Towards Concepts for Machine and Detector

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THERA Workshop
DESY
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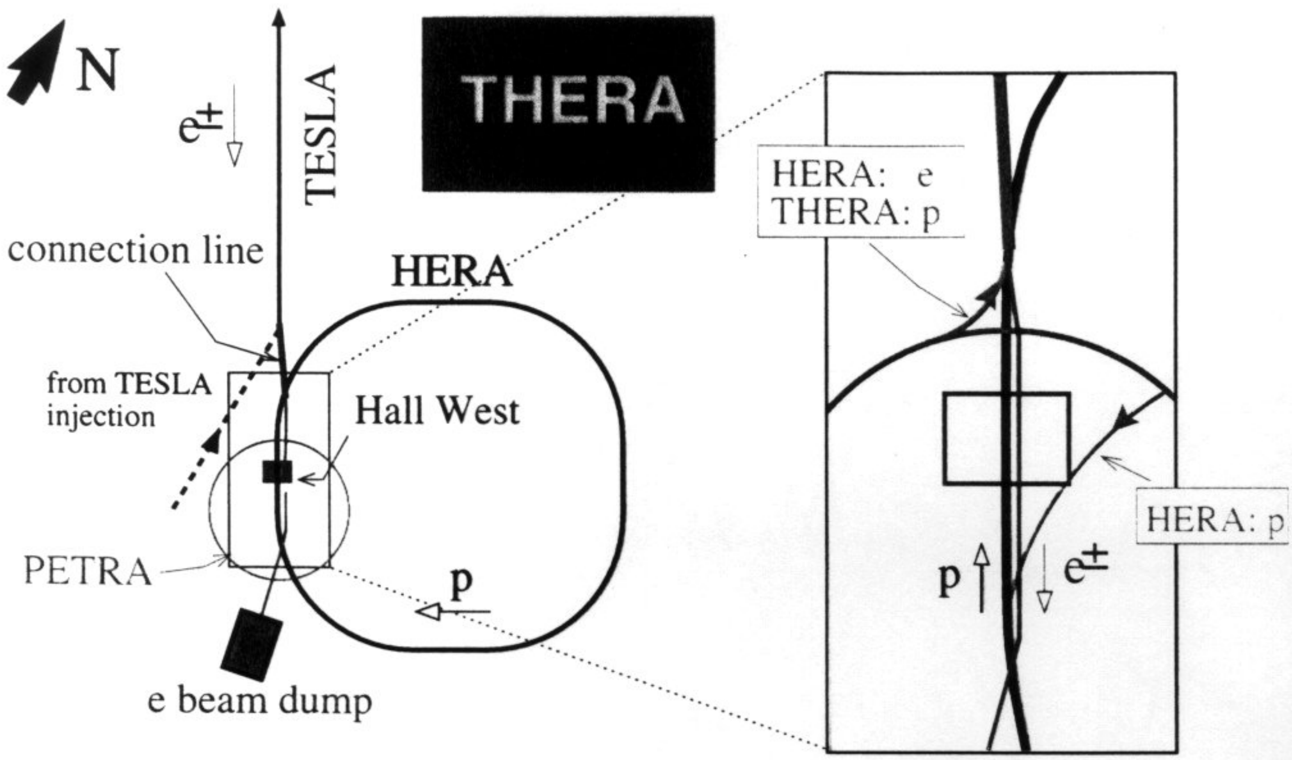
- News on the accelerator complex
- Detector requirements
  - boundary conditions
  - what to measure
- Approaching a detector concept
  - overall sketch
  - rear components
  - central part: recycling?
  - forward region

