The Two-Beam Test-Stand in CTF3

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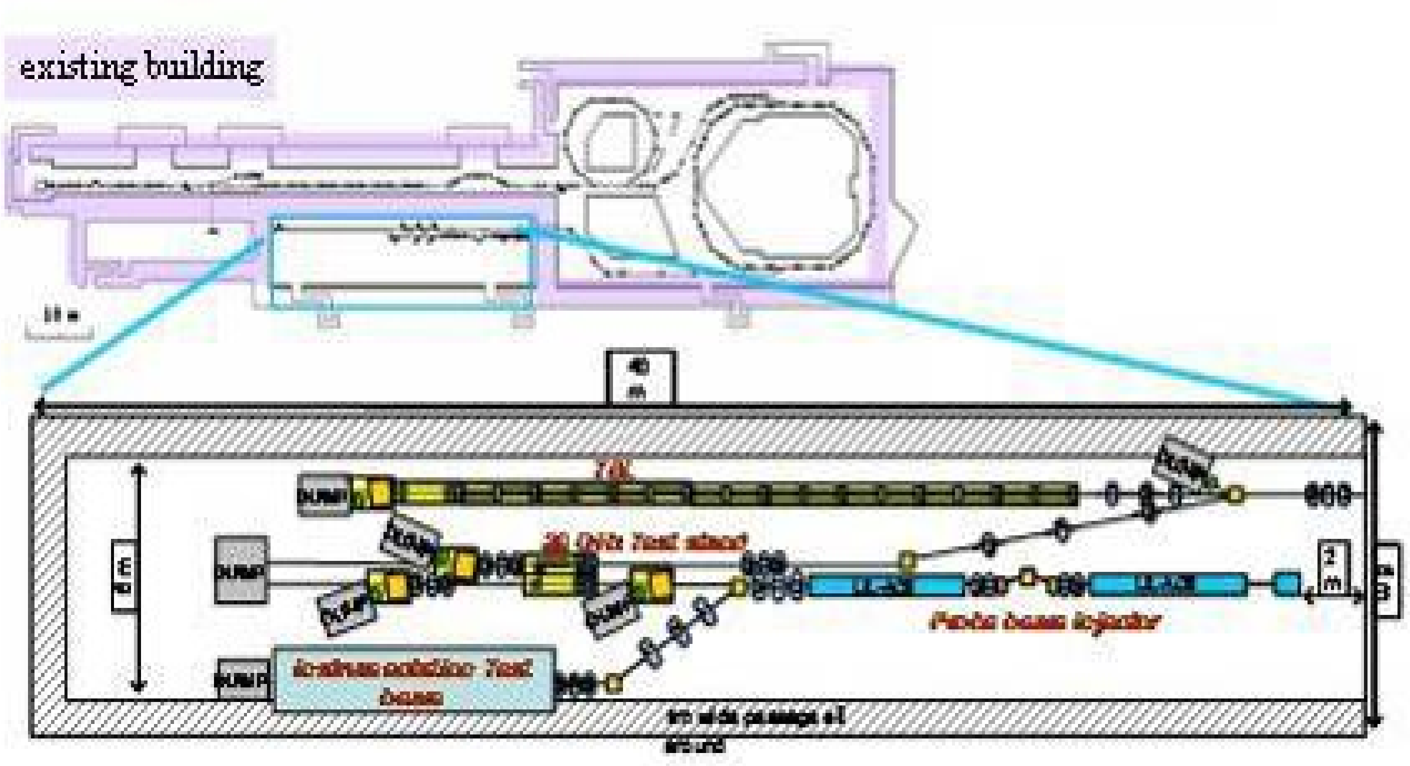
The CLEX building

