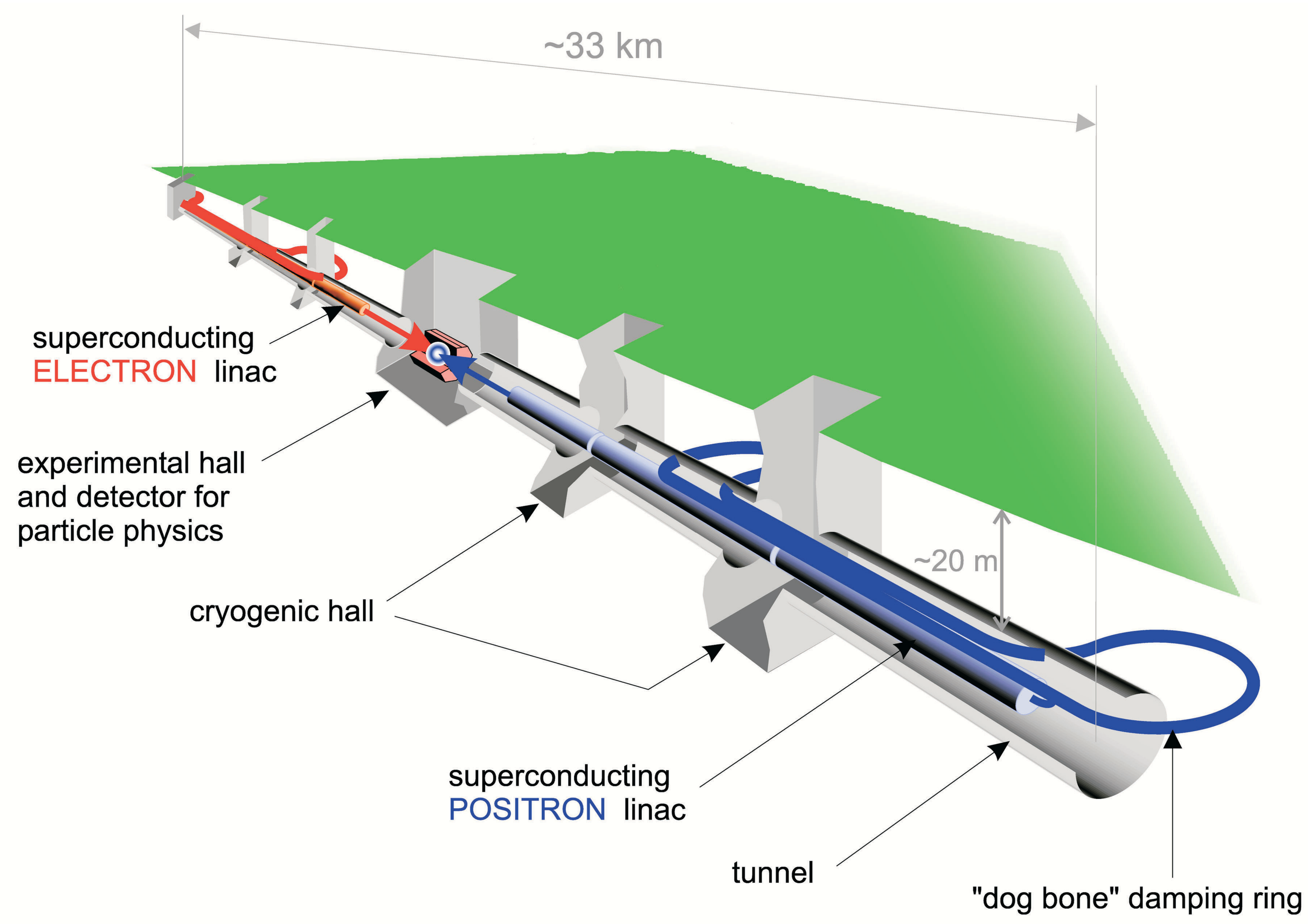
TESLA Linear Collider

TESLA
TeV Energy Superconducting Linear Accelerator
The 90 – 800+ GeV Superconducting Linear Collider

