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A Forward Silicon Tracker for H1

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Abstract:

It is proposed to build a forward silicon strip detector (FST) for the H1 experiment to be installed during the HERA luminosity upgrade shutdown. The FST will make use of existing technology, and partially of electronics and silicon detectors from the Backward Silicon Tracker (BST) and the Very Low Q^2 Tagger (VLQ). The BST will be shortened and the VLQ dismantled to allow a superconducting magnet to be installed in the backward detector region around the beam pipe. The FST will consist of five planes of silicon strip detectors in order to improve tracking in the forward direction for $8^o \leq \theta \leq 16^o$ and to enhance the lepton identification capability of the H1 detector. High momentum and spatial resolution permit heavy quark physics to be extended to large x and the charge of secondary leptons from sequential exotic particle decays to be determined.

1 Introduction

The H1 Collaboration has been aiming at precision measurements of low Q^2 structure functions and low x charm production by building [1] and upgrading [2, 3] a Backward Silicon Tracking (BST) telescope covering an acceptance region down to polar angles of 176^o. In particular the BST has the goals to provide access to the high y region at low Q^2 for accurate measurements of the longitudinal proton structure function and to extend the heavy flavour production cross section measurements to lowest possible x.

However, only recently the machine and beam pipe configurations in the H1 detector after the HERA luminosity upgrade shutdown have been fixed. This necessitates changes for the silicon detectors which are due to an eccentric, elliptical beam pipe and due to the installation of superconducting quadrupoles inside the forward tracker and the backward SPACAL calorimeter. As a consequence the VLQ Detector will be dismantled, the ladders of the Central Silicon Tracker (CST) will be rearranged, and the Backward Silicon Tracker (BST) will be shortened. This makes resources available to build a Forward Silicon Tracker (FST). This detector, as outlined in the present proposal, is designed to resemble the BST as much as possible.

This proposal relies on previous documents which describe the configuration of the BST [1, 2, 3] and the *ep* physics which H1 wishes to investigate beyond 1999 [4]. It expresses the intention of RWTH Aachen I, DESY Zeuthen, LUND University, MPI Munich, University and Academy of Sciences Prague and RAL to build a five plane FST to be installed in the forthcoming long HERA shutdown in the year 2000, which will be devoted to a substantial upgrade of the HERA luminosity.

Section 2 presents the physics motivation for the FST, i.e. its tracking capabilities, heavy flavour physics and deep inelastic scattering at very large Q^2. The mechanics, silicon sensors, electronics, the time schedule and finances of the FST project are discussed in Section 3. A summary is given in Section 4. A first appendix briefly presents the potential of HERA to discover new heavy particles (leptoquarks, squarks) which is one of the physics motivations for the FST. A second appendix summarizes the consequences of the luminosity upgrade for the BST and represents thus a brief update to the original proposal for an eight plane BST which was endorsed by the PRC in January 1998 [3].

2 Physics with the FST

2.1 Disk Arrangement and Track Acceptance

The configuration of the H1 Silicon Trackers after the luminosity upgrade is illustrated in Figure 1. The fiducial volume of the SPACAL for electron identification will then extend to polar angles of about 173^o compared to now 177^o. Therefore the length of the existing BST will be reduced to have five planes surrounding an eccentric, elliptical beam pipe with the beam line approximately concentric with the tracking detectors. It is intended to build the FST basically as a "BST mirror" in order to simplify the mechanical and electronic design and fabrication.

The FST and BST geometries are adjusted to optimize the polar angle acceptance, to ensure redundancy of the track reconstruction and to make optimum use of existing silicon sensors and readout electronics. The extension of the FST in the $+z$ direction is limited due to backscattered synchrotron radiation which requires a widening of the beam pipe starting at about $z = 50$ cm. The FST will therefore cover an angular range between 8^o and 15.5^o with ≥ 3 hits per track segment, see Figure 2. This geometry matches the forward tracker system (FTD) well [5]. The FST adds redundancy, momentum resolution, primary and secondary vertexing and lepton identification capability in the forward region.

2.2 Heavy Flavour Physics

The changes in acceptance for charm physics with the FST and the BST are illustrated in Figure 3. The BST extends the charm acceptance towards low x and the FST towards large x, approximately by one order of magnitude in both directions. Both detectors, together with the CST, will enhance the reconstruction efficiency also in the central region by nearly a factor of two. The effect of the maximum (minimum) accessible angle is also illustrated in Figure 3 comparing efficiencies for two η cut values, 3.0 and 2.5, corresponding to angular acceptance limits of 175^o for the BST (or 5^o for the FST) and of 170^o (10^o), respectively.

The FST, equipped with r and ϕ-detectors [3] of about 20 μm resolution, has a momentum resolution $\delta p_T/p_T^2 \simeq 4\%$ when combined with the run vertex, and of $\delta p_T/p_T^2 \simeq 2\%$ when combining FST and forward tracker (FTD) track segments independently of the vertex. A detailed simulation study has shown that tracks reconstructed in the FTD can be extrapolated back to the first FST plane with a spatial resolution of about 2 mm. Thus FST track segments can be associated uniquely to backward extrapolated FTD tracks. The combined track momentum resolution translates to an $r-\phi$ impact parameter resolution for single tracks of about 90 μm which should be compared with mean decay lengths of charm and beauty particles between 150 μm (D^o), 450 μm (D^+) and 700 μm (B). The mean momenta of the D meson decay particles in forward direction rise towards smaller angles from about 3 to 10 GeV in the FST acceptance range. Inclusion of the FST into the charm particle reconstruction will enable charm decays to be reconstructed using the mass difference method with a resolution of ΔM of about 1 MeV.

Maximum coverage of the x range will lead to a precise, high statistics measurement of the charm structure function F_2^c in a large range of x [7]. This is necessary for understanding the role of heavy flavours in NLO QCD [6] and in particular for an improved determination of the gluon distribution in the proton using charm production [8]. The measurement of the beauty quark structure function F_2^b [7] requires the beauty sample using vertex tagging to be enriched for which the resolutions appear to be well suitable.

The FST permits the open charm production cross section to be measured down to $W_{\gamma p} \simeq$ 20 GeV, to study J/ψ forward production, to measure the gluon density in the photon both with charm and beauty quarks and also to investigate the intrinsic charm hypothesis.

2.3 Deep Inelastic Scattering at Very High Q^2

The FST will measure DIS electrons in the region of very large y and very large Q^2 as is illustrated in Figure 4. The identification of the scattered electron or positron will profit from the reconstruction of lepton track segments in the FST, in front of the dead material of the central and forward drift chamber systems. This extends the cluster track link requirement to very forward angles, beyond the present limit of about 20^o, and improves also the vertex reconstruction efficiency. Using the upgraded forward tracker [5] and the FST, the inclusive cross section measurement is expected to be precise up to highest Q^2 and y. In this range the neutral current cross section receives important contributions from the nonsinglet structure function xF_3 which is dominated by photon-Z boson interference. The measurement of this function requires the lepton beam charge asymmetry of the DIS cross section to be precisely determined with high luminosity (> 100 pb^{-1} for both beam configurations) [9, 10].

2.4 Searches for New Physics

2.4.1 Leptoquark Searches

The decay products of a high mass resonance are strongly boosted in the forward direction. Hence, such resonant processes would lead to final state leptons with small polar angles, see Figure 5a. Even at largest leptoquark masses the very forward final state leptons will remain within the acceptance of the FTD and FST detectors due to the distortion of the LQ Breit-Wigner resonance, given the steep decrease of the underlying quark densities in the proton with increasing x. Leptons from a high mass two-body decay have large transverse momenta p_t (as seen in Fig. 5b), and the inelasticity y_e distribution of these events is flat (for scalar LQ). Thus the γp contamination can be removed by requiring e.g. $p_{t,e} > 15$ GeV and $y_e < 0.9$. The reconstruction efficiency of the signal $LQ \rightarrow l + \text{jet}$, applying the selection criteria of [11], is rather high. The detection efficiency for muons, however, coming from LQ decays is now vanishingly small for $\theta < 10^\circ$ and only $\simeq 17\%$ for $10^\circ < \theta < 15^\circ$. A similar situation is observed for $LQ \rightarrow \tau$ followed by a hadronic decay of the τ, with a lower efficiency plateau due to the τ-jet identification requirements. Hence, for μ's and τ's in the final state, the FST would provide an important improvement in the region of maximum lepton occurence. The electron identification would profit from a track-cluster link established prior to the dead material. Note that similar statements as for leptoquark decays hold for W production and their semi-leptonic decays.

