Introduction

- HERA to be upgraded in 1999/2000, $\mathcal{L} = 1.5 \times 10^{31} cm^{-2}/s \rightarrow 7 \times 10^{31} cm^{-2}/s$, yearly luminosity of 35 $pb^{-1} \rightarrow 150\ pb^{-1}$.
- Allows detailed study of high Q^2, high x physics, forward direction becomes most important part of HERA detectors.
- Detection efficiency for good tracks in high multiplicity events using current FTD about 50%.
- Detection efficiency decreases with increasing multiplicity, resulting systematic errors large.
- Aim of upgrade is to increase FTD efficiency to above 90%.

HERA luminosity upgrade

- Achieve 4- to 5-fold increase in luminosity by tighter focusing of beams in interaction regions.
- Requires 3 new magnets within HERA detectors, one in forward region.

Changes to accommodate new magnets

Item	Cost (kDM)
Magnet support	600
Beam pipe	500
Lumi system	300
SpaCal mods	100
BST/CST mods	15
Plug Calo	10
FPS and FNC	50
ToF veto, veto wall	100
N_2 shield	10

- Total 1.7 MDM.

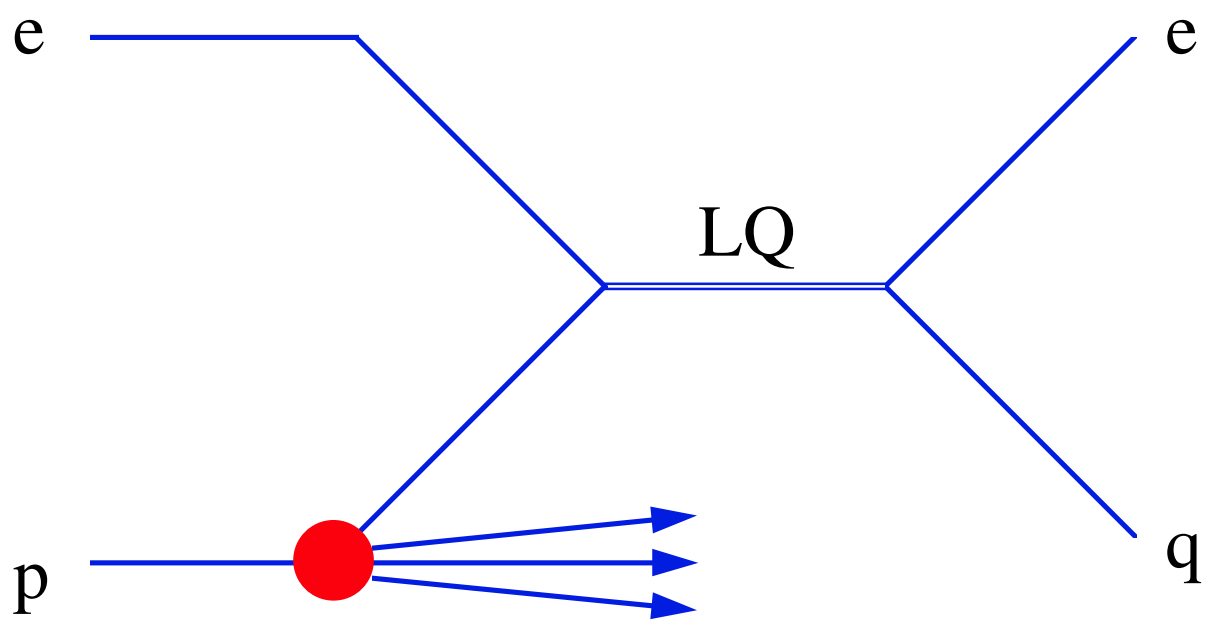
H1 upgrade projects

Item	Institute	Cost (kDM)
New CIP	HD/Zurich	700
CJC readout	DESY/RAL	700
BST ϕ strips	DESY-Zeuthen	500
BST r strips	DESY-Zeuthen	200
LAr DAQ	Paris groups	50
LAr trigger	MPI Munich	100

