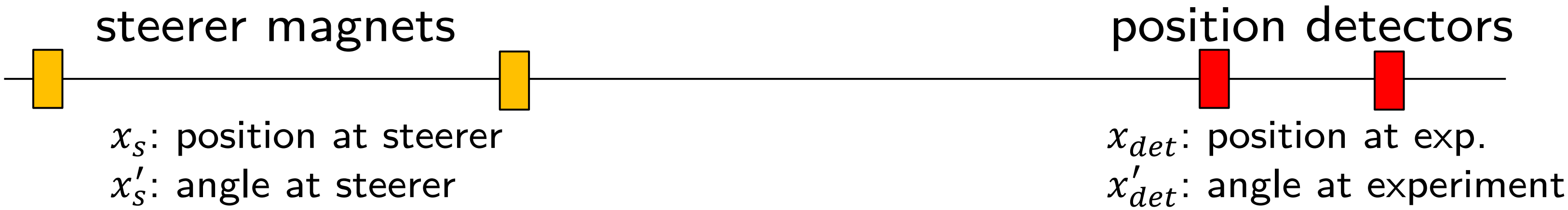




cooling water stability on 17.08.2005 (0^{00} – 12^{00})

0.1°C Changes of cooling water temperature influences the resonance frequency of the linac sections. This freq. change is compensated by the movement of two tuning plungers per sections. As a second order effect, this small tuning plunger movements lead to a small change of the field profile of the section and a change in accelerating gradient and phase results. As a consequence the energy is slightly changed.

Beam position stabilisation



$$\begin{pmatrix} x_{det} \\ x'_{det} \end{pmatrix} = M \cdot \begin{pmatrix} x_s \\ x'_s \end{pmatrix}, M = \begin{pmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \end{pmatrix}$$

Transfermatrix *M* between steerer and position detector

$$\Longrightarrow \begin{pmatrix} x_s \\ x'_s \end{pmatrix} = M^{-1} \cdot \begin{pmatrix} x_{det} \\ x'_{det} \end{pmatrix}$$

Measurement of position gives steerer correction $\Delta x'_s$

$$x_{det} \longmapsto 0$$
$$\Longrightarrow \Delta x'_s = \frac{x_{det}}{m_{12}}$$

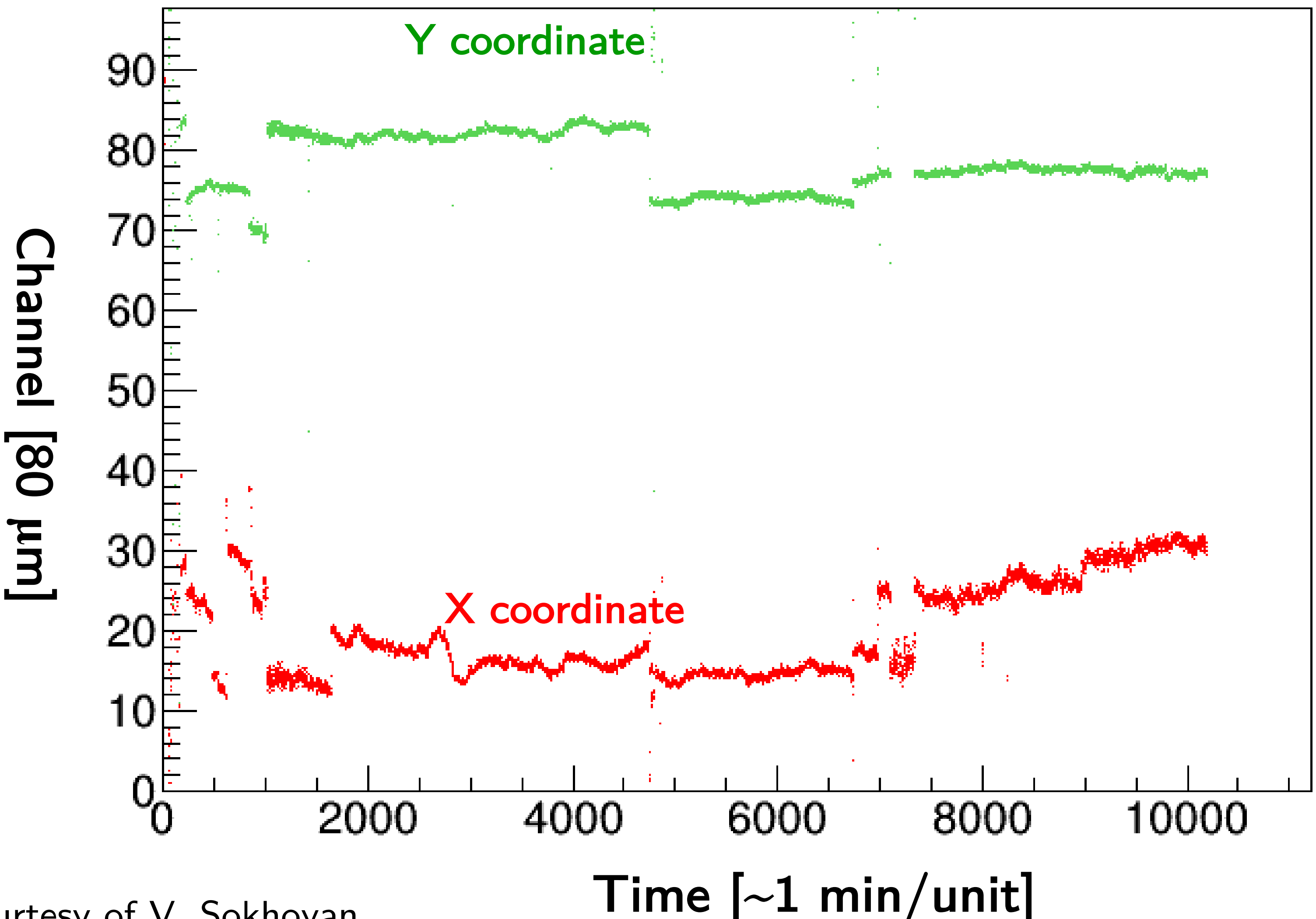
Neglecting parameters x_s and x'_{det} gives the optimisation algorithm (iterative)