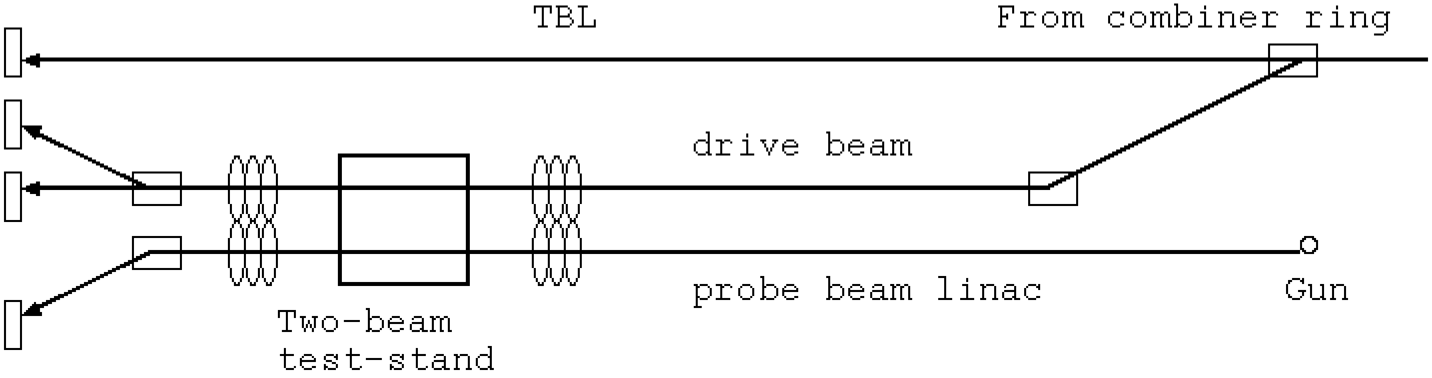


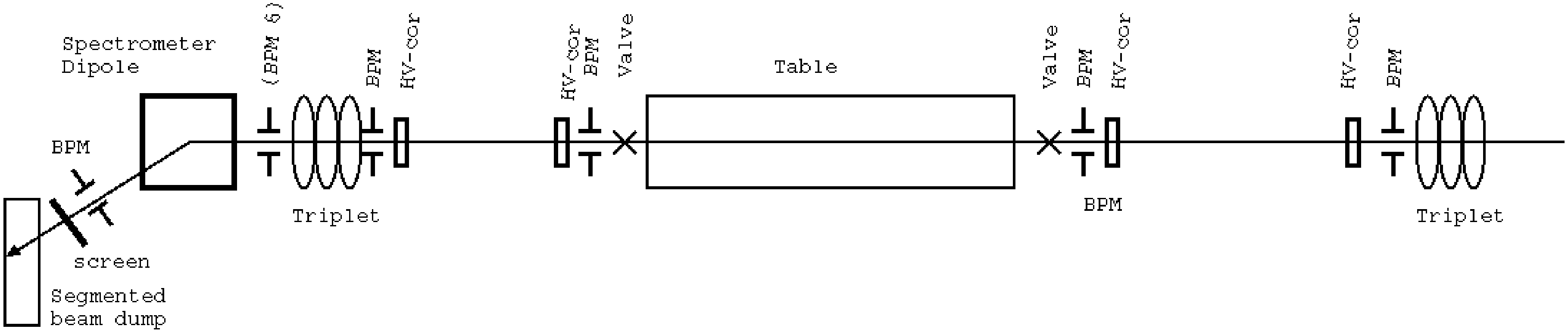
Under construction in connection to the existing CTF-buildings. The building itself will be finished late 2006, and installation of general utilities: electricity, water etc. will begin during 2007.