The FST will enable LQ decays to heavy quarks to be tagged. These will be emitted with large momenta of about half the LQ mass. In theories with alternatives to the Higgs mechanism, leptoquarks may couple to lepton-quark pairs with a strength proportional to the constituent mass, i.e. preferentially to $b\tau$. There exist no severe constraints so far for LQs possessing non-vanishing diagonal couplings. With high luminosity HERA has an important discovery potential [11] with $M > O(100)$ GeV for which resolving a $b\tau$ final state will be essential.

2.4.2 Squark Searches

In R-parity violating ($\not{R}_p$) supersymmetric theories squarks ($\tilde{q}$) can couple to electron-quark pairs. Via such Yukawa couplings they could be produced similarly to leptoquarks. At the decay vertex, the $\not{R}_p$ decay into a lepton and a quark would compete with "gauge" decays into a quark and a gaugino-higgsino. The gaugino-higgsino could be a neutralino χ_i^0 or a chargino χ_j^+ in the decay processes $\tilde{q} \rightarrow q + \chi_i^0$ or $\tilde{q} \rightarrow q' + \chi_j^+$. All SUSY particles including the lightest are unstable in $\not{R}_p$-SUSY theories and the "cascade" decays of the χ_i^0 and χ_j^+ will lead to final states as described in the following:

$e^\pm$ **and multijet final states :** In the case where the decay $\tilde{q} \rightarrow q + \chi^0$ is followed by $\chi^0 \rightarrow e^\pm + jet + jet$, the final state consists of a forward $e^\pm$ of moderate p_t and several jets. The kinematic cuts mentioned in section 2.4.1 on $p_{t,e}$ and y_e would induce here a huge efficiency loss on the signal. In [12] such events were looked for by requiring an $e^\pm$ candidate with $E_{T,e} > 5$ GeV found in the LAr calorimeter and $0.4 < y_e < 0.95$. The y_e distribution of such events is indeed strongly shifted towards highest values, precisely where jets coming from γp processes are expected to fake electrons (Figure 6a and b). To remove this γp background, the e candidate was required to be linked to a "good quality" vertex fitted track. Fig. 6d shows the efficiency of this cluster-track link requirement which at low θ_e is only 25%. An improved tracking system in the forward region would restore this efficiency to its plateau value of 90%.

Moreover, the resulting improved e/π rejection would allow the upper cut on y_e to be relaxed and thus the signal efficiency to be still increased.

If the squark decay proceeds via a neutralino, a striking signature with lepton number violation $e^+ + p \to e^- + \text{multijets} + X$ could be observed, due to the Majorana nature of the neutralinos. Since the p_t of the lepton is moderate ($<$ 25 GeV in $\simeq$ 60% of cases as seen in Fig. 6c), the FST could provide a charge measurement of this lepton. The probability to correctly assign the charge to a lepton track has been simulated and found to be larger than 80% for $p_t \leq 25$ GeV using the FST and the run vertex.

Multileptons and multijet final states : Depending on the values of the SUSY parameters, the dominant decay mode of the squark could be $\tilde{q} \to \chi_1^+ + q'$ followed by $\chi_1^+ \to \chi_1^0 + f + f'$, and by the $R\!\!\!/_p$ decay of the χ_1^0 into $e^{\pm}/\nu + \text{jets}$. These could lead to signatures with several leptons, several jets and missing transverse momentum. As before, the study of di-electron final states, where both electrons have moderate p_t and high y, requires a powerful and efficient e/π separation. This is especially relevant for the case of the stop, since $\tilde{t} \to b + \chi_1^+$ is expected to be the dominant decay mode as soon as kinematically allowed.

3 The H1 Forward Silicon Tracker

3.1 Mechanics

The structure of the FST is determined by the available space between the elliptic beam pipe and the mounting tube which is attached to the inner proportional chamber CIP. The cross section of a carbon fibre support wheel (Figure 7) shows that silicon sensors of the same trapezoid shape and size as those used for the BST (with sensitive radii between 5.9 cm and 12.0 cm) can be mounted to 12 of the 16 ϕ positions per plane. The beam axis for electron-proton collisions is concentric to the detectors while the positron beam axis will be displaced by about 8 mm.

As for the BST, the FST voltage distribution and line driver electronics is placed on repeater boards close to the detector. The mechanical support of this repeater has to be replaced to accomodate the elliptic pipe. Contrary to the BST all cabling will have to enter from the forward direction, through the gap between the Forward and the Central Tracker, since the CST and BST do not leave any substantial space in radial direction. As a consequence, there will be a special installation procedure: a cable and pipe fixing ring (a so called 'contact ring') has to be placed at the +z end of the Central Tracker. This ring is connected to the 24 signal and control cables of the FST which are routed from the $+z$ CTD endflange over the Central Tracker to the cable distribution area. The contact ring has to be fixed inside the silicon detectors mounting tube (see Figure 8) and has to be fully connected before the tracker is moved into the cryostat. Afterwards, with beam pipe and magnets already installed, the FST will be slid into its position from the $-z$ end of the CTD. Repeater and contact ring have to match within the mounting tube and will be locked by remote tools. A 1:1 model of this system (see Figure 9) is currently being designed.

The FST will dissipate a power of about 50W in the detector volume while each repeater board adds another 10W to the heat load. As for the BST, heat convection will be enforced by means of nitrogen flow. A water circuit will provide cooling at the contact ring which has thermal contact to the repeater. The FST hybrids require water cooling which may be realized with thin pipes fed from the $-z$ end and routed in the free space between C/BST and the elliptic pipe. The FST will split into an upper and a lower half, as the BST, in order to allow its installation around the beam pipe. Installation requires a new mechanics tool to be built based on previous experience with the BST.

3.2 Silicon Sensors

The FST silicon sensors will use half of the r strip modules currently in operation for the BST and half of the ϕ sensors ordered for the BST. Each detector plane carries 12 long sensors, mounted back to back, instead of the 16 used presently. Experience with these has been gained during the running of the BST equipped with r detectors in 1996/8 and also with ϕ detectors in 1998.

The r detectors are double metal, polysilicon biased detectors. They have a S/N of 13 (peak value) and an internal resolution of 16 μm. The detectors were used in the measurements of inclusive deep inelastic and of J/ψ photoproduction cross sections presented by H1 at the 1998 ICHEP Conference in Vancouver. During access periods, the leakage current level of the BST r detectors was measured and it was found that the active area and guard currents rose both in 1996 and in 1997 by about a factor of 2. This is tolerable given the rather low level of currents; in the 1 μA (total current) range for most of the r strip detectors. Some of the detectors delivered by MICRON in spring 1998 had higher currents and will have to be inspected carefully when they become accessible.

The eight ϕ detector prototypes, all operated in H1 during the 1998 running period, have a S/N of 25 and a, preliminary, resolution of 16 μm. This detector was designed by DESY Zeuthen and MPI Munich and produced by CIS Erfurt in the fall of 1997. Its design is simpler than that of the r detector, since it is a single metal design where the strips are routed from the inner to the outer radius, parallel to one of the detector edges. The detector is AC coupled and punch-through biased. The ϕ wafer series sensors are essentially copies of the prototypes which have now been tested successfully.

The combination of r and ϕ strip coordinates allows the particles' momenta to be reconstructed. This is illustrated in Figure 10 which shows an event from a recent run with a BST track matched in space and momentum to a cluster in the SPACAL. Figure 11 shows a raw data plot of the correlation of the transverse energy measured in SPACAL and the transverse momentum measured with the BST r and ϕ detectors. Although no cluster quality or electron identification requirements have been imposed and the BST alignment is still preliminary, it can already be seen that the BST can measure momenta well. At low energies the BST momenta are being used to calibrate the SPACAL hadronic energy scale. At high energies the kinematic peak will be used to calibrate the BST momentum reconstruction. The track charge and momentum determination will be used also to understand the high y photoproduction background at low Q^2.

To cope with the large synchrotron radiation fan the elliptical beam pipe will be eccentric. Thus the wafers in one quarter of the support wheels of the BST and the FST would have to be shorter, see Figure 7. This has already been discussed in [3]. It was then decided to design short detectors for the BST which have been ordered since. Given the limited time available and the complexity of the devices to be built, it is intended at present to keep this sensor type, with its cabling, repeater etc., as an option for the FST.

3.3 Electronics

Since the FST will be built of the same type of sensors as the BST, the electronics design criteria of the BST apply to the FST to a large extent. The FST will include 102400 channels with fully assembled wheels. The detectors are read out by the Analogue Pipeline Chip (APC) [13] which is used for the CST and the BST already. It contains a storage array of 128 channels, 32 events deep, with one trigger time slice being read out serially. Five APCs are placed on one hybrid. This chip requires 14 control signals which are derived from a dedicated 'Decoder' chip. The Decoder is controlled by four clock signals which are generated in the sequencer part of the OnSiRoC module [14]. Separate OnSiRoC modules are foreseen for r and ϕ detector types. The clock signals are fanned out 1:8 in an external module and brought to the repeaters. The analogue output signals of two hybrids (1280 channels on one line) are buffered on the repeater and fed through cable via an adapter card to the PowerPC based RIO modules. The BST repeater design has to be modified as the original layout [1] assumed a coarser readout pitch of the ϕ detectors than has been realized [3]. The adapter card provides all voltage supplies to the repeater and frontend. The FST will be integrated into the Silicon DAQ system [15]. It will require 10 RIO modules, 10 Adapter Cards and 4 Clock Fanouts in its final configuration. There will be improvements in the signal transmission and the clock distribution as compared to the present BST. CAN bus based slow control circuitry for temperature measurements and voltage status will be added to the repeater, which will be operated from the existing BST slow control modules.