$$m_{12} = x_{det}/x'_s$$

Measurement of m_{12}

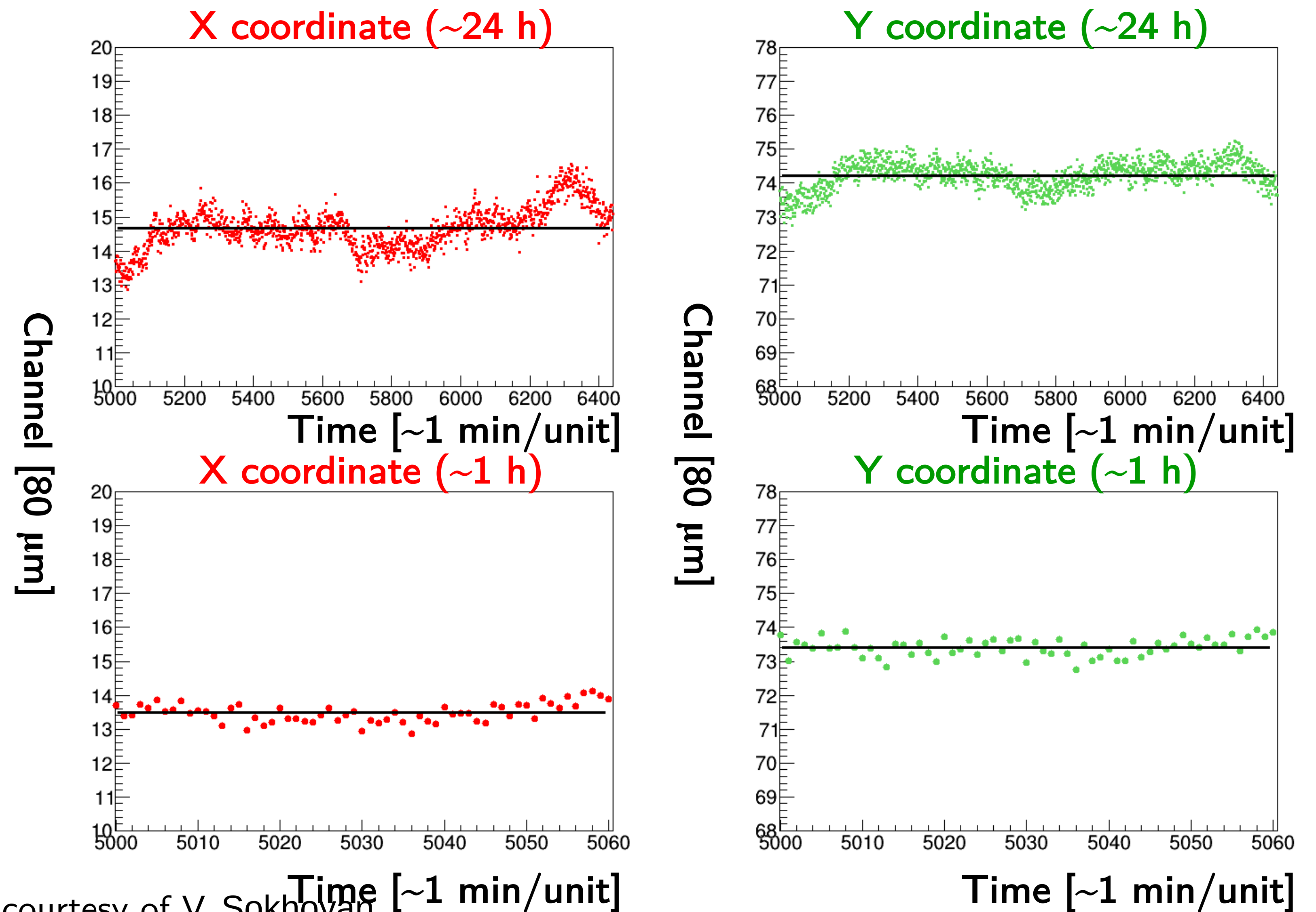
- Beam position measurement has to be done by the experiment (too low beam current!)
- Position data (raw number) published via simple protocol (i.e. HTTP, telnet, or similar)
- Position data should be updated continuously (approx. 1/s)