The THERA complex

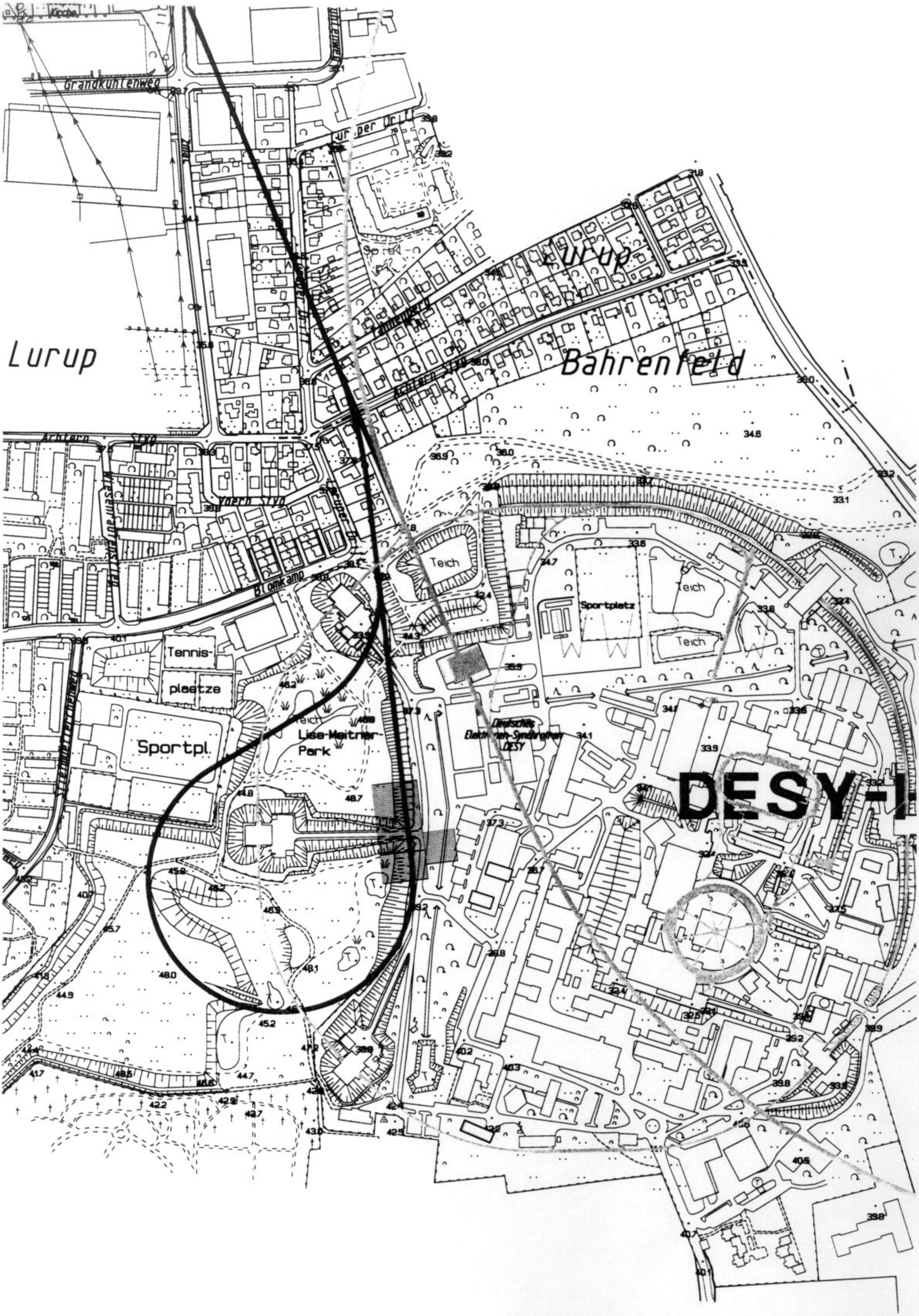


HERA p-ring and tunnel modifications

- Reverse proton direction
  - New magnets for p injection to HERA (7 T or new tunnel)
  - Move p dump or beam kickers
- ep beam separation, new p focusing
- Option: Additional RF to reduce p emittance
- Transfer e beam into and out of HERA tunnel

New components

- Transfer line from TESLA to HERA
  - civil engineering, not on DESY area
  - no active beam line elements
  - "thin" tube might be sufficient
- e beam dump
  - $1 \times 1 \times 8\,m^3$ H_2O in 4 m concrete walls
  - tunnel HERA→dump
  - not clear whether sufficient space on DESY area