3.4 Schedule, Responsabilities and Cost

The schedule of building the Forward Silicon Tracker is given in Table 1. During 1999 the 120 ϕ modules for the BST and FST will be produced at Zeuthen. These were ordered from CIS Erfurt and delivery is planned to proceed in three batches in May, August and September 1999. No further prototype phase is necessary as the sensors ordered require only very small modifications of the mask layout. Two important milestones are the test of the modified repeater with the

item	end date	comment
hybrid prototype	4/99	ϕ modules
hybrid series	9/99	
wafer delivery	11/99	
modules assembled	1/00	
test of repeater, converter card and contact ring	11/99	r/o electronics
powerPCs delivered	2/00	
repeaters produced	3/00	
cable delivery and assembly	3/00	
contact ring ready	4/00	
test of support structure and installation tool	12/99	mechanics
BST access and disassembly	5/00	detector
r module reassembly	7/00	
FST assembly	9/00	BST assembly in parallel
FST installation	10/00	

Table 1: *Schedule for building the H1 Forward Silicon Tracker FST*

contact ring and converter card, in November 1999, and also the test of the carbon fibre mechanics support structure with the new installation tool, in December 1999. After access to the BST, scheduled now for May 2000, there are 5.5 months available until installation of the FST. This time is the necessary minimum for dismantling the BST, reassembly and test of the r strip detector modules and the subsequent assembly of the FST and BST. Installation after tests of the detectors is scheduled for October 2000.

The collaborating institutes share the work and responsabilities to build the FST as described in Table 2.

institute	item
DESY Zeuthen	silicon modules, repeater design, mechanics, software
LUND University	radiation monitor
MPI Munich	sensor layout
Prague University and Academy	repeater and converter cards, FST operation
RAL	integration into CDAQ
RWTH Aachen I	installation mechanics

Table 2: *Responsabilities for building the Forward Silicon Tracker FST*

The reduction of the BST from 8 to 5 planes and the introduction of the elliptical beam pipe imply that roughly one half of its r and ϕ strip detector modules will be available for installation in the FST. This accounts for the basic cost effectiveness of the current proposal. Moreover, the VLQ readout electronics (PowerPC and OnSiRoC modules, crate and DAQ Macintosh) can be used for the FST. Table 3 lists the main components, the total numbers required, the numbers needed on top of the BST and VLQ equipment, their cost and origin. The additional expenditure of the 5 plane BST and FST strip detectors, as compared to the original 8 plane BST proposal, is thus estimated to be 118 kDM, disregarding prototype and spare module costs estimated to be less than 50 kDM. Note that a completely new FST in the proposed configuration would cost about 520 kDM.

4 Summary

The modification of the H1 backward detector region during the HERA luminosity upgrade shutdown will limit the useful acceptance of the SPACAL calorimeter to polar angles $\leq 173^o$. The BST will thus be shortened (see Appendix 2), and it is proposed to build a forward silicon tracker. The detector represents an important improvement in the forward tracking capability of H1 which is challenging due to the high particle density and the amount of material in front of the forward tracking chambers. The FST enhances the discovery potential of H1 and extends heavy quark physics towards larger Bjorken x. The FST is designed to be essentially a “mirror version” of the BST which permits it to be built in time. It will make use of about half of the BST silicon strip detector modules and also of the readout electronics of the VLQ silicon detector which cannot be operated following the luminosity upgrade. It thus can be realized with an additional cost of about 118 kDM. The extra manpower for building and operating the forward silicon tracker will be realized with an extended effort of the groups of DESY Zeuthen, LUND University, the Academy of Sciences in Prague, of MPI Munich and the RAL. Aachen I and Prague University will also join the present BST group.

item	price/kDM	total numbers	required	sum/kDM	source
r sensors	2.3	60	-	-	BST
hybrids	0.5	60	-	-	BST
preamplifiers		300	-	-	BST
ϕ sensors	1.6	60	-	-	BST
hybrids	0.5	60	-	-	BST
preamplifiers		300	-	-	BST
repeater boards	2.5	8	8	20	new
converter cards	2	10	8	16	new+BST
Power PCs	7	10	3	21	new+VLQ+BST
OnSiRoCs	5	2	-	-	VLQ
clock fanouts	1.5	4	4	6	new
cables		24	-	-	BST
contact ring	10	1	1	10	new
mechanics				25	new+BST
installation device	20	1	1	20	new
total estimated cost				118	

Table 3: *Estimated cost of the FST assuming that the BST detector r and ϕ modules and VLQ electronics can be used. The quoted sums represent the additional cost of the FST as compared to the ϕ BST upgrade configuration [3].*

Appendix 1
Discovery Potential of HERA for New Physics

For leptoquarks possessing only flavor diagonal couplings (i.e. $LQ \to e + q$ and $LQ \to \nu_e + q$ only) a recent H1 preliminary analysis [11] shows with current luminosity a sensitivity to LQ masses up to 275 GeV for an electromagnetic strength of the Yukawa coupling ($\lambda = 0.3$). This mass range extends beyond the domain exluded by the Tevatron experiments of $M \lesssim 242$ GeV established for a branching ratio $\beta_e = \beta(LQ \to eq) = 1$.

Moving away from the simplest LQ models and allowing for other decay modes of the LQ, the leptoquark discovery potential at HERA is even more striking. For example, for $\beta_e = 10\%$, masses up to only $\simeq$ 110 GeV are excluded by the D∅ experiment [17], while the current sensitivity of the H1 data probes masses up to $\simeq$ 210 GeV. Small values of β_e are naturally obtained for LQ possessing couplings λ_e to eq as well as couplings to μq or τq pairs. For example, if $\beta(LQ \to eq) = 10\%$ and $\beta(LQ \to \tau q) = 90\%$, HERA's current sensitivity allows LQ masses up to 275 GeV for $\lambda_e = 0.3$ to be excluded, while a direct third generation LQ search carried out by the D∅ [18] and CDF [19] experiments lead to a lower mass limit of $\simeq$ 100 GeV. An important discovery window is thus open for HERA for high mass leptoquarks decaying with a small branching ratio to eq and a high branching to τq.

Searches for SUSY particles yielded mass dependent limits on the Yukawa coupling [12] using all available e^+p data. Squark masses up to 262 GeV could be excluded for $\lambda = 0.3$. The recent specific $\not{R}_p$-SUSY searches carried out by the Tevatron experiments [20, 21] allowed the probing of a competitive mass domain (up to 252 GeV). Yet, this assumed five degenerate squarks. If one squark (e.g. one state of the stop) is much lighter than the other squarks, these limits fall to around $130 - 150$ GeV, leaving open an important window for a future discovery at HERA.

Appendix 2
Changes to the Backward Silicon Tracker in 2000+

The BST proposal [1], the extension of the detector to eight planes [2] and the ϕ upgrade of the BST [3] had three essential physics goals. All are affected by the acceptance reduction from about 177^o to 173^o which results from the installation of a superconducting magnet inside the SPACAL calorimeter:

- The SPACAL, BDC and BST backward detectors provide the instrumentation for precision measurements of the deep inelastic cross section at low x and low Q^2. First results including the BST were presented at the 1998 ICHEP Conference in Vancouver [22]. The 173^o acceptance cut will limit the Q^2 range to about $Q^2 \geq 10$ GeV ^{2} for $x \geq 10^{-3}$. The lower Q^2 region will then be accessible only with special runs with reduced electron beam energy. In the quoted x region the relation
$$Q^2 \simeq 4 \cdot E_e^2 \cdot \tan^2 \frac{\theta_e}{2} \tag{1}$$
holds, i.e. by operating HERA at $E_e \simeq 15$ GeV values of Q^2 down to about 2 GeV^{2}can be reached (and lower at smallest x). The luminosity for precise inclusive measurements is about 10 pb^{-1} while semi-inclusive measurements will require a larger luminosity. This option will certainly be very important when HERA will be run with nuclei or in proton polarization mode.