Mupix data, 2019 (without correcting for offsets)



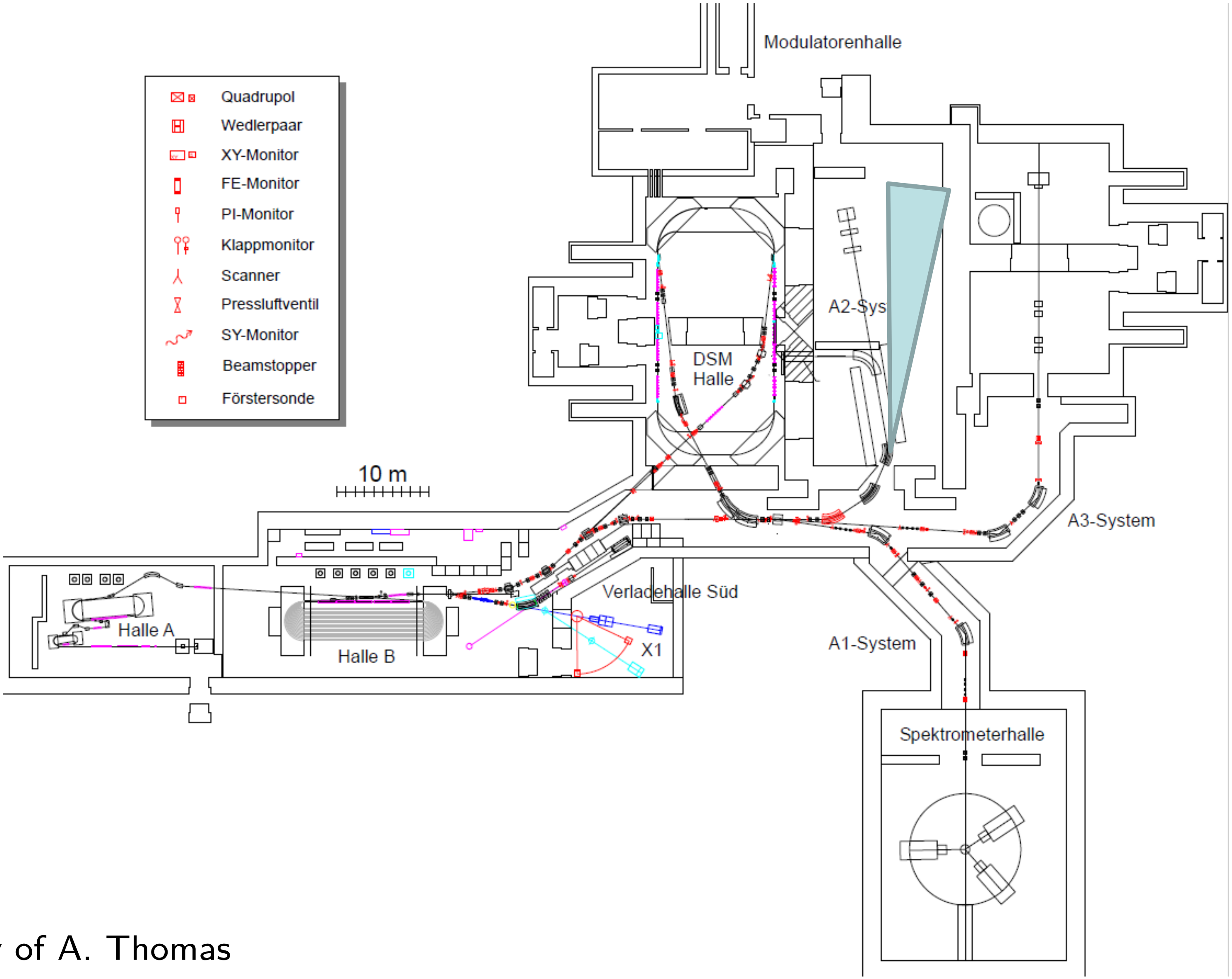
By courtesy of V. Sokhoyan

Mupix data, 2019 (without correcting for offsets)