Grandkuhlenweg
Lurup
Lurup
Bahrenfeld
Achtern Styg
Blomkamp
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Sportpl
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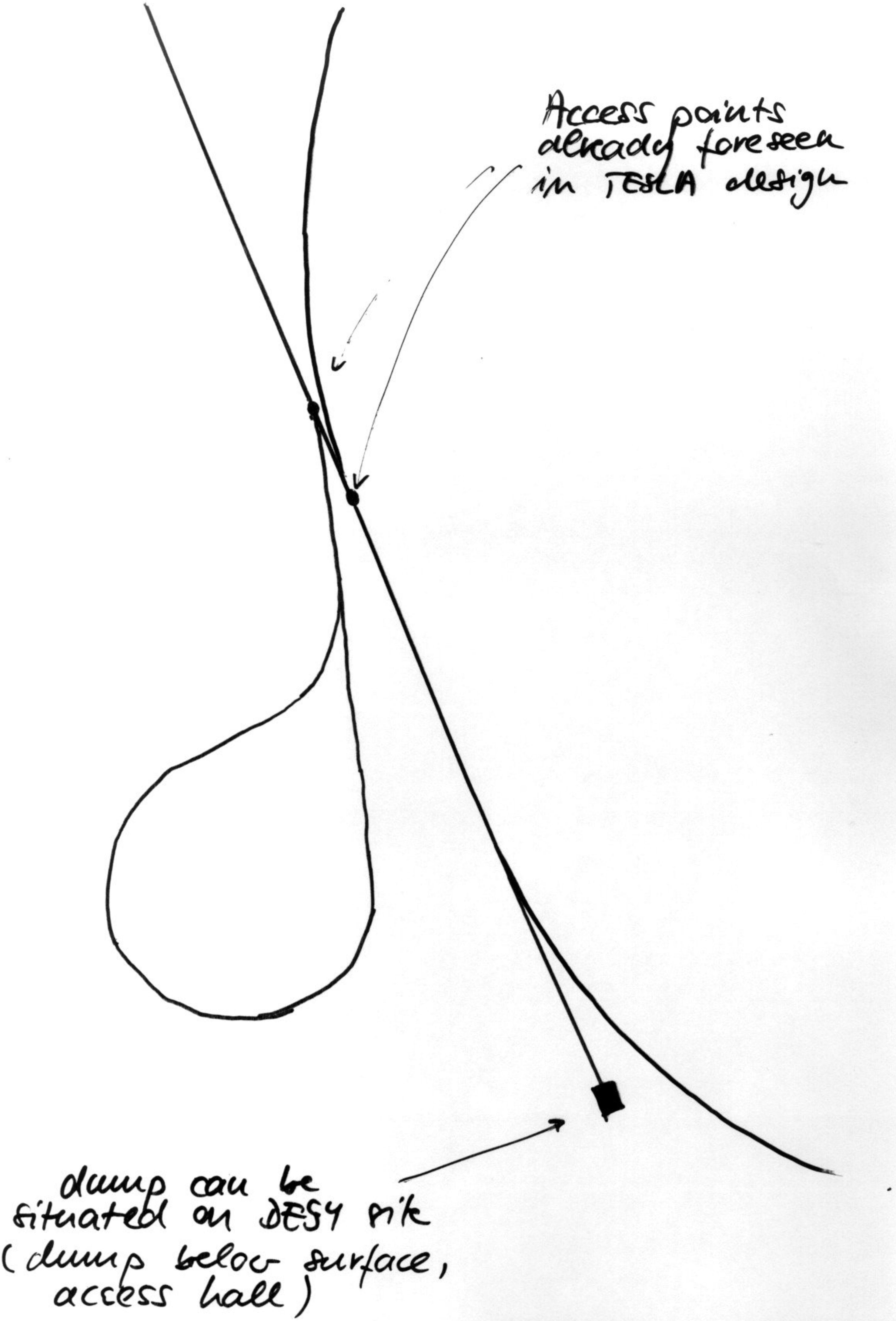
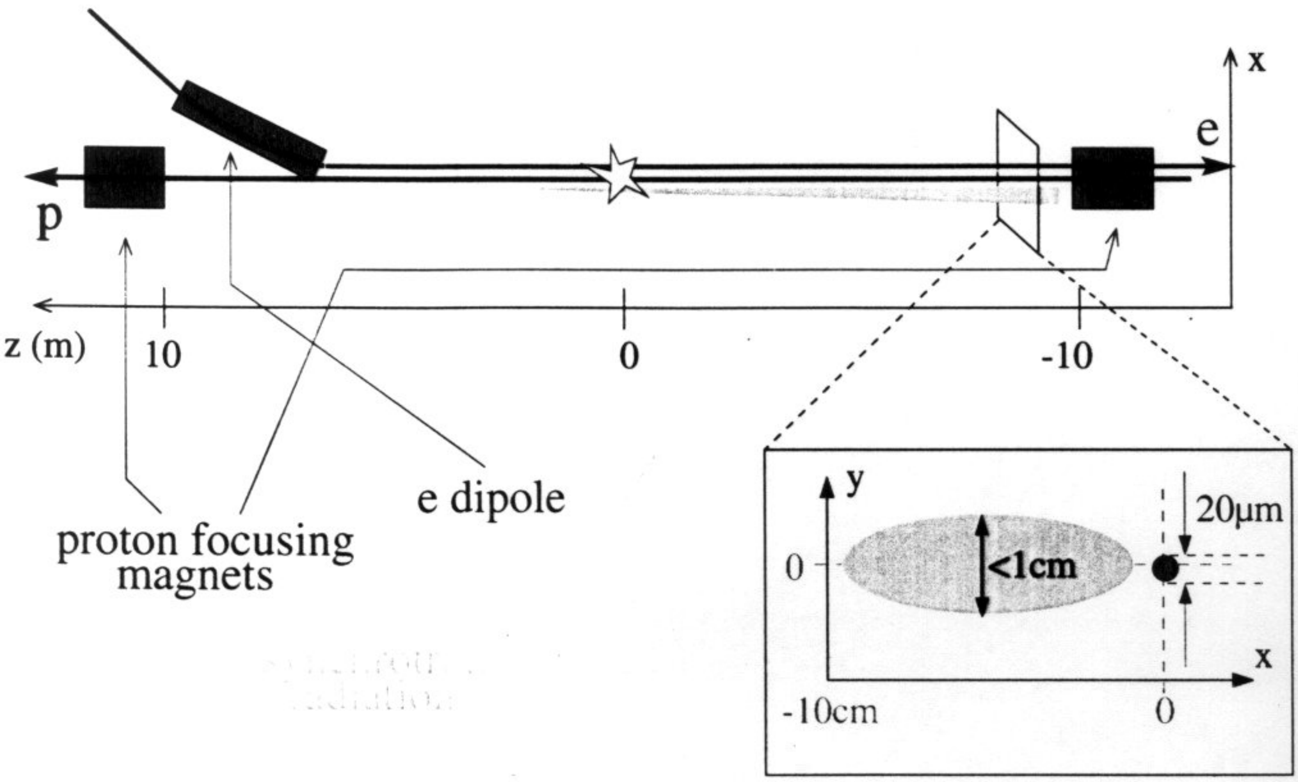
Lise-Meitner-
Park
DESY
DESY-I


Access points
already foreseen
in TESLA design
dump can be
situated on DESY site
(dump below surface,
access hall)

THERA interaction region



beam elements:	protons: $\sim 10\,\text{m}$ from IP preferred: symmetric setup, superconducting lenses
interaction zone:	longitudinal: proton-dominated, like in HERA ($\sim 10\,\text{cm}$) transverse: circular, diameter $\sim 20\,\mu\text{m}$
sync. radiation:	a fan of ca. $10\,\text{cm} \times 1\,\text{cm}$ at $10\,\text{m}$ distance from I.P.
crossing angle:	head-on collisions preferred

- √ measurements at $\theta \sim 0.5°$ possible with (almost) 2π coverage
- √ e, γ and p taggers possible
- √ vertex constraint useful for heavy-flavor measurements

DETECTOR DESIGN GOALS

HERMETIC CALORIMETER COVERAGE:

++
- Necessary for good $(E-p_z)$ measurement
- CC, (cross-)calibration, ...