- The longitudinal structure function $F_L(x, Q^2)$ has not been measured independently of assumptions on F_2 yet, and the accuracy of the indirect determinations may be limited to about 10-15%, even after the 1999 running period. The BST ϕ detectors were proposed to enable a precision measurement of F_L [23] which is one of the ultimate tests of QCD in NLO. The reduction of the polar angle acceptance implies that future measurements of F_L will be limited to about $Q^2 \geq 5$ GeV^2.

- The effect of the acceptance cut on charm physics has been briefly discussed above. As can be seen in Figure 3 the charm reconstruction efficiency at low x will be somewhat reduced (compare the calculated efficiencies for the different η cuts). Since for D decays, however, the opening angle is not small, this loss is smeared over x and appears to be tolerable, in particular, as it will be more than compensated for by the FST.

The following changes to the BST detector configuration are foreseen:

- The detector will be reduced from the current eight to five planes.

- The mechanical support structure has to be redesigned because of the eccentricity and dimension of the elliptical beam pipe. This requires the fabrication of new carbon fibre wheels which, in the outer region, will have the same dimensions as the present wheels. These wheels will be identical for the BST and the FST. The new z arrangement of the detector planes and the repeater require a new device for installation and transport of the BST. This device will be very similar to the one to be built for the FST. Both will utilize concepts and parts of the presently existing devices for installing BST1 and BST2.

- As was already mentioned in [3], the repeater has to be redesigned because of the larger number of channels for the ϕ detectors than foreseen in the original proposal [1]. Moreover the elliptical pipe and the need for a safe connection to the contact ring pose additional constraints. The BST repeater design will be used as well for the FST.

The BST comprises also a Silicon pad detector system for triggering on backward scattered particles. This is an essential feature for future low Q^2 data taking in order to reduce the low Q^2 trigger rate. The pad detector system development has been delayed due to the rather large common mode noise of the MICRON pad detectors. This has been extensively discussed within H1 and with the PRC referee. Based on measurements with further pad sensors agreement has been reached on a technical solution permitting installation of the pad detectors during the upgrade shutdown.

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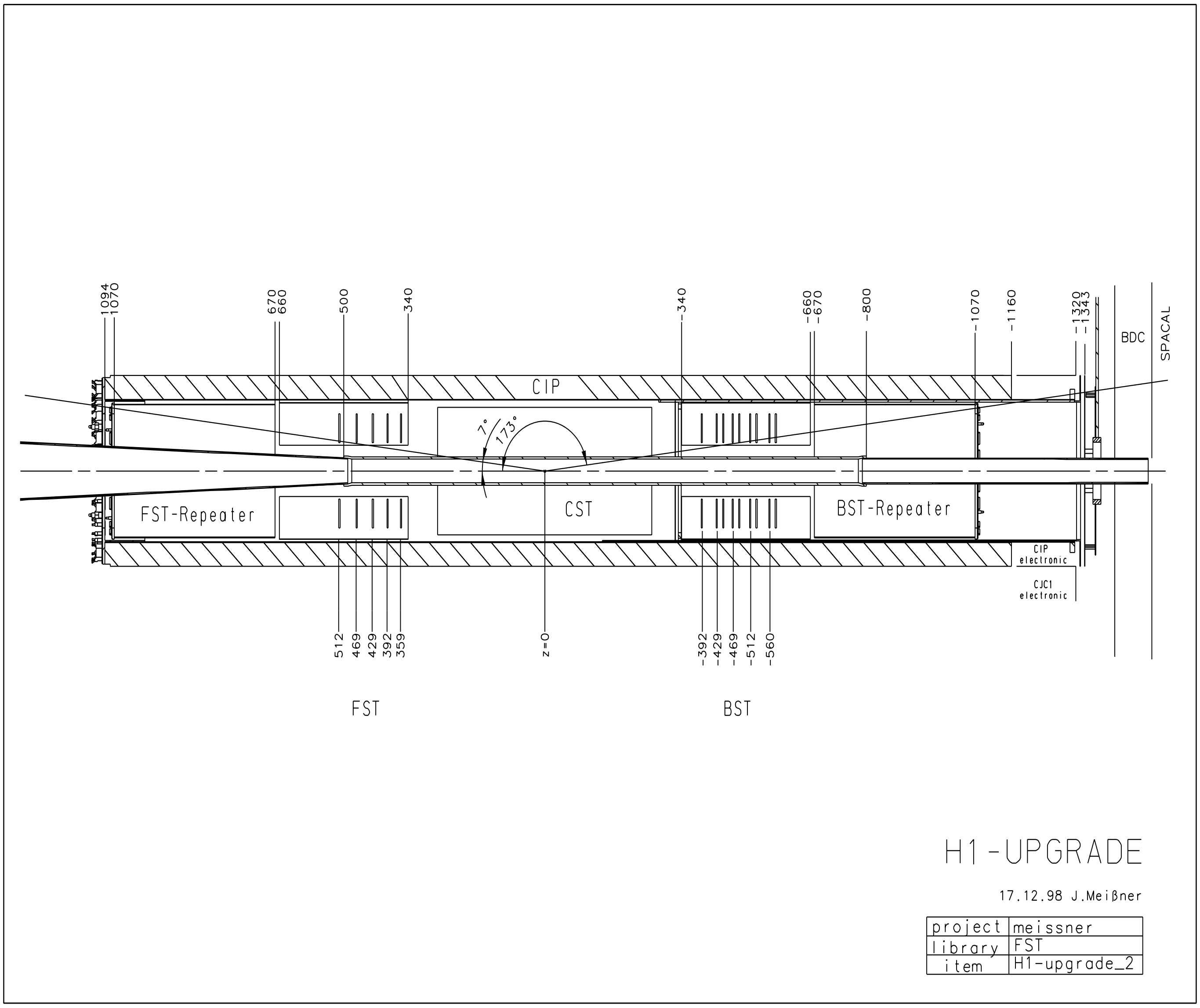

Figure 1: Side view of the inner H1 detector region after the luminosity upgrade with the Silicon Trackers FST, CST and BST.

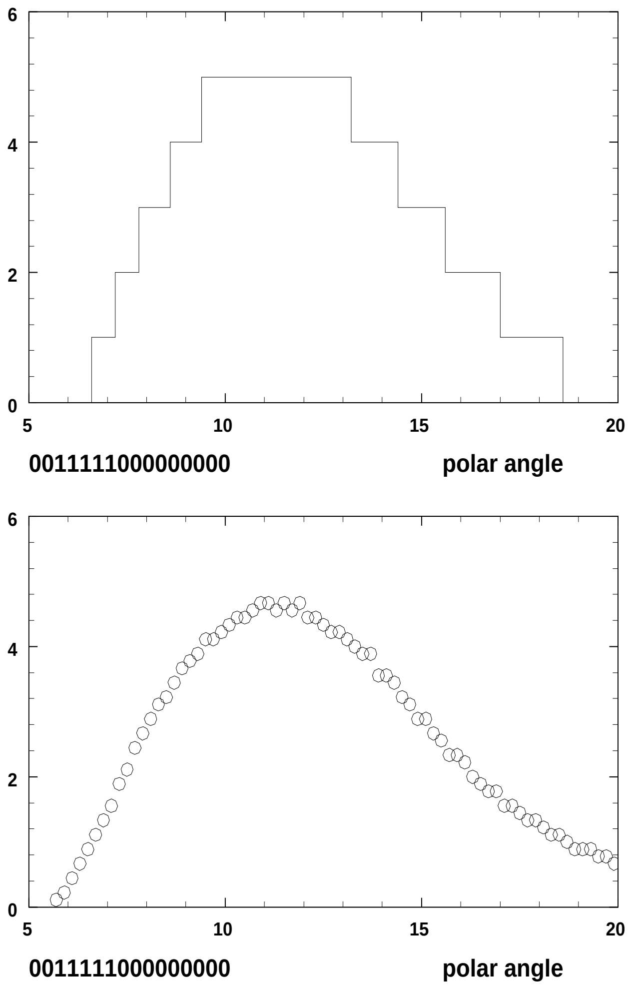

Figure 2: Polar angle acceptance of the FST for the disk z positions as given in Figure 1. Plotted is the mean number of silicon sensor planes for a given angle, in degrees, crossed by particles from the nominal interaction vertex (top) and by particles originating in the interaction region with the expected vertex z distribution (bottom).