Purpose of the two-beam test-stand

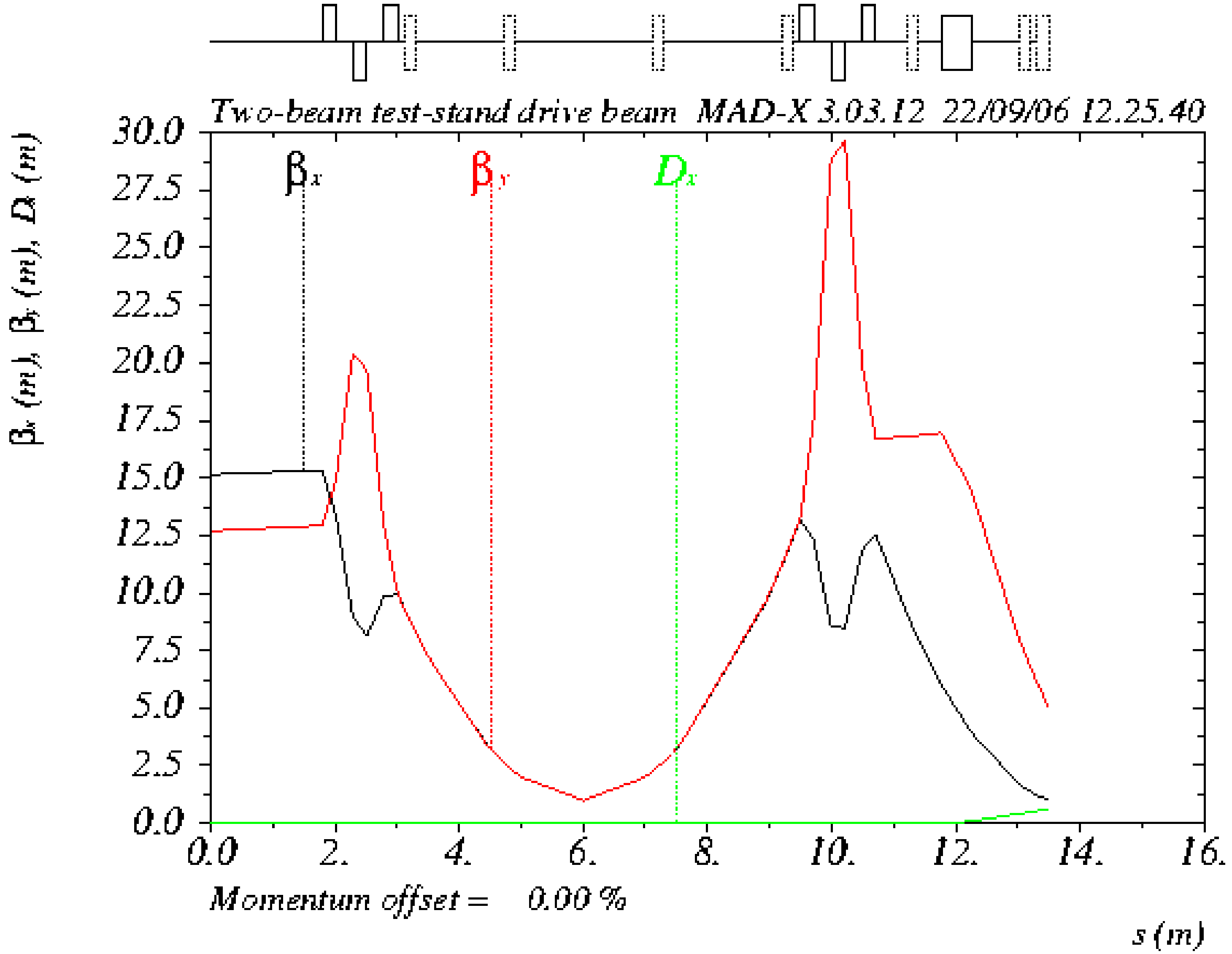
- Demonstrate operation of full CLIC module
  - The whole two-beam scheme will be tested for the first time: RF power will be extracted from the drive beam with PETS and used to drive accelerating structures in order to accelerate the probe beam.
- Operate PETS up to 300 MW and 60 ns pulse length
  - Will use longer PETS with same geometry to reach same power level despite smaller beam current of 30 A instead of 160 A in CLIC.
- Measure effect of RF-breakdown on drive and probe beam
  - Crucial to determine the acceptable breakdown rate in CLIC.
  - Might bring new insight into the breakdown-phenomena.