BACKWARD (e-DIRECTION)

Energy scale = E_e = 250 GeV

++ • Identification and measurement of e to 179.5°

+ • Heavy-flavor physics: → measure hadronic tracks and energies to 179°...179.5°

+ → Muon-identification

FORWARD (p-DIRECTION):

Energy scale = $E_p \simeq$ 1 TeV ⇝ HERA-like

+ • Forward jets down to ~1° [at 0.5°...2° no tracking necessary]

+ • Precise measurement of energy flow → diffraction

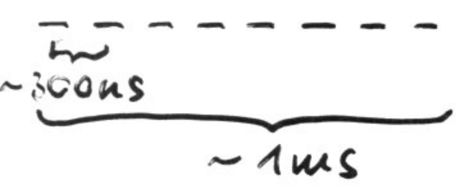
DETECTOR: BOUNDARY CONDITIONS

SPACE:

- Fit into West hall ($\sim 25 \times 35\, m^2$)
- Accomodate interaction region
  [→ p focussing magnets O(1m) from interaction point]

BUNCH TIMING:

bunch trains @ 5 Hz:

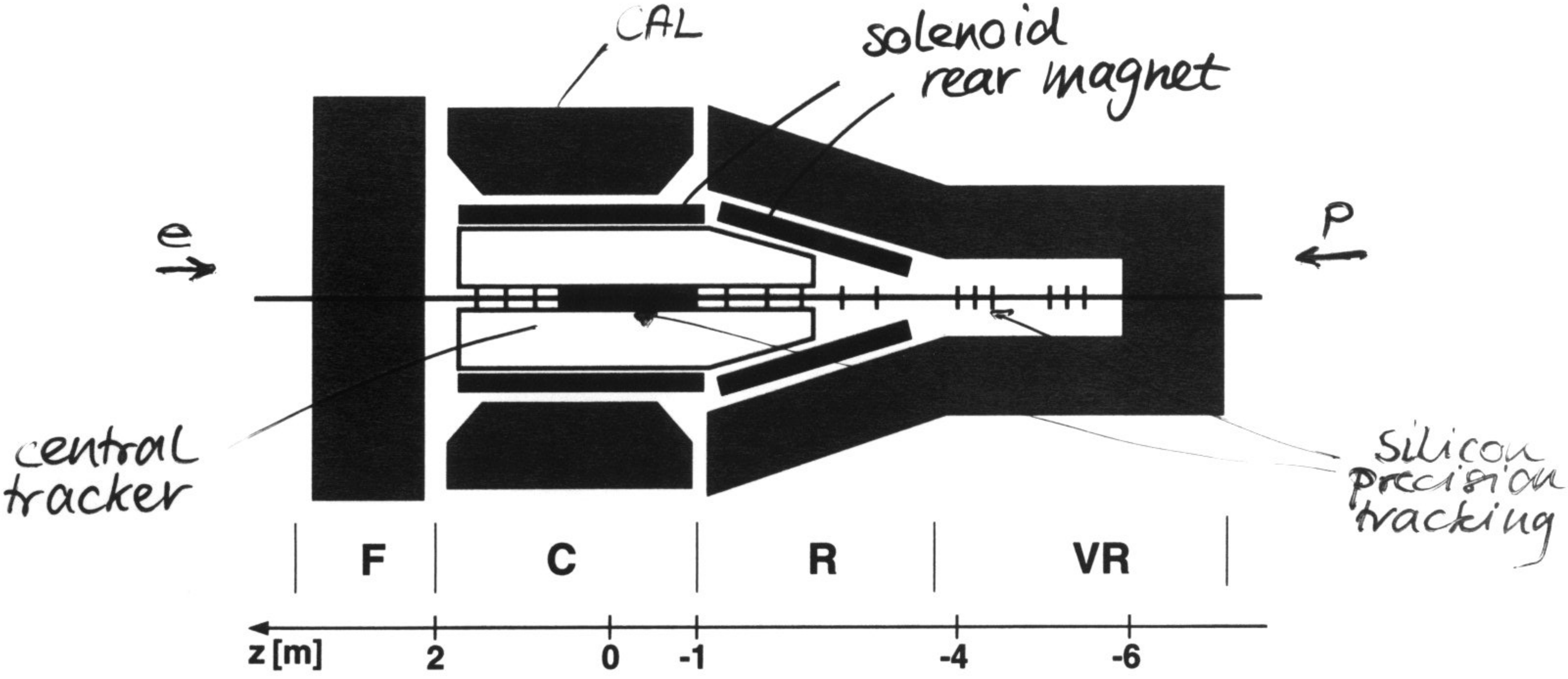


- O(300 ns) between subsequent bunch crossings
  → requirements less restrictive than at HERA, LHC

COST:

- "As low as possible"
  → small compared to TESLA
  → THERA detector ≙ THERA infrastructure?
  → Recycle existing ZEUS / H1 components?

A FIRST SKETCH OF THE THERA DETECTOR



not all details are to be taken seriously!