TESLA is a proposed superconducting electron-positron collider with an initial centre of mass (cms) energy of 500 GeV, extendable to at least 800 GeV, with high luminosity. Planned as a large-scale research facility, internationally funded, built and operated in the framework of a Global Accelerator Network (GAN), TESLA provides unique possibilities for basic research in the understanding of the structure of matter on sub-atomic scales. The high cms energy and the high luminosity provide possibilites of not only finding new principles in the interplay of the basic building blocks of matter but also open a window into the microcosm by allowing measurements of unprecedented precision. The TESLA technology also allows for the operation of Free Electron Lasers in the X-ray regime. Therefore TESLA satisfies the criteria for new large endeavours in science: it is unique, opens completely new research possibilities and should carry the promise to advance our knowledge of nature in many branches of science.

TESLA Test Facility

The TESLA Test Facility (TTF) has been operational since 1997 and provides an integrated system test for the TESLA key components including the cavities, the RF system, and the SASE Free Electron Laser.

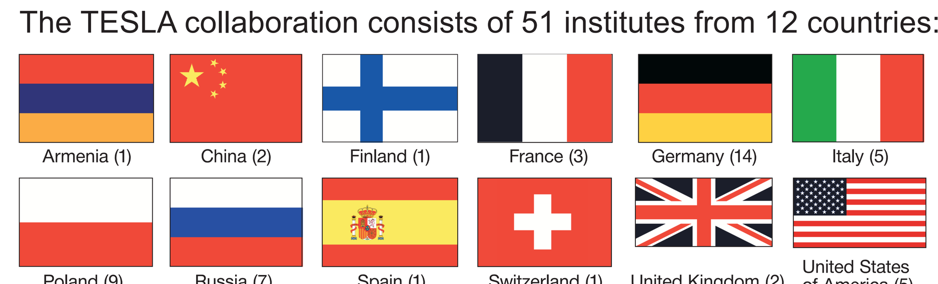


Proposed Site

The proposed TESLA tunnel runs tangentially from DESY's HERA accelerator towards the northwest on a total length of ~33km, 20-30m underground. The collision point between the electrons and positrons is in the middle near the village of Ellerhoop where the TESLA research campus is planned.

The TESLA Collaboration

The TESLA collaboration consists of 51 institutes from 12 countries:



TESLA Parameters

cms energy	500	800	GeV
gradient	23.4	35	MV/m
repetition rate	5	4	Hz
bunches/pulse	2820	4886	
pulse length	950	860	ms
bunch spacing	337	176	ns
bunch charge	2.0	1.4	$x10^{10}$
pulse current	9.5	12.7	mA
AC power (2 linacs)	97	~150	MW
IP beam sizes (x,y)	553, 5	391, 2.8	nm
IP bunch length	0.3	0.3	mm
beamstrahlung DP/P	3.2	4.3	%
vertical disruption D_y	25	27	
luminosity	$3.4x10^{34}$	$5.8x10^{34}$	$cm^{-2}s^{-1}$

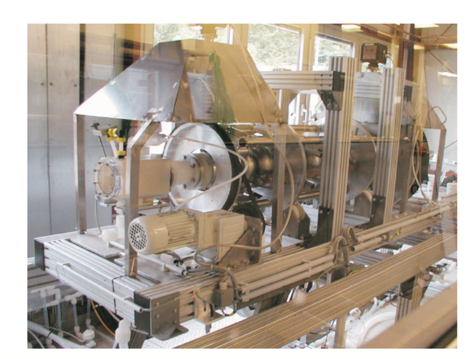
Why Superconducting?

The heart of the TESLA accelerator are the superconducting accelerating cavities (above) made from pure Niobium. The superconducting structures offer many advantages over conventional (warm) copper structures:

- low RF frequency (1.3 GHz), reducing the wakefields and therfore relaxing the alignment tolerances.
- long RF pulses from low peak power RF sources, allowing for long bunch trains with large bunch spacing.
- losses in the cavity walls essentially zero, leading to a large RF-to-beam power transport efficiency.