Setup


TBL
From combiner ring
drive beam
probe beam linac
Gun
Two-beam test-stand

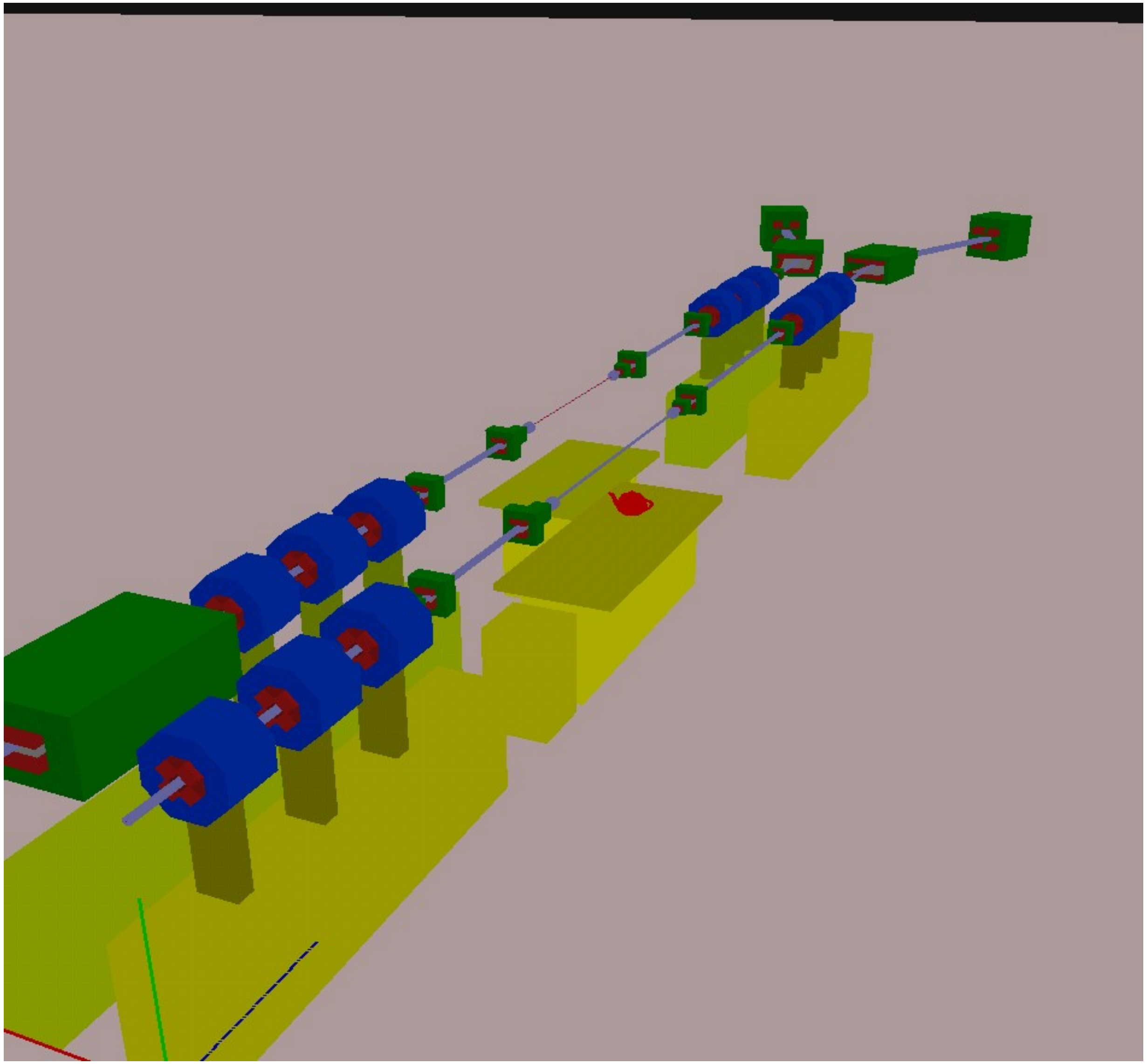

Spectrometer Dipole
(BPM 6)
BPM
HV-cor
HV-cor
BPM
Valve
Table
Valve
BPM
HV-cor
HV-cor
BPM
BPM
Triplet
BPM
Triplet
screen
Segmented beam dump