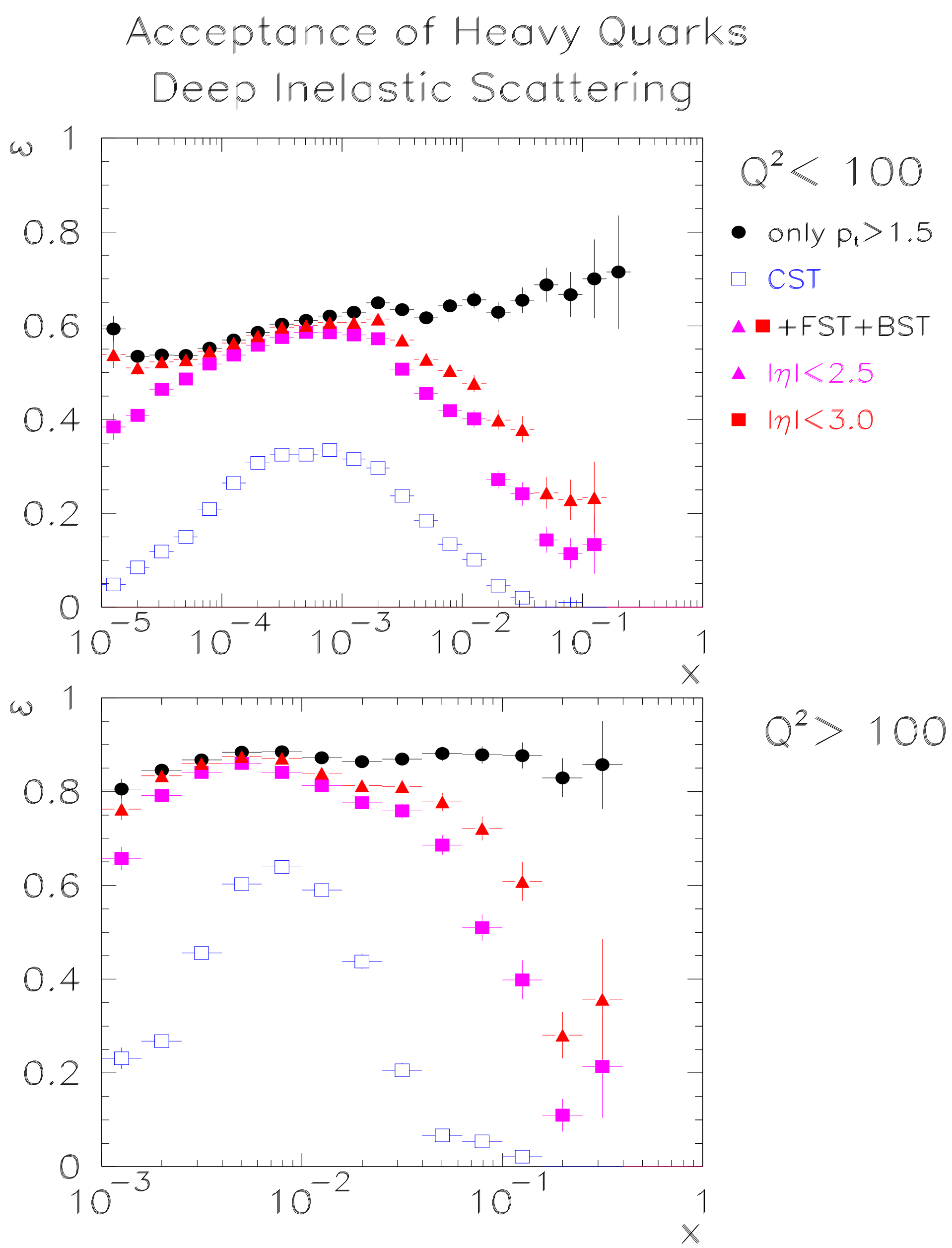

Figure 3: Acceptance for charm events ($ep \to D^*X \to D^o\pi_sX \to K\pi\pi_s + X$) using the central tracker and the CST (open points) and adding the BST and the FST with different assumptions on the acceptance range η of the D^*.

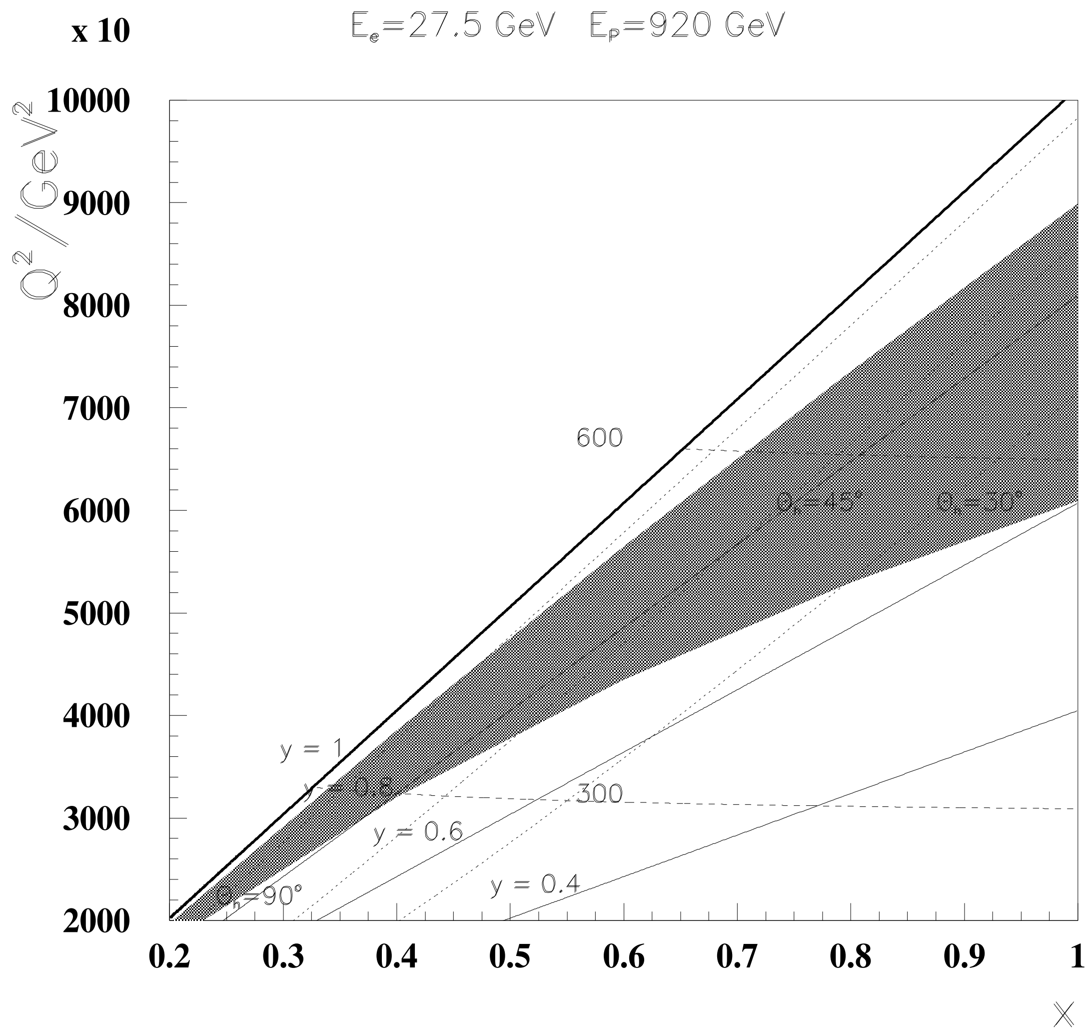

Figure 4: DIS kinematics in the very high Q^2 region where Z boson exchange and valence quark interactions are sizeable. The FST covers the shaded high y region corresponding to $8 < \theta_e < 16^o$. Also drawn are lines at constant $\theta_h = 90, 45, 30^o$ which demonstrate that the hadronic jet is emitted at a larger angle than the scattered lepton crossing the FST. The scattered DIS leptons have very large energy (see the nearly horizontal dashed lines for electron energies of 300 and 600 GeV) since in this region the approximate relation $Q^2 \simeq 4 \cdot E_e' \cdot E_e$ holds.