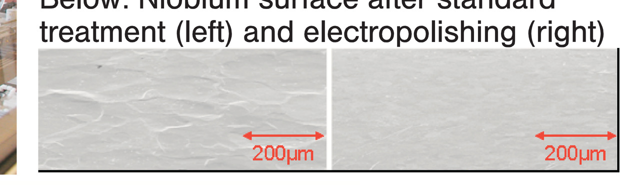
Reaching High Gradients for TESLA-800

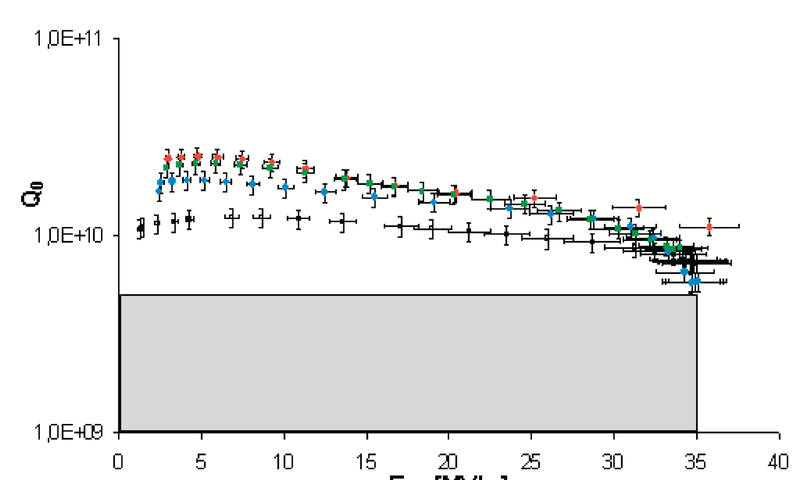
Realising a cms energy of 800 GeV in the given length of ~33km requires acceleration gradients of 35 MV/m in the superconducting cavities. Crucial for this is the surface treatment of the Nb cavities. Standard technologies (etching, polishing) have been proven to be sufficient to reach 23.4 MV/m, the design goal for 500 GeV cms energy. Electropolishing of the cavities has been developed by KEK, CERN, CEA and DESY to reach the TESLA-800 design goal.



Left: New electropolishing facility at DESY

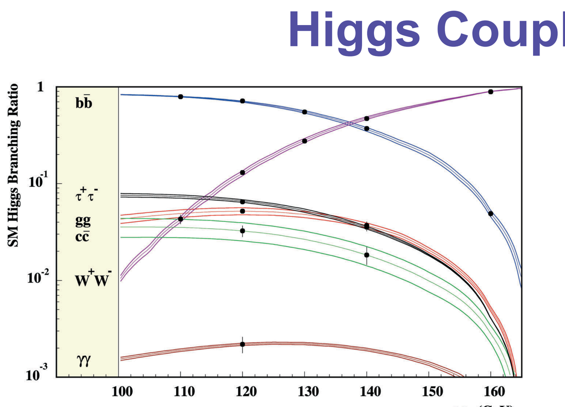
Below: Niobium surface after standard treatment (left) and electropolishing (right)





A number of nine-cell electro-polished cavities reach the TESLA-800 design goal of 35 MV/m with a quality factor of Q>5E09 (indicated by the grey box in the figure left).

Higgs Couplings

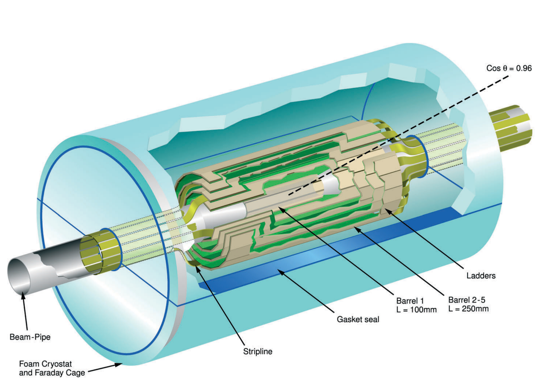


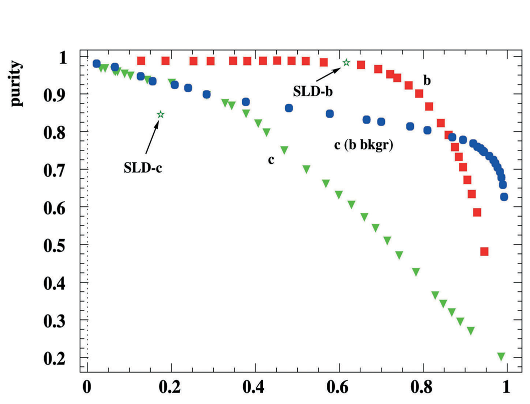
Precision measurements of the Higgs branching ratios give access to the Higgs couplings and could therefore unveil whether the Higgs mechanism is the origin of the fermion masses.