Beam optics



Two-beam test-stand drive beam MAD-X 3.03.12 22/09/06 12.25.40
β_x (m), β_y (m), D_x (m)
β_x
β_y
D_x
30.0
27.5
25.0
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0.0
2.
4.
6.
8.
10.
12.
14.
16.
Momentum offset = 0.00 %
s (m)

3-D visualization of the two-beam test-stand



RF–breakdown

- Occurs in the accelerating structure, PETS or any equipment with high electric fields.
- Locally the surface field is enhanced by surface irregularities: field emitters.
- The result is RF–breakdown, or arcing.
- A plasma is produced locally, and electrons are ejected into the cavity. These electrons interact with the strong accelerating field in the cavity, producing high currents, up to kA levels.
- Breakdown will damage the structure, removing material from the affected areas.
- Breakdown will also give the beam a kick. One of the challenges for the two-beam test-stand is to determine the characteristics of this kick.

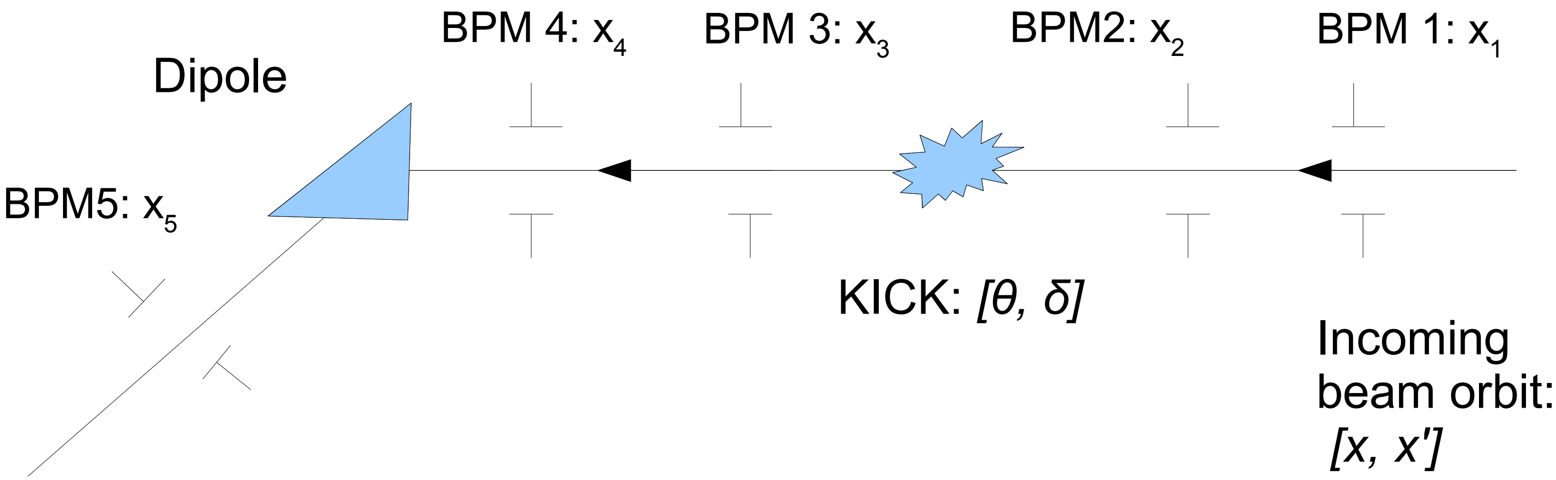
RF-breakdown diagnostics

- RF-signals will be handled like in the current high-gradient test-stand in CTF; the 30 GHz signals will be extracted with directional couplers, mixed down and sampled on digitizers.
  - Same analysis as in CTF: missing energy, reflected power...
- Other equipment can be added to allow more specialized measurements of various phenomena; acoustic waves in the structures, temperature changes, emitted light...
  - These measurements should be designed to be as general as possible. That is: try and remove the machine-dependence in the measurements.