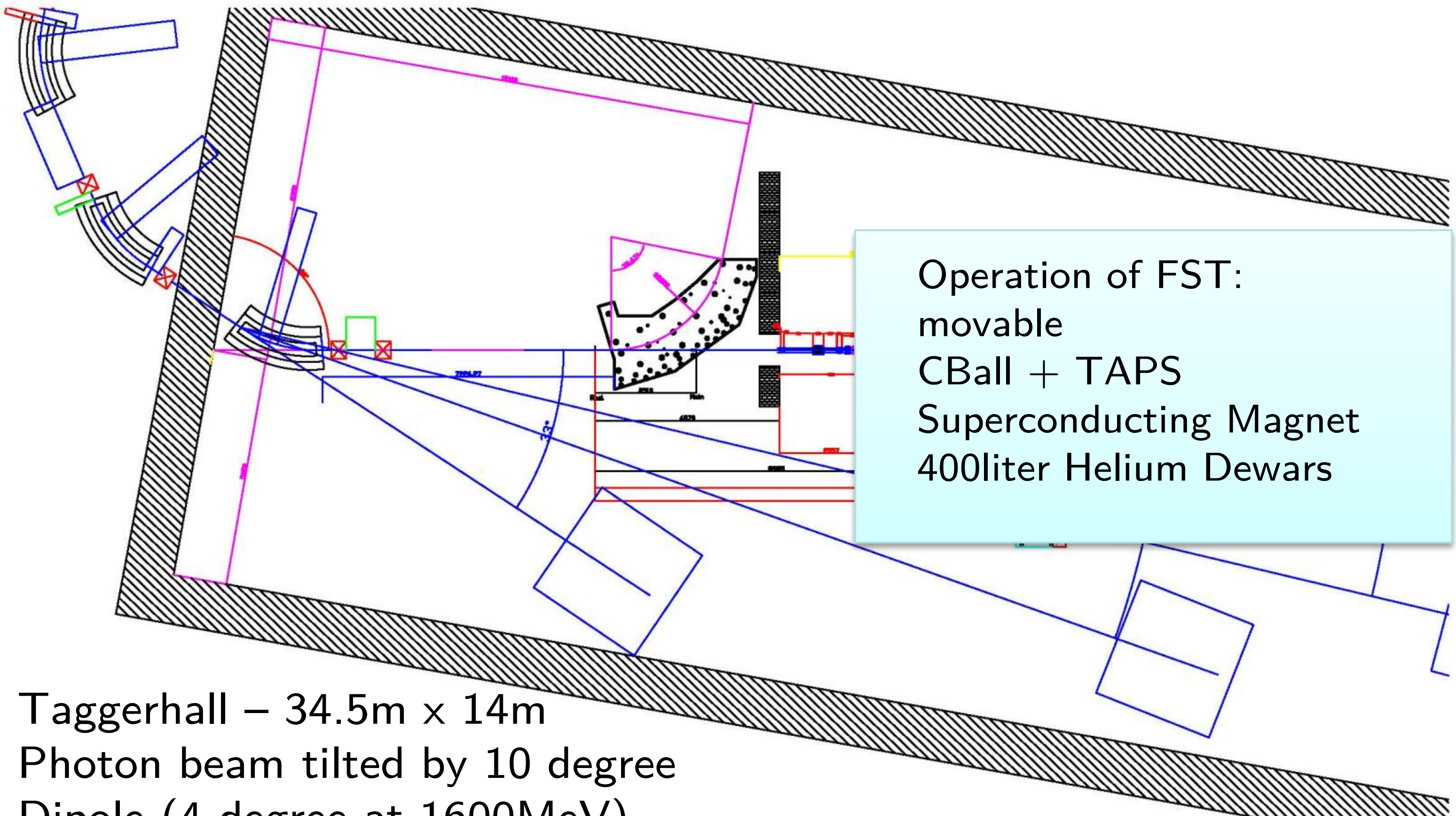


By courtesy of V. Sokhoyan

Possible location of the TPC at A2



By courtesy of A. Thomas