The vertex detector design has to provide efficient and pure quark flavour ID:

- 5 layer pixel detector
- Inner Radius: 15mm
- Pixel: 20 x 20 μm^2
- 800 mio channels
- Resolution (r, φ),(r, z):

$\sigma = 4.2 + 4.0/p(GeV)\ \mu m$

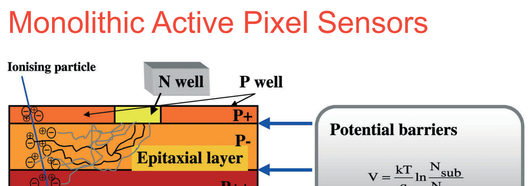




The expected efficiency and purity for b quarks is comparable and for c quarks more than 2 to 3 times better than at the SLD vertex detector.

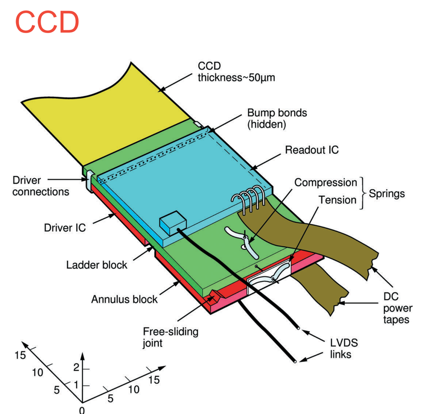
Vertex Detector R&D Efforts

Monolithic Active Pixel Sensors



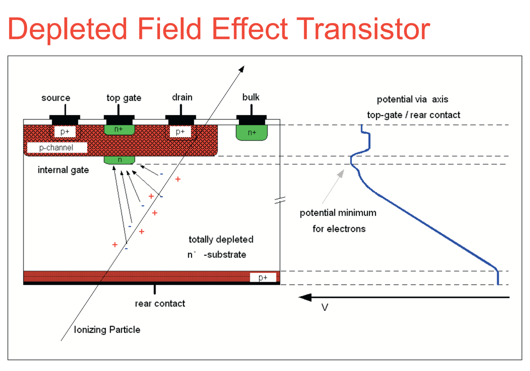
(Geneva, Glasgow, Hamburg, IReS, LEPSI, Liverpool, NIKHEF, RAL)

CCD

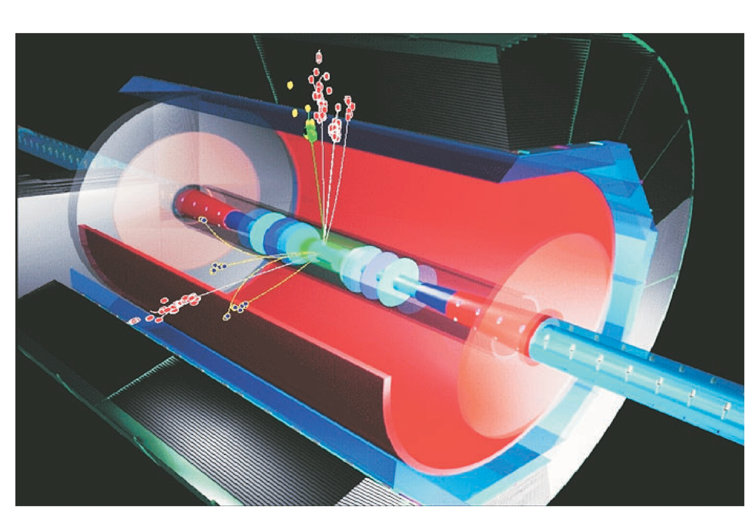


(LCFI Collaboration: Bristol, Glasgow, Lancaster, Liverpool, Oxford, RAL)

Depleted Field Effect Transistor



(DEPET Collaboration: Bonn, MPI HLL Munich)