Kick parameters

- TBTS will use BPMs to determine parameters of the kick from a breakdown.
- Incoming beam defined by 2 parameters: transverse beam offset, x, and beam angle x'. (First approximation: 1D only, no coupling x-y).
- RF breakdown causes a kick on the beam, and can change the beam angle, as well as energy of beam → two more parameters: θ and δ.
- These parameters determine the read-out of the BPMs. The dipole make the last BPM dependant on the kick energy, δ.
- Transfer matrices, M^{ba} relate the parameters $[x, x', \theta, \delta]$ with the readout of the BPMs.

Kick parameters



Dipole

BPM 4: x_4

BPM 3: x_3

BPM2: x_2

BPM 1: x_1

BPM5: x_5

KICK: $[\theta, \delta]$

Incoming beam orbit: $[x, x']$

$$X_0=[x, x', 0]$$
$$K=[0, \theta, \delta]$$

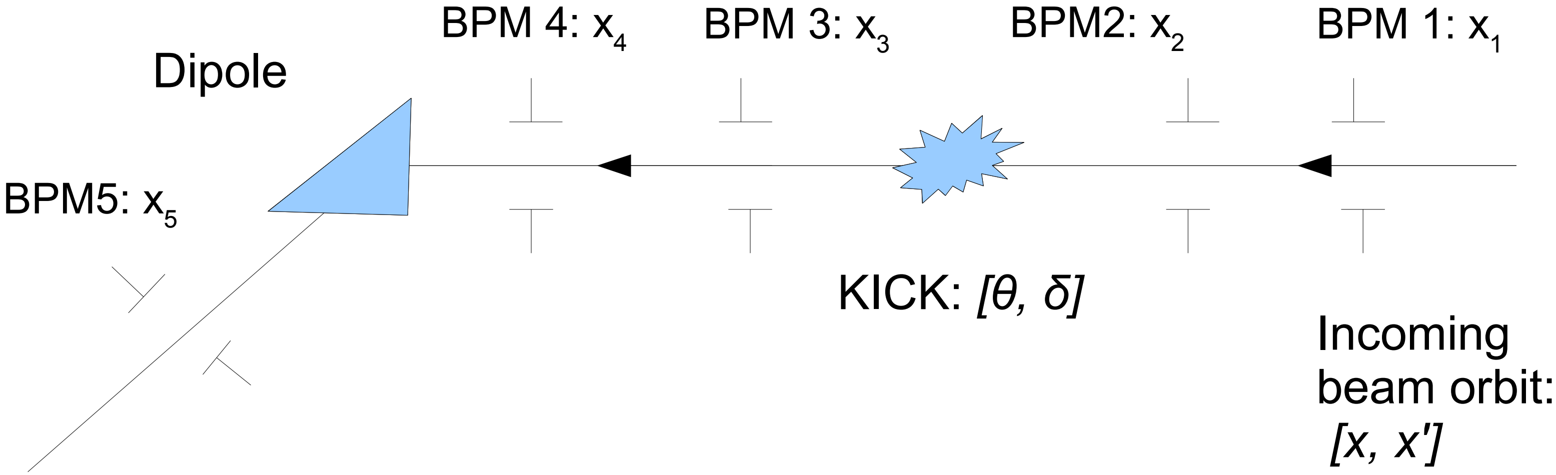
$$x_1 = [X_0]^1$$
$$x_2 = [M^{21} * X_0]^1$$
$$x_3 = [M^{31} * X_0 + M^{3C} * K]^1$$
$$x_4 = [M^{41} * X_0 + M^{4C} * K]^1$$
$$x_5 = [M^{51} * X_0 + M^{5C} * K]^1$$