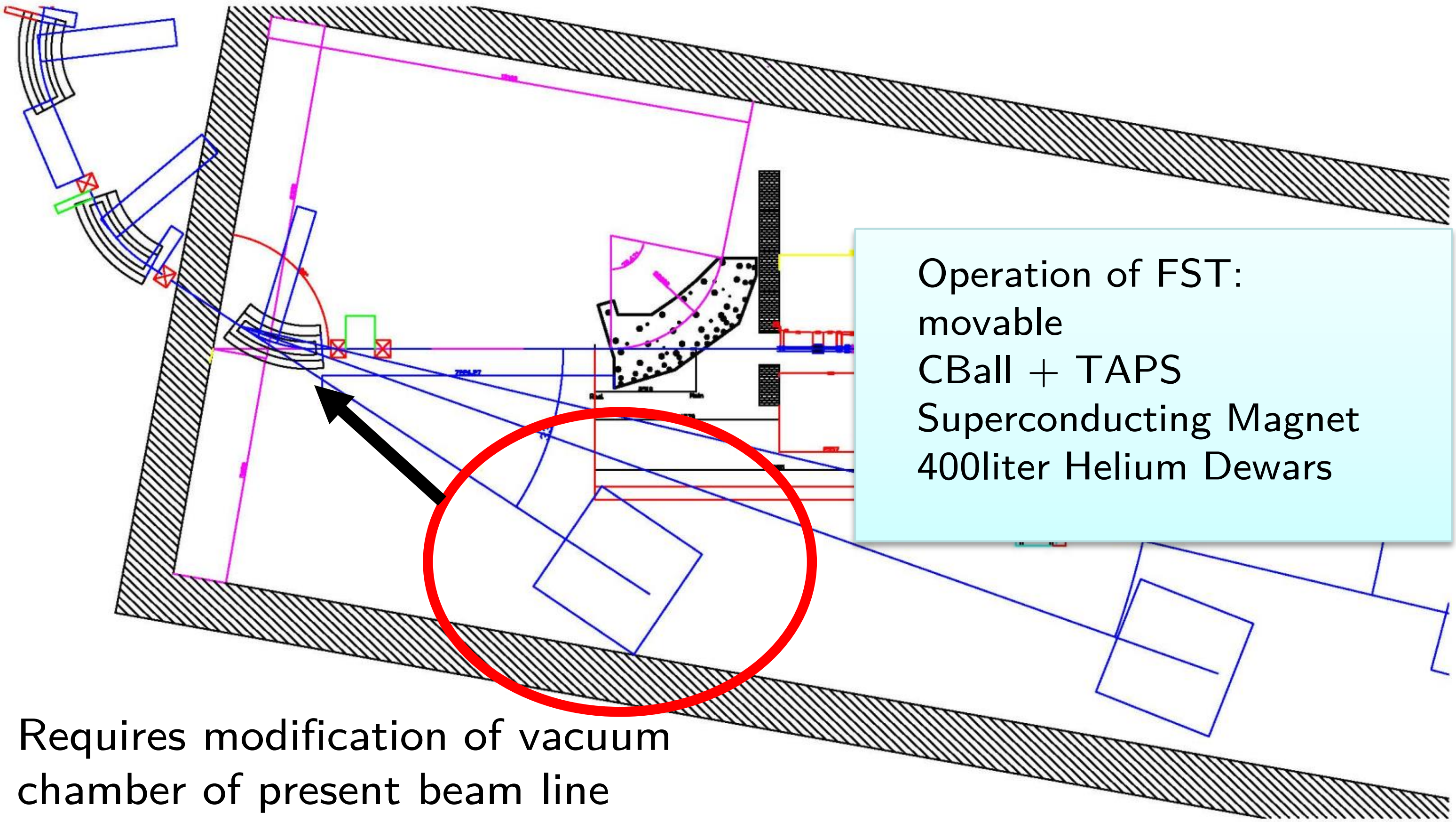


Operation of FST:
movable
CBall + TAPS
Superconducting Magnet
400liter Helium Dewars