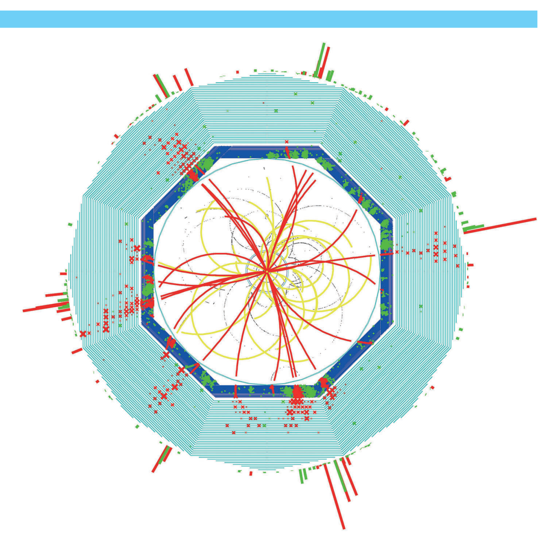
TESLA's Physics Potential Challenges Detector R&D

ECFA Study
Physics and Detectors for a Linear Collider

Multi Jet Final States

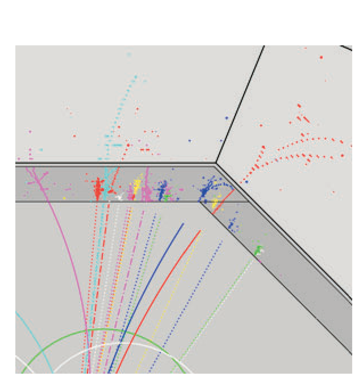
Many of the interesting physics processes have signatures wich include 6 or more jets. The high luminosity of TESLA e.g. allows for the determination of the higgs potential in the reaction $e^+e^- \rightarrow ZHH \rightarrow qqbbbb$.

Another example is the production of a pair of top quarks at $\sqrt{s}$=350 GeV shown here.



The aim for the jet energy resolution is

$\Delta E/E = 0.3 / \sqrt{E}$ (GeV)



Energy flow technique

Exploits the very good energy resolution of the tracking system using:

- the tracking system for charged particles
- the electromagnetic calorimeter for photons
- the hadronic calorimeter for neutral hadrons

ID and separation of the particles requires excellent granularity of the calorimeter

HCAL

- Option I: Stainless steel and scintillator tiles with advanced photo detectors
- Option II: Stainless steel and digital readout (RPCs, wire chambers, GEMs)

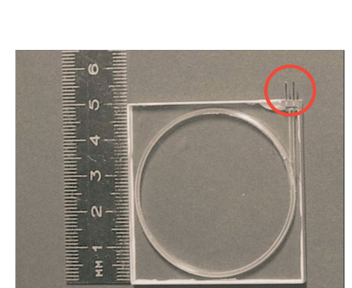
ECAL

SiW sampling calorimeter

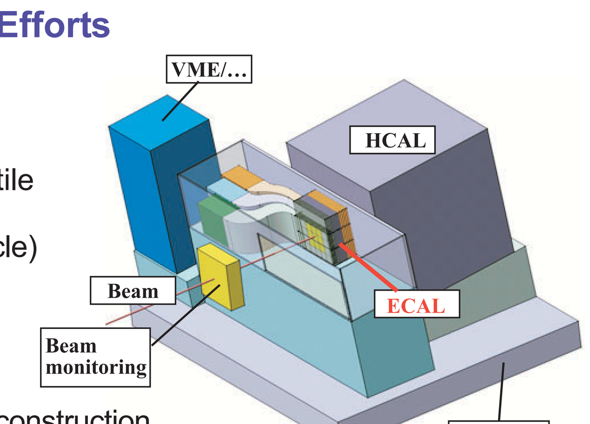
Segmentation: 1cm x 1 cm, 40 layers, $24X_0$

- $\Delta E/E = 0.11/\sqrt{E(GeV)} + 0.01$

Calorimeter R&D Efforts



Left: HCAL scintillator tile with one silicon photo multiplier SiPM (red circle) directly attached. No optical fiber readout is needed.