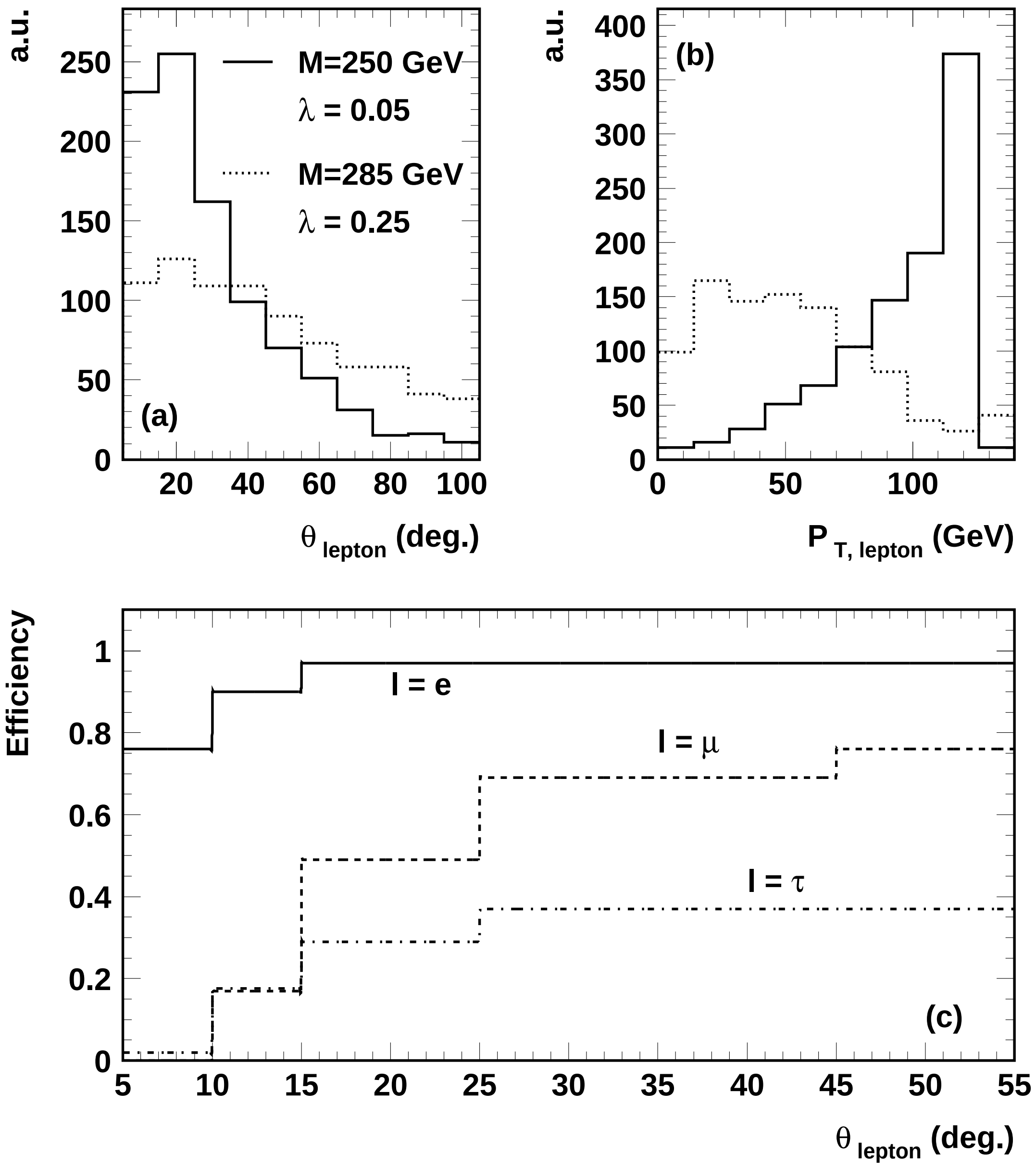

Figure 5: (a) Polar angle of the lepton coming from LQ decay and (b) transverse momentum of this lepton. Two sets of (M_{LQ}, λ) have been chosen, λ being the Yukawa coupling at the $LQ - e - q$ vertex. Both histograms (full and dotted lines) correspond to 1000 generated events. The p_t spectrum of decay leptons from LQ's with mass close to the kinematic limit is rather soft due to the steep decrease of parton densities with x at high values of x. (c) Reconstruction efficiency for $LQ \to l + q$ for $l = e$, μ and τ with the present H1 detector. Here, only hadronic decays of the τ's are considered.

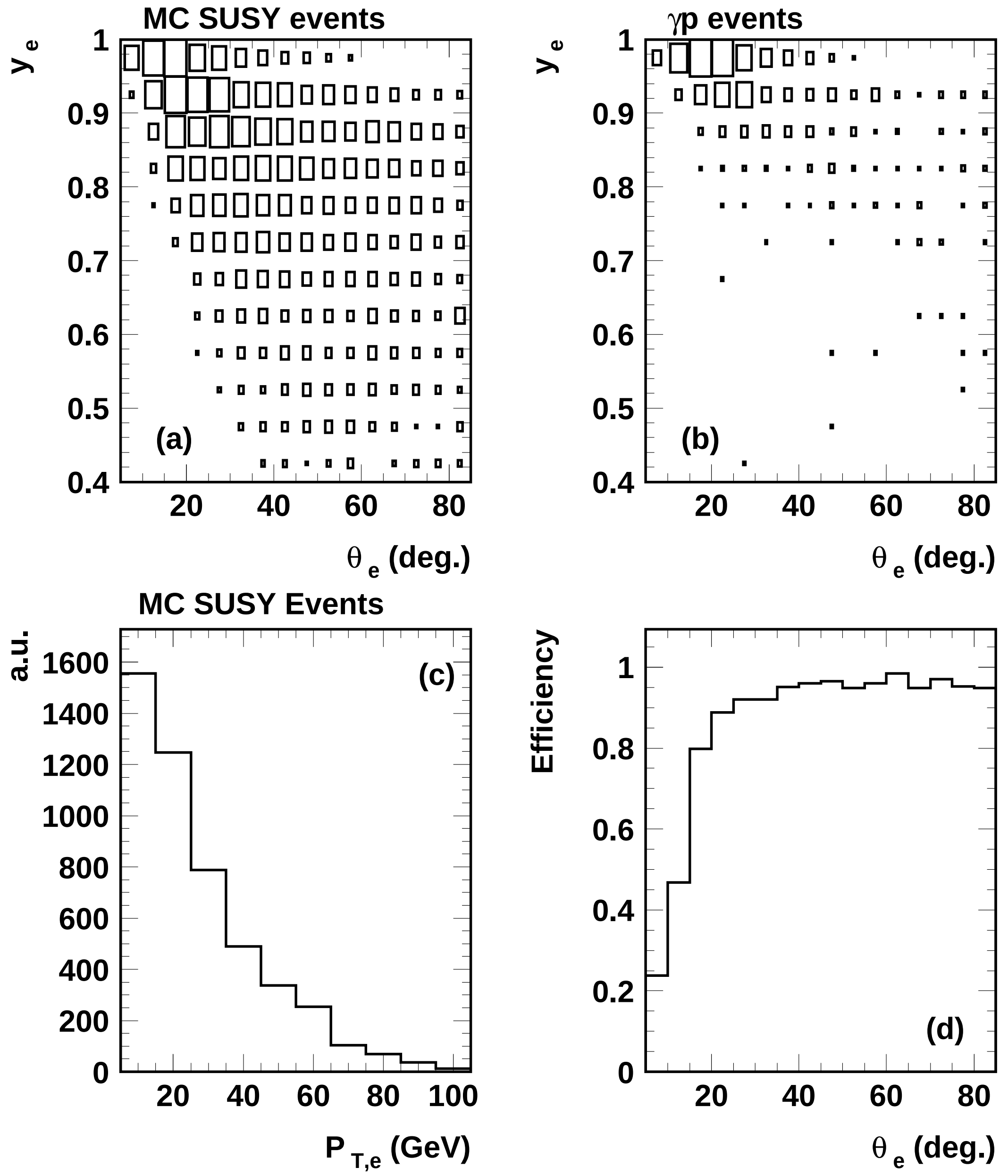

Figure 6: (a) Simulated SUSY events for cascade decays leading to e + multijet final states, in the plane y_e vs θ_e; (b) Idem for γp events where a jet fakes an electron. The background is located at high y in the FST acceptance range; (c) Transverse momentum of the final state lepton in SUSY events; (d) Electron identification probability applying the cluster-track link (CTL) requirement with the present detector.