(R+VR) : BEAMPIPE AND TRACKING

(1)

BEAMPIPE RADIUS:

- Crucial parameter — determines "detector length" in rear direction
- $\Theta = 179.5° \rightarrow$
  $\pi - \Theta \simeq 9$ mrad
  $\Rightarrow |z|_{max} = O(10^2 R_{BP}) + 4m$
- Assumed : $R_{Bp} = 4$ cm

SYNCHROTRON RADIATION:

- ca. 10 cm "fan" at $z = -10$ m
- to be investigated in more detail
- Only affects azimuthal range of 45 ... 90°

BEAMPIPE SHAPE:

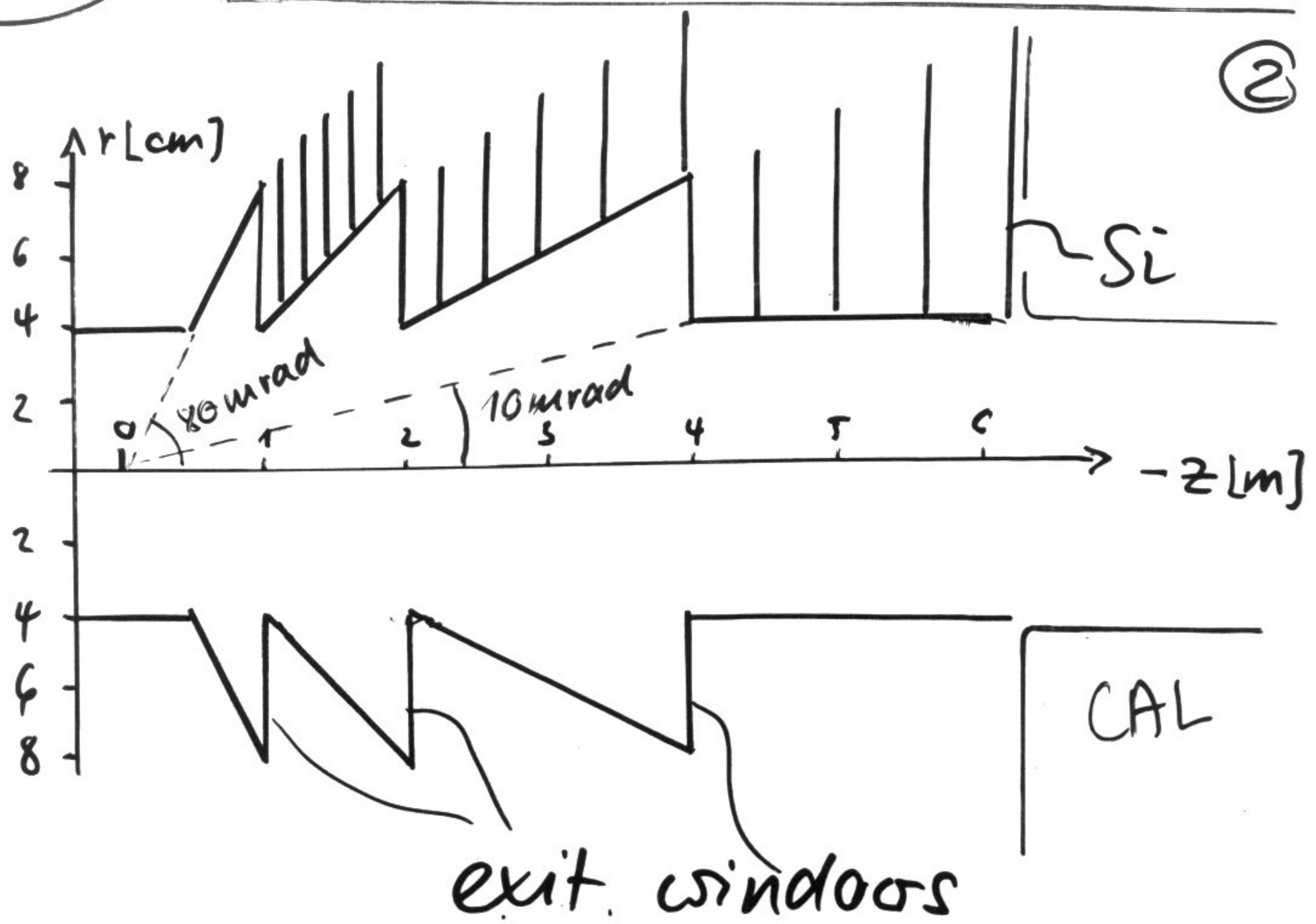
- Simple cylindrical or elliptical shape impossible (too much material @ 10 mrad)

(beampipe with 1% X_0 $\rightsquigarrow$ e sees 100% X_0 @ 10 mrad)

- $\rightsquigarrow$ need exit windows for electrons (and for charged hadrons if precision tracking required)