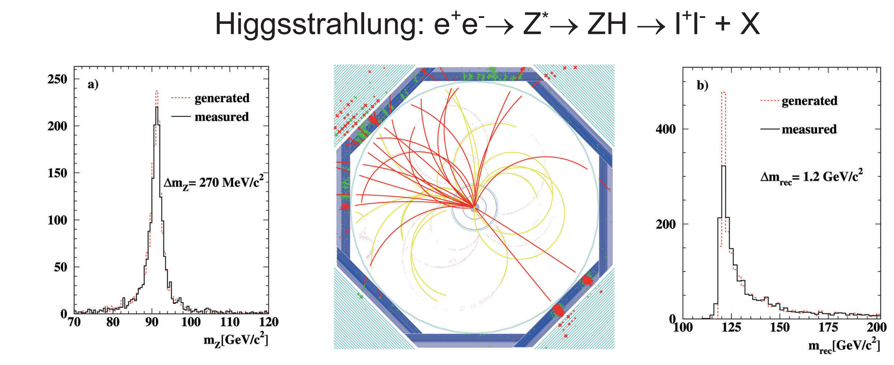


A Combined ECAL/HCAL prototype (right) is under construction and will be used in test beams starting 2004.

(CALICE Collaboration: 26 institutes from 9 countries)

Model Independent Reconstruction of the Higgs

Higgsstrahlung: $e^+e^- \rightarrow Z^* \rightarrow ZH \rightarrow l^+l^- + X$

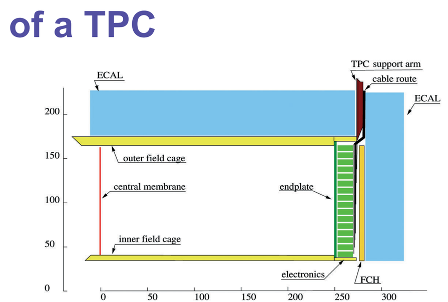


Recoil mass distribution to the leptons enables: M_H, σ_{ZH}, g_{ZZH}, spin
Angular distribution of the leptons gives: Spin, CP, ...

Required: Precision measurement of the lepton momenta
Goal: $\Delta M_{\mu\mu} < 0.1 \times \Gamma_Z \rightarrow \Delta(1/p) = 7 \times 10^{-5}$/GeV

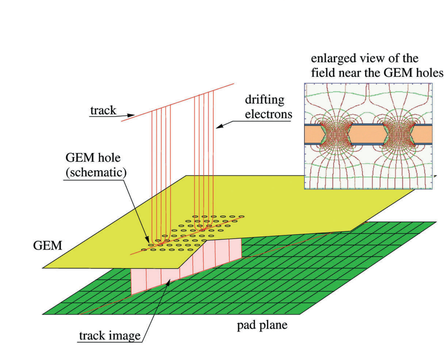
Benefits of a TPC

- Many 3 dim tracking points provide robust track reconstruction
- Low material budget improves calorimetry
- Particle ID via dE/dx
- Track reconstruction at large radii (0.4 < r < 1.6m)

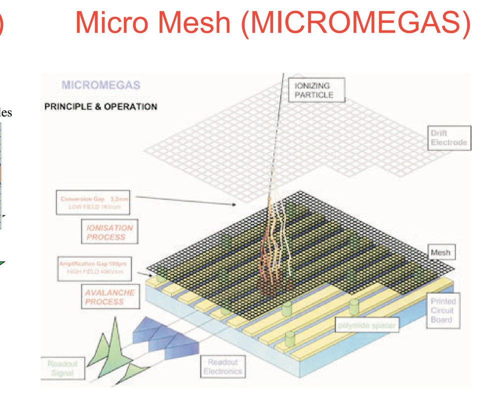


Electron Amplification

Gas Electron Multiplier (GEM)



Micro Mesh (MICROMEGAS)



TPC R&D Efforts

- Amplification properties in magnetic fields (right: 5T magnet facility at DESY)
- Ion feedback
- Space charge effects
- Gas
- Pad structures
- Low material support strucutres
- Electronics

(Aachen, Carleton, Cracow, DESY, Hamburg, Karlsruhe, LBNL, MIT, Montreal, MPI Munich, NIKHEF, Novosibirsk, Orsay, Rostock, Saclay, Victoria)