$$M^{51} = M^{54} * M^{43} * M^{32} * M^{21}$$

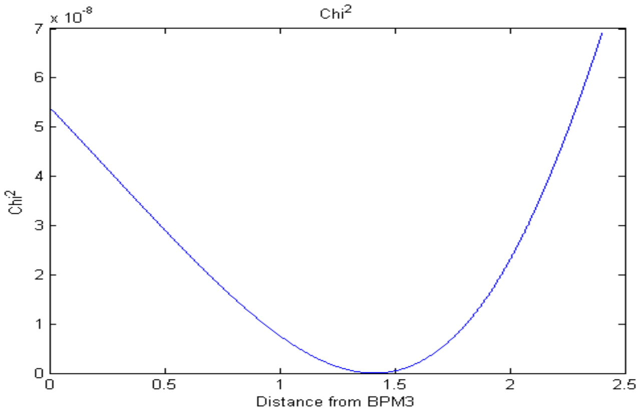
Least square estimation of parameters

- $[X] = [A] * [x, x', \theta, \delta]$
- Where $[X]$ = BPM readout = ($x_1, x_2, \ldots, x_5, (x_6)$),
- $[A]$ = Relates the parameters $[x, x', \theta, \delta]$ with the BPM readout. Depends on the transfer matrices $[M^{ba}]$.
- To find the parameters: solve the over-determined system (5-6 BPM readout and 4 parameters) in the least-square sense, and is equivalent to:
- $([A]^T * [A])^{-1} * [A]^T * [X] \approx [x, x', \theta, \delta]$

Least square estimation of the position of the kick



Divide the position between BPM2 and BPM3 into *n* pieces. Construct a transfer matrix ***[M$_{3c}$]*** for each *n* and do a least square estimation for all *n.* Choose the *n* that minimize the error to be the location of the breakdown.



Error estimation

- The error due to inaccuracy in BPMs can be estimated by the covariance matrix, *[C]*:
- $[C] = ([A]^T * [A])^{-1} * \sigma^2$
- Where *[A]* is defined above, σ is the error in the BPMs (about 10 μm).
- The error for parameter *n* is then given by
- (Error for parameter *n*) = $\sqrt{([C]_{nn})}$

Results error estimation

- (Slightly) Smaller errors with 6 BPMS than 5 BPMs. *σ* is the error of the BPMs ≈ 10 µm :

Number of BPMs	5	6
Error in position, *x*	0.9691 * σ	0.9577 * σ
Error in angle, *x′*	0.6853 * σ / m	0.5968 * σ / m
Error in kick angle, *θ*	1.1056 * σ /m	0.8435 * σ /m
Error in relative energy from kick, *δ*	3.1612 * σ /m	2.7301 * σ /m

A kick with a voltage of 2 kV corresponds to a kick angle ≈ 10 µrad.

Conclusions

- The two-beam test-stand will for the first time test a fully operational CLIC module: PETS will generate high power to drive accelerating structures, which will accelerate a beam.
- The effect of breakdown on both the probe-beam and drive-beam will be tested.
- The accuracy with which we can measure the kick parameters are sufficient according to early estimations.

Explanations to Setup

- Two beams: drivebeam from combiner ring and probe beam from probe beam linac (also located in the CLEX building).
- PETS=Power Extracting and Transfer Structure
- TBL = Test Beam Line. Used to test the drivebeam stability in PETS
- Match the beam size to PETS, accelerating structures → quadrupoles.
- Steering in structures → two dipole correctors before and after table.
- Position measurements → inductive Gasior BPM, also needed for the kick-measurements. In total 5 or 6 BPMs.
- Energy measurements → BPM after spectrometer magnets.
- Energy spread → OTR screens before the dump, possibly later a segmented beam dump.
- Vacuum → valves to decouple experimental tables.
- 75 cm distance between probe and drive-beam → this is close to the planned distance in CLIC, and also reasonable small in order to avoid losses.