(VR+R) BEAMPIPE AND TRACKING

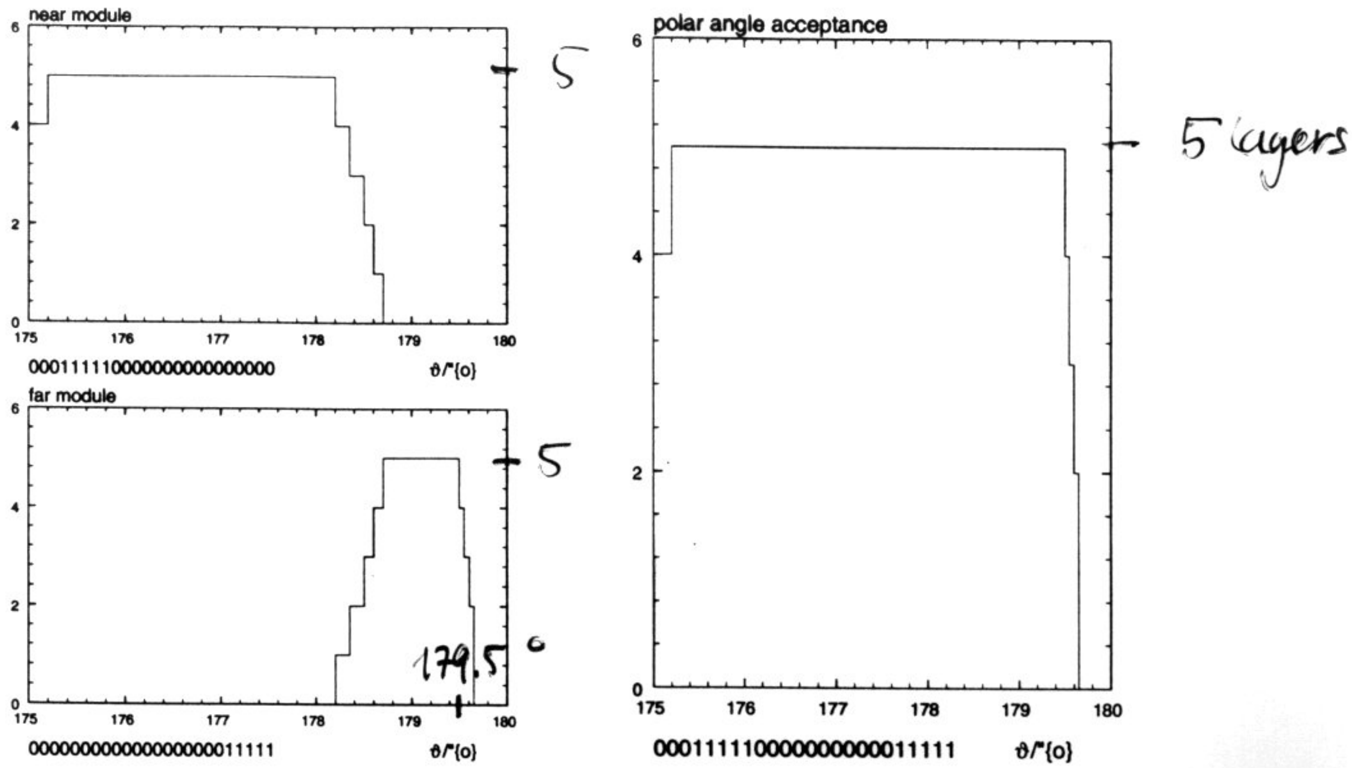
2



- Beampipe of this type seems feasible
- Exit windows can be thin [~> ≲ 1 mm Al ≙ ≲ 1% X_0]

→ Geometrical coverage from 10 - 80 mrad, acceptance losses in "trumpets" small.

→ Full azimuthal acceptance (modulo synchrotron radiation)



THERA Backward Silicon Tracker - Geometry

- 6 inch Silicon detectors, $R_i = 4$ cm, $R_o = 11$ cm
- Near Module - z = 128.1 139.2 151.1 164.2 178.3
- Far Module - z = 480.5 521.3 566.8 615.6 668.6 cm
- 240 wafers = 12 wafers * 2 sides * 2 modules * 5 planes
- rough cost estimate
  720kDM Si, 700k readout + development cost = 2MDM

Study by Max Klein using the H1 BST simulation

(VR+R)

e - IDENTIFICATION AND B - FIELD

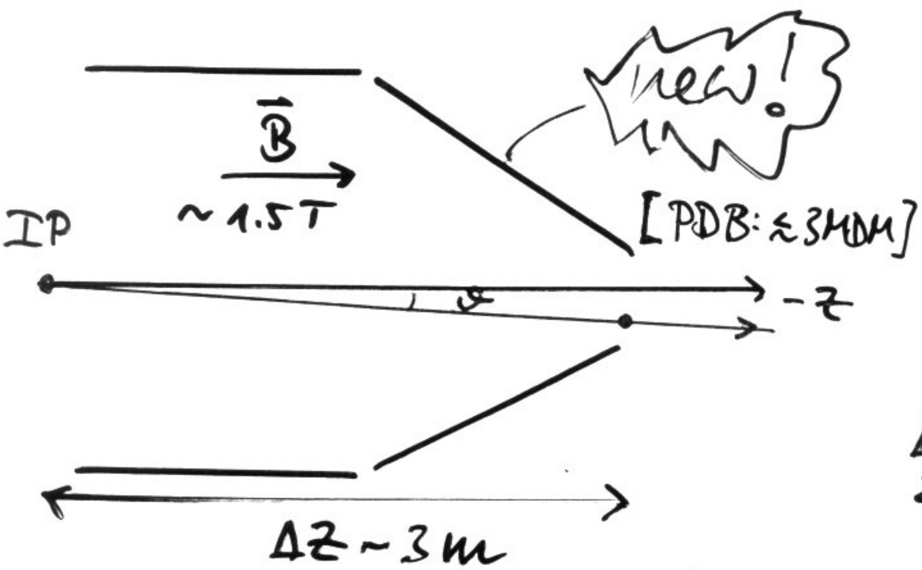
e IDENTIFICATION METHOD:

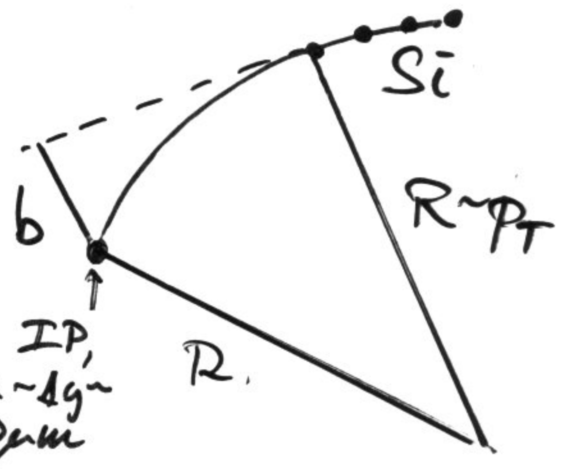
- [Isolated] elm. shower in CAL
- Matching track in silicon tracker
- Statistical subtraction of wrong-sign background

(requires measurement of e charge)

B - FIELD:

- Needed to determine track momentum/charge

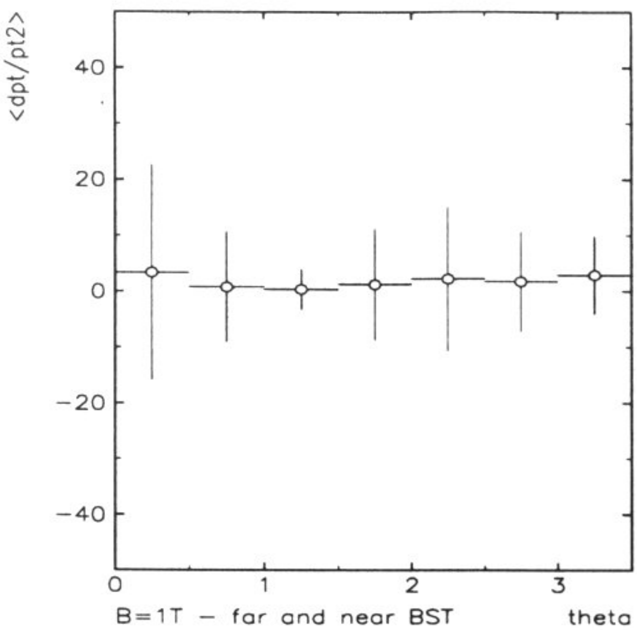


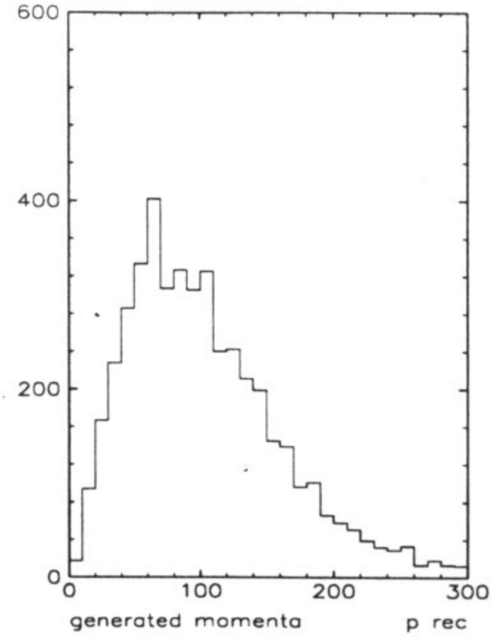


$$b = \Delta z \cdot \frac{\sin\vartheta \cdot \Delta z[m] \cdot B[T]}{6.7\, p_e[GeV]} \xrightarrow{p_e = 250\,GeV} b \simeq 80\,\mu m$$

o.k. !

Simulation by Max Klein





BST - Momentum Measurement

- x, y vertex with 20 μm as defined by TESLA
- assume 20 μm resolution in x and y - e.g. BST(H1)
- magnetic field 1T
- the interplay of geometry (in z) and inclination leads to theta dependent $\delta p_T/p_T^2(\theta) \simeq 10-20\%$ for $\theta \simeq 0.5^o$
- pipe 0.6mm Carbon fibre of 3.5cm radius, MS important for impact parameter, heavy flavour, not so much for charge or momentum measurement since $\boldsymbol{E_e}$ is large

slightly different scenario: B = 1T over full length

→ for p = 250 GeV and ϑ = 10 mrad ⇒ p_T = 2.5 GeV } ⇒ $\frac{\delta p_T}{p_T} \simeq$ 25-50 %

(VR+R) CALORIMETRY

TASKS:

- Close central CAL in rear direction ("endcap")
- Measure e and hadr. energies upto 250 GeV (even 500 GeV ...)
- Identify elm. showers, allow track-CAL matching, determine e isolation.

(ZEUS+H1 rear calorimeters not made for such energies, beam holes too large)

POSSIBLE SOLUTION:

- Adapt TESLA CAL technology:
  - Si W (one option)
  - $R_{Molière} \simeq 1$ cm
  - transverse cell sizes: 1.2×1.2 cm^2
  - fine longitudinal segmentation
  - ~ 300 MDM for (huge!) TESLA CAL.