Taggerhall – 34.5m x 14m
Photon beam tilted by 10 degree
Dipole (4 degree at 1600MeV)
to make beam horizontal needed

By courtesy of A. Thomas

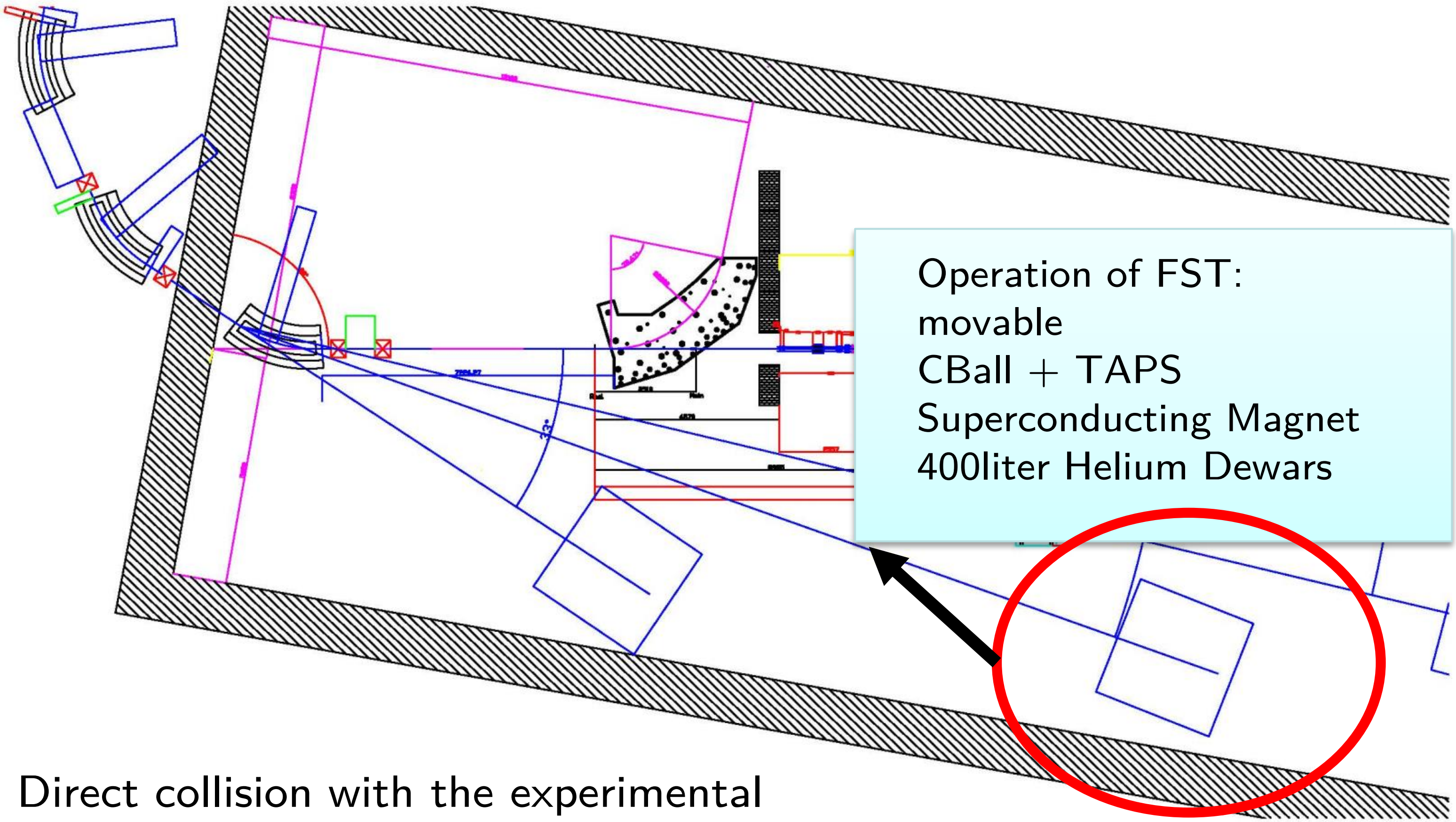
TPC at A2



Operation of FST:
movable
CBall + TAPS
Superconducting Magnet
400liter Helium Dewars

Requires modification of vacuum chamber of present beam line
Strong impact on ongoing experiments!