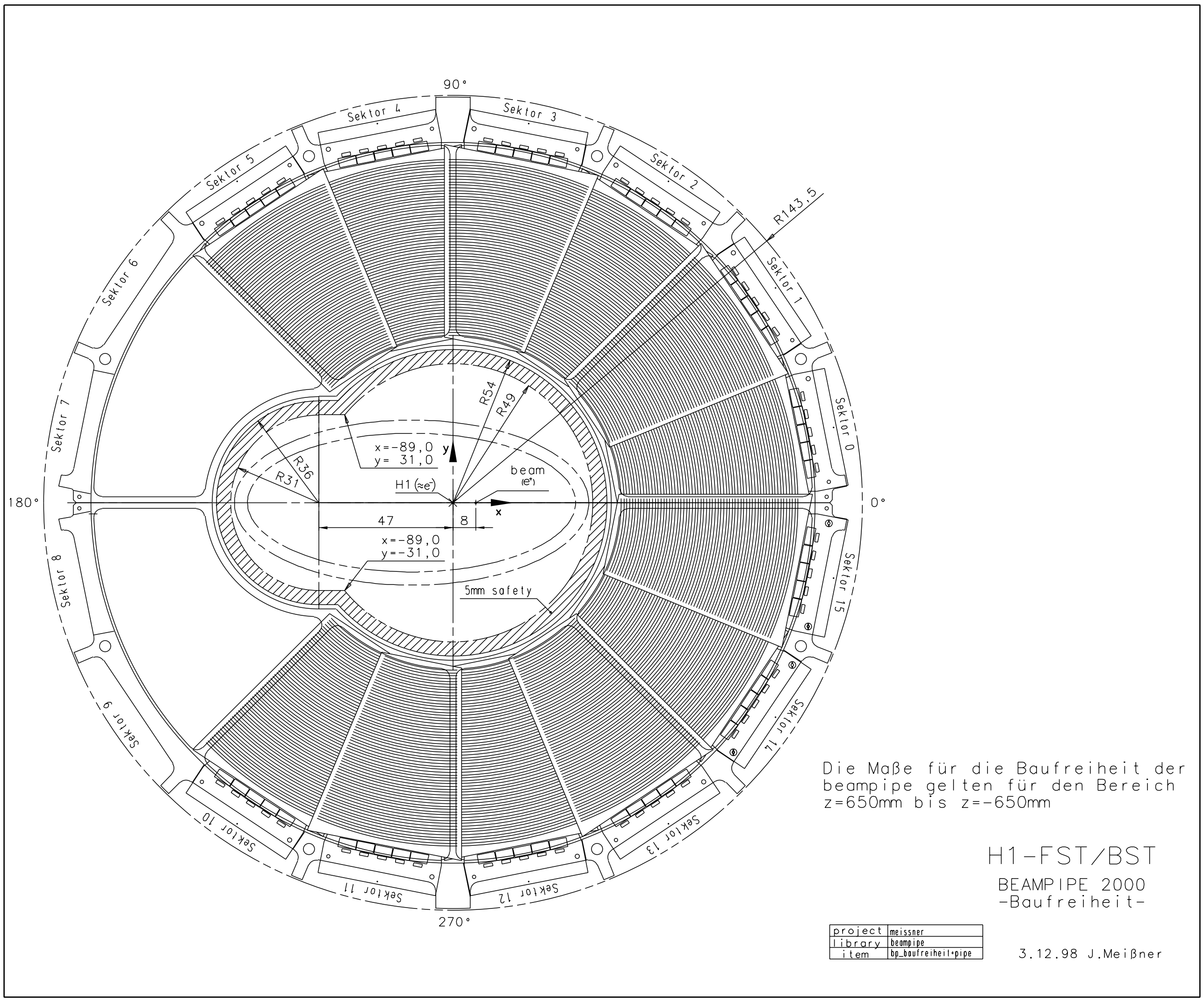

Figure 7: FST detector disk. 12(16) ϕ sectors can be assembled with BST silicon strip detectors mounted on a carbon fibre support wheel with an eccentric opening for the beam pipe.

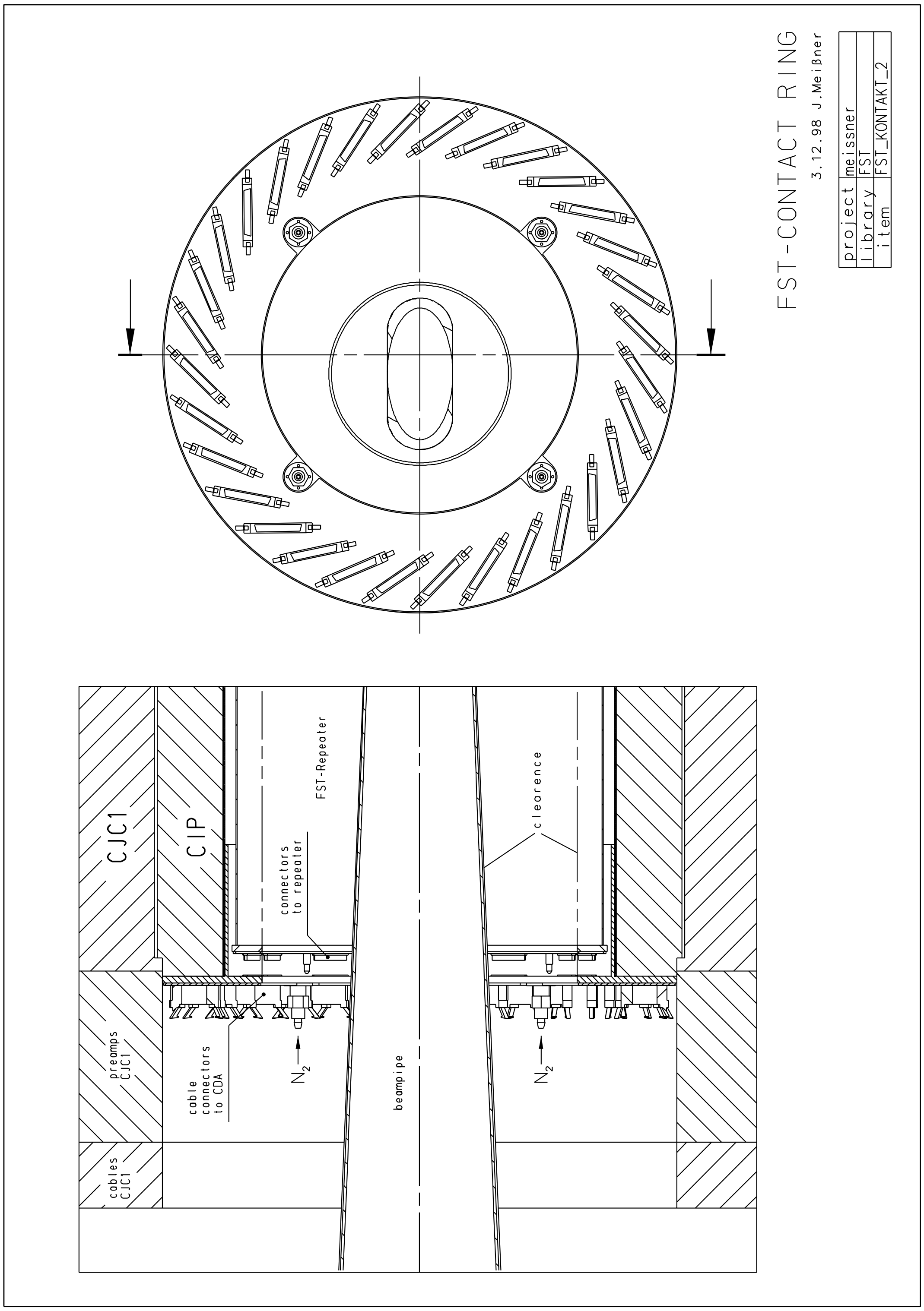

Figure 8: Side view of the connection between the FST repeater and the signal cables *via* the contact ring below the $+z$ endflange of the CIP.