(Maybe even too good for us?)

NEEDED:

- Simulation studies to obtain solid estimates of resolution and granularity requirements.

(generator level?)

⤳ studies under way

(C) RECYCLING: CALORIMETER AND SOLENOID

REQUIREMENTS:

- Hermeticity
- e/hadronic energies up to a few 100 GeV [larger than at HERA in rear part]
- e identification, jets, B-field for tracking

IDEA:

Use BCAL and solenoid from ZEUS

H1 CAL might also be possible, problem: cryostat

→ transport technically feasible (probably ...)

→ CAL suited for THERA energies + tasks

→ electronics, readout etc. usable (if still working ...)

→ ZEUS solenoid: designed for B ≃ 1.8T

(C) TRACKING

RECYCLING?

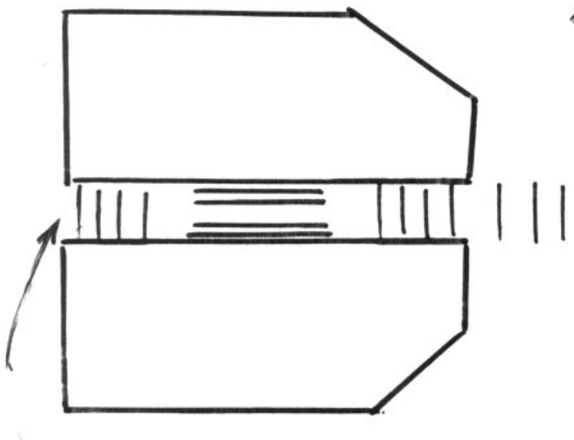
- Probably impossible due to life time restrictions of detectors

→ How would we design central tracking given the HERA experience?

IDEA:

- One (or several) tracking chambers covering full length of central volume

→ avoid "end flanges" inside tracking volume



- Silicon precision tracking in "inner volume"

→ $r \lesssim 15$ cm, full length of tracking volume

→ extended to rear direction

at $r = 4$ cm, $z = 2$ m

→ coverage down to $\theta = 1^\circ \ldots 2^\circ$

⑦ CALORIMETER

GOALS:

- Measure jets down to $\theta \simeq 0.5° \ldots 1°$

→ coverage at small r
[r = 4 cm @ z = 3m]

→ granularity determined by jet structure + hadronic shower sizes

RECYCLING?

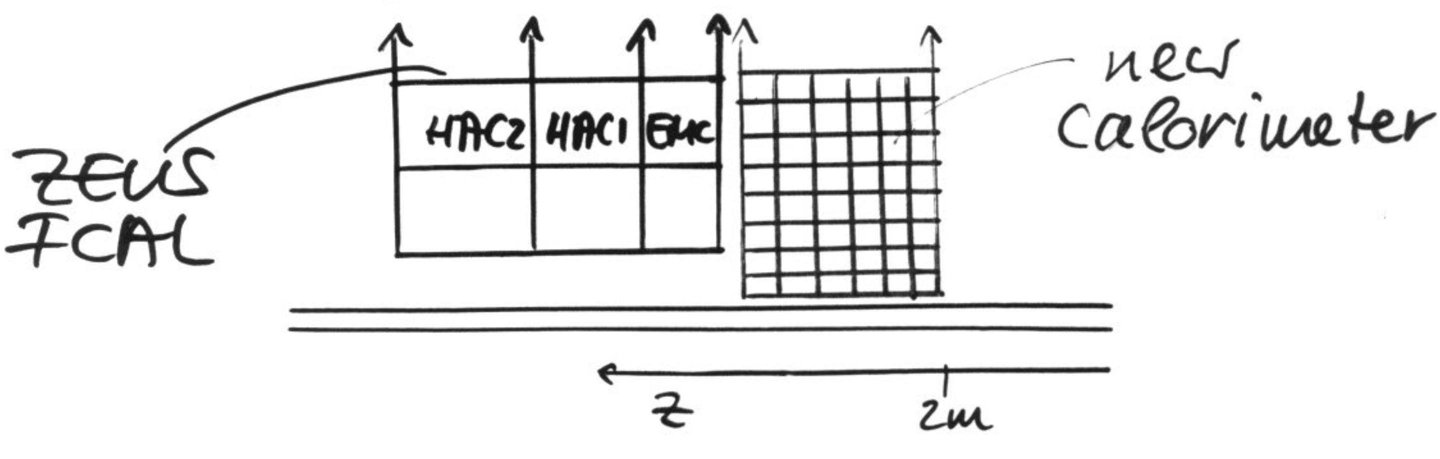
- Problems with existing calorimeters:

→ beam hole too large

→ granularity?

IDEA:

- Build new, fine-grain, high-resolution "elm." calorimeter
- Use ZEUS FCAL as "hadronic section"



SUMMARY

THERA INFRASTRUCTURE:

- No show stoppers (so far).
- Beam dump can be on-site

DETECTOR:

- Status of studies:
  - → essentially "after brainstorming"
  - → basic ideas exist,
  - → quantitative studies needed to produce solid concept.
- ZEUS/H1 recycling partly feasible
- Rear direction needs development of a new detector → very demanding!

THERA physics goals seem to be accessible !