By courtesy of A. Thomas

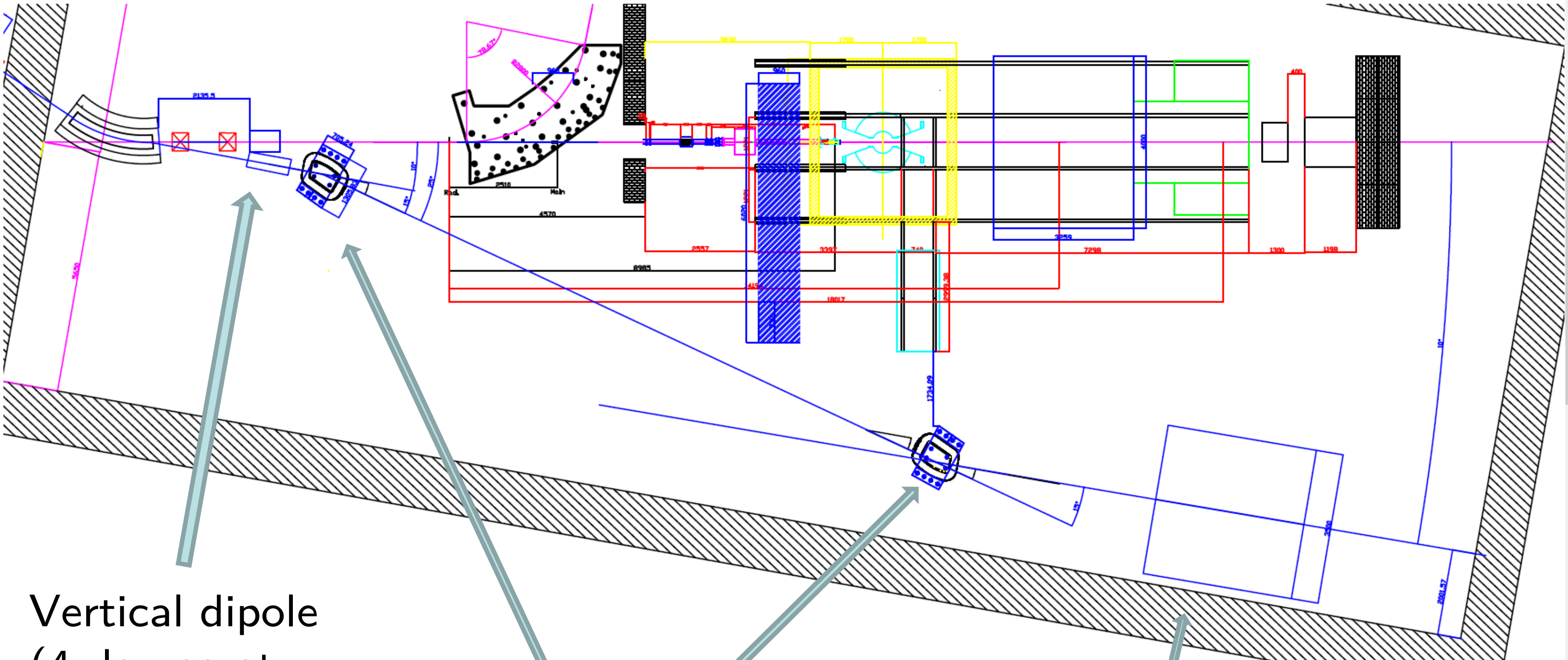


Operation of FST:
movable
CBall + TAPS
Superconducting Magnet
400liter Helium Dewars

Direct collision with the experimental equipment, not possible.

By courtesy of A. Thomas

TPC at A2



Vertical dipole
(4 degree at
1604MeV)

2 horizontal dipoles
(15 degree at 1604MeV)

Space for ‚core' TPC
3.5m x 3.5m

By courtesy of A. Thomas

Pictures of A2 and beam line elements