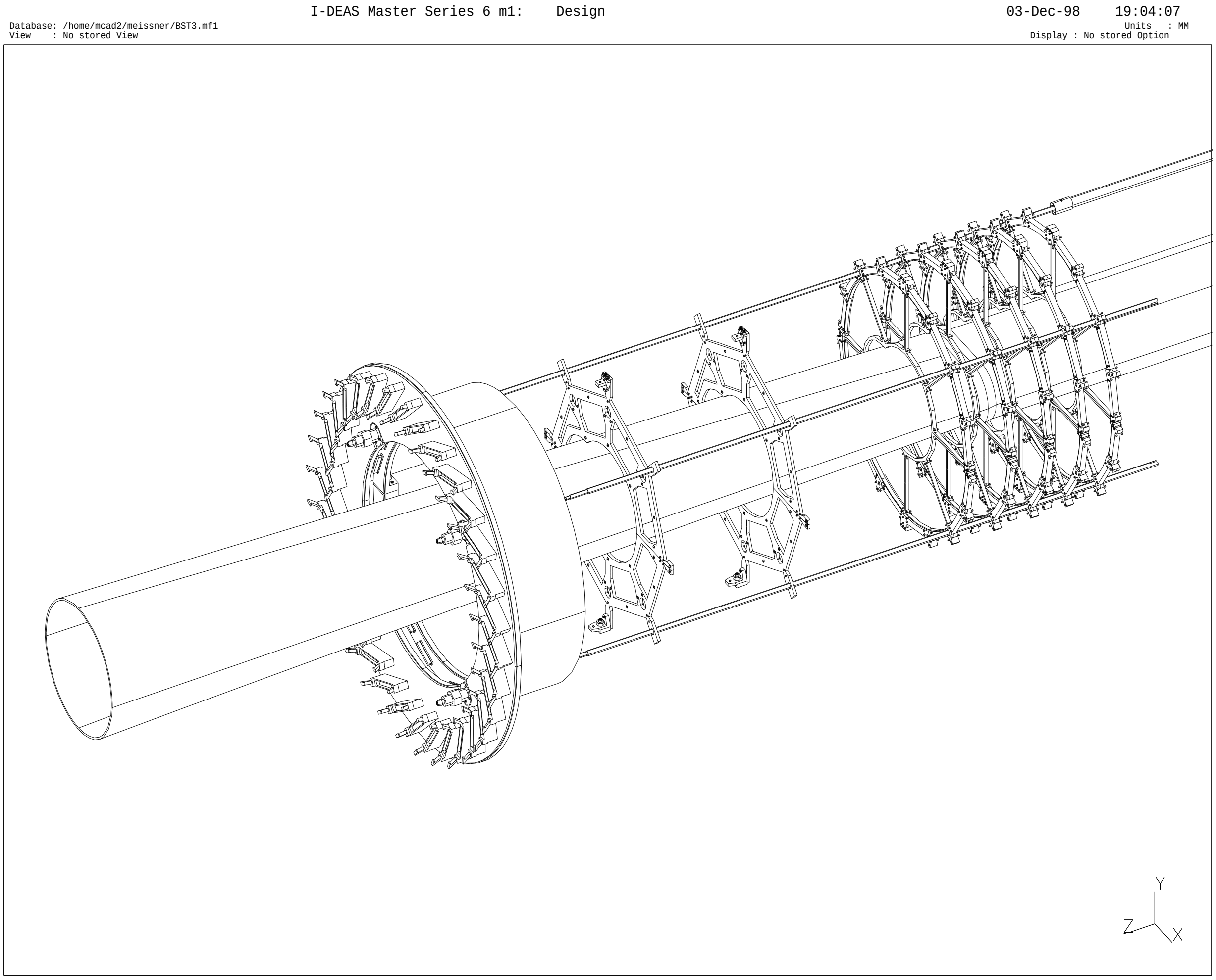

Figure 9: Schematic view of the FST and repeater support structure, the contact ring and beam pipe.

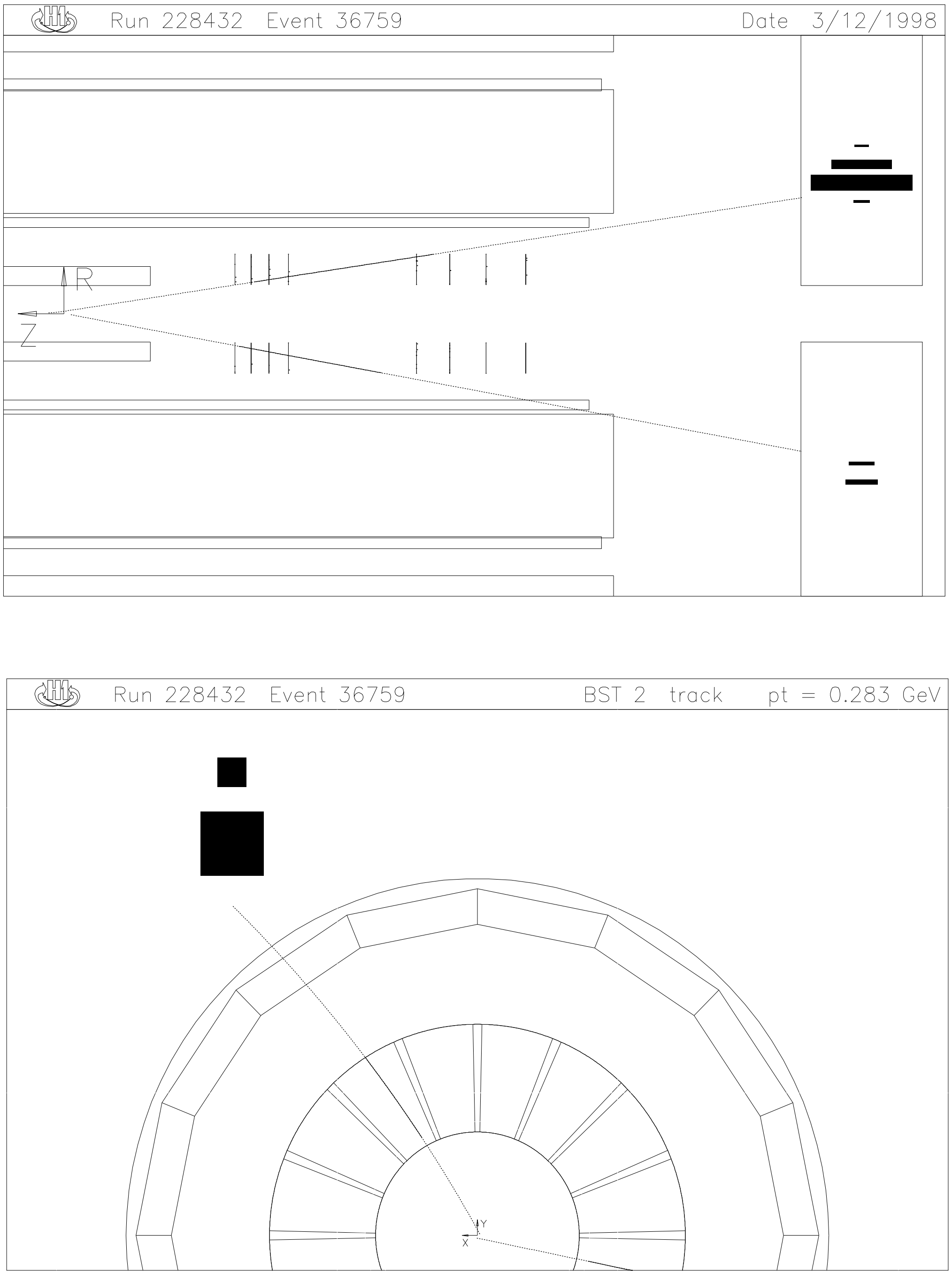

Figure 10: rz and xy views of an event with a SPACAL energy cluster and a linked track of about 300 MeV transverse momentum as reconstructed using the BST r and ϕ strip detectors, from the 1998 run. The rz view shows two tracks pointing to SPACAL clusters. The lower one passed the new BST2 while the upper one links BST1 and BST2. This has a reconstructed momentum as it passed the one BST sector which was equipped with ϕ detector prototypes.

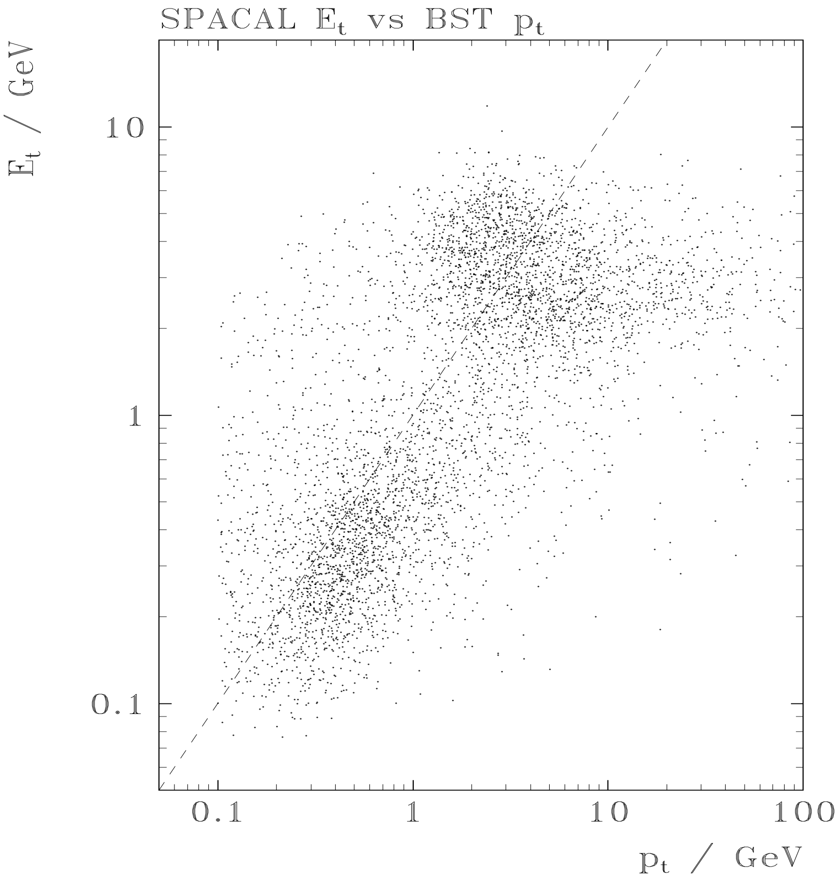

Figure 11: Raw distribution of the transverse energy E_t measured in SPACAL and the transverse momentum p_t measured with the BST r and ϕ strip detectors. No event selection, cluster quality or electron identification criteria were applied. Thus at low E_t most of the particles are hadrons. The accumulation at large E_t is due to the kinematic peak where the BST momentum measurement is less precise than the calorimetric energy measurement.