- Total cost 2.3 MDM.
- H1 investment in HERA upgrade adds up to ~ 4 MDM

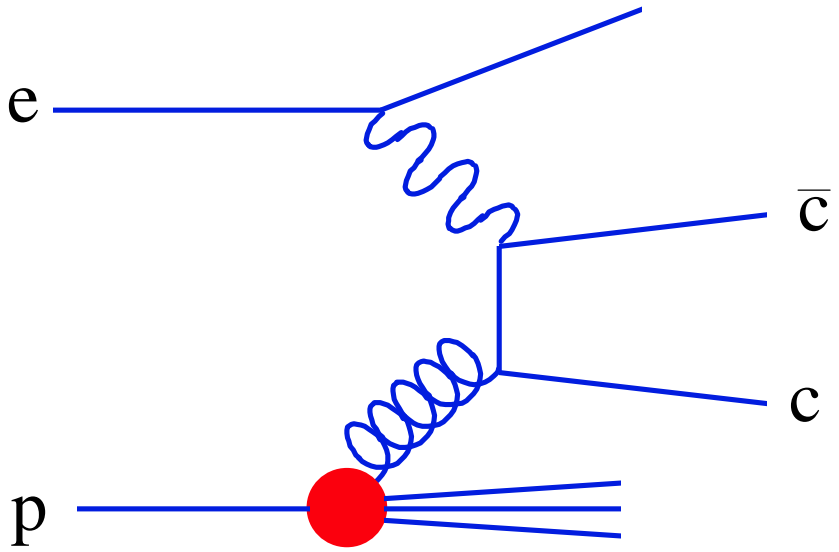
Physics with upgraded FTD

- New physics.
  - Any new high mass state travels forward in HERA detectors.
  - e.g. scalar leptoquark m = 200GeV decays so either lepton or quark in FTD 75% of time
    $\rightarrow$ 100% of time if m = 250 GeV.

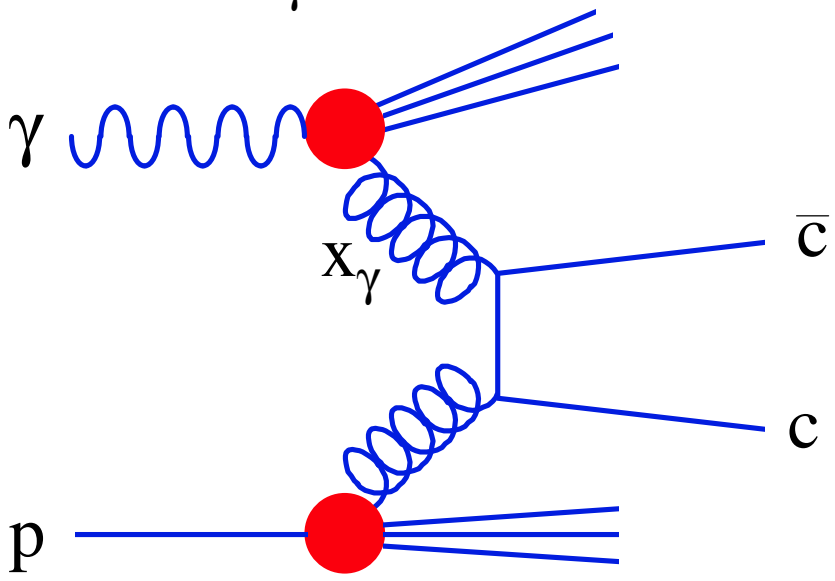


Physics with upgraded FTD

- Many SM measurements improved.
  - Better FTD allows study of charm at high x in DIS:

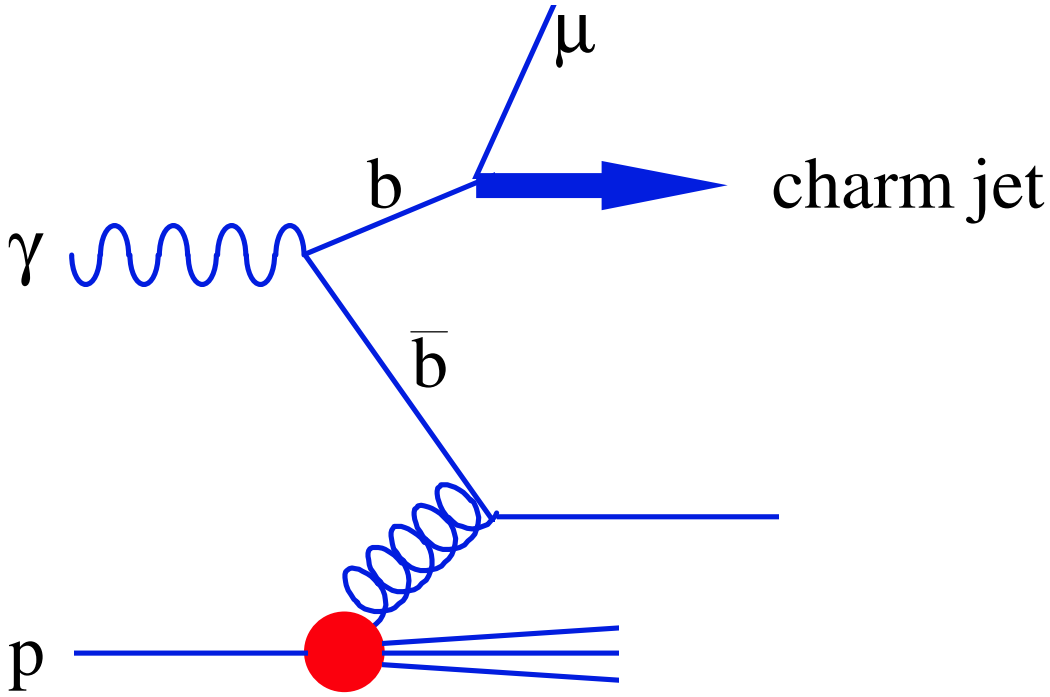


  - and at low x_γ in photoproduction:



Beauty in photoproduction

- Identify using momentum of muons transverse to jets in di-jet events.



Charm in DIS in forward region

- Identify via decay chain:

$$D^{*+} \rightarrow D^0 \pi^+$$

$$D^0 \rightarrow K^- \pi^+$$

  - Combine particles (≥ 1 "forward") with $p_T > 0.4$ GeV to make D^0.
  - If $\left| m_{K\pi} - m_{D^0} \right| < 100\,\text{MeV}$ combine with "slow π", $p_T > 150$ MeV.
  - Histogram $m_{K\pi}$ and background subtracted $\Delta m = \left| m_{K\pi\pi} - m_{D^*} \right|$.
  - Kinematic region:
    - » $Q^2 > 4\ \text{GeV}^2$, $x > 0.007$.
    - » "Struck quark" angle $\theta_q < 30^o$.
    - » $p_{T\,D^*} > 2\,\text{GeV}$.

Charm in DIS

$Q^2 < 100\ GeV^2$

$p_T > 1.5\ GeV$

CTD + FTD

CTD

$Q^2 > 100\ GeV^2$

Beauty cross section

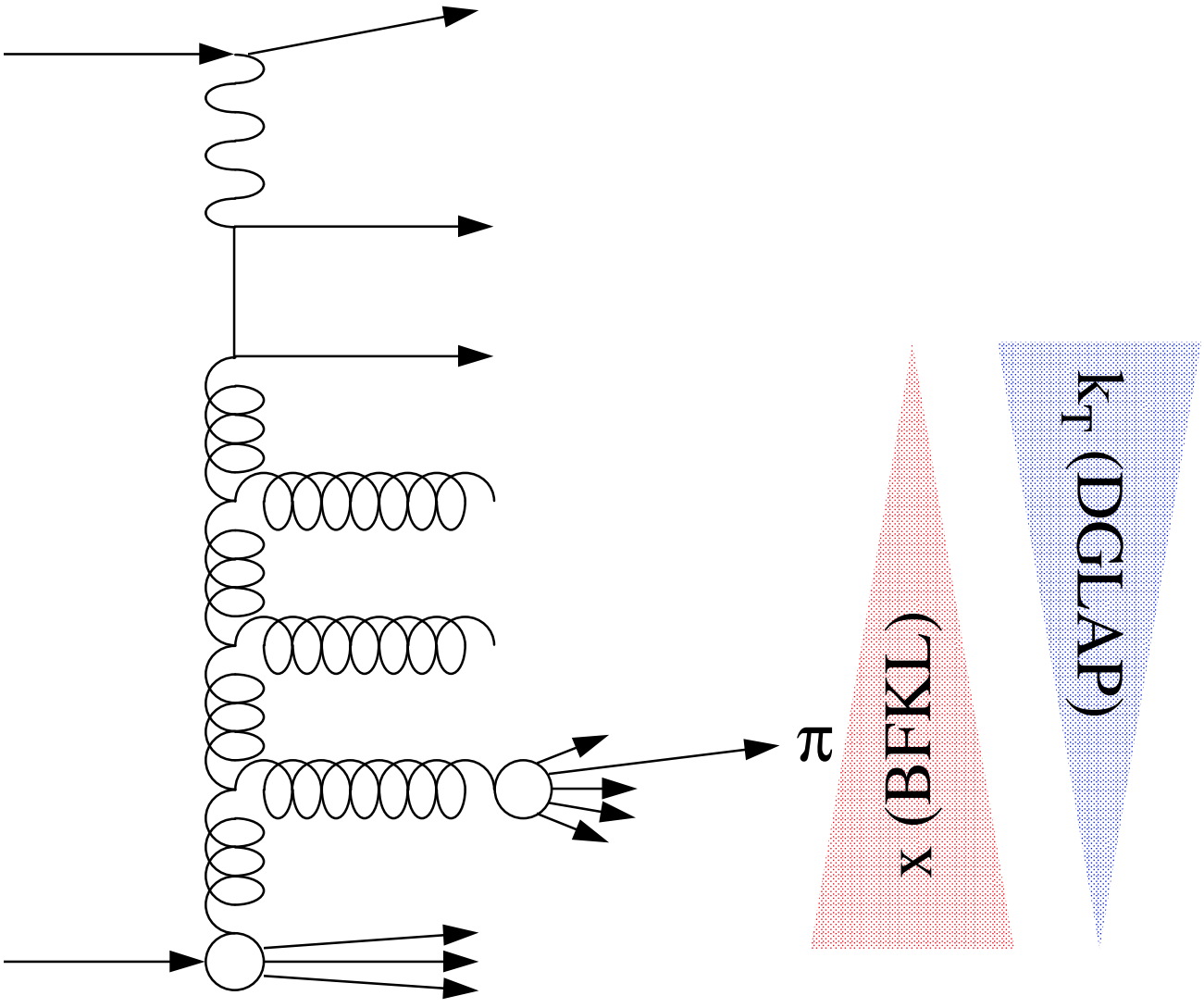
- Cross section measured to be:

$$\sigma_{b\bar{b}} = 0.93 \pm 0.08 \,^{+0.17}_{-0.07} \text{ nb}$$

- Cf. LO expectation $\sigma_{b\bar{b}} = 0.191$ nb

QCD studies

- DGLAP and BFKL approximations predict differing energetic forward π rates at low x.
  - $k_T^2 \sim Q^2$, DGLAP rate ~ 0
  - $x_\pi = E_\pi/E_p >> x$, BFKL rate >> 0

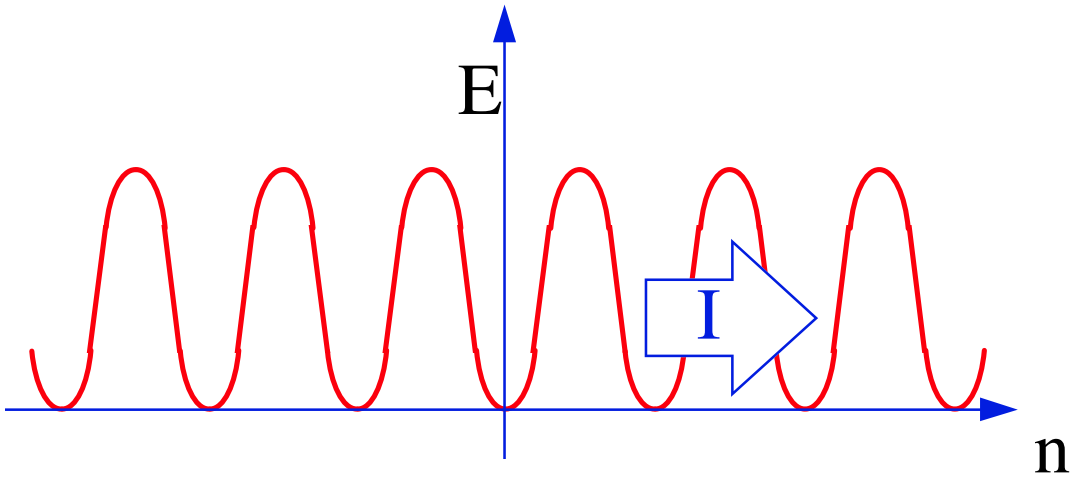


Forward $\pi^{\pm}$ rate

- Look at statistical/systematic errors expected after one years running with current/upgraded FTD after luminosity upgrade.

- Kinematic region $E_e > 12$ GeV, $y > 0.1$, $173^o > \theta_e > 156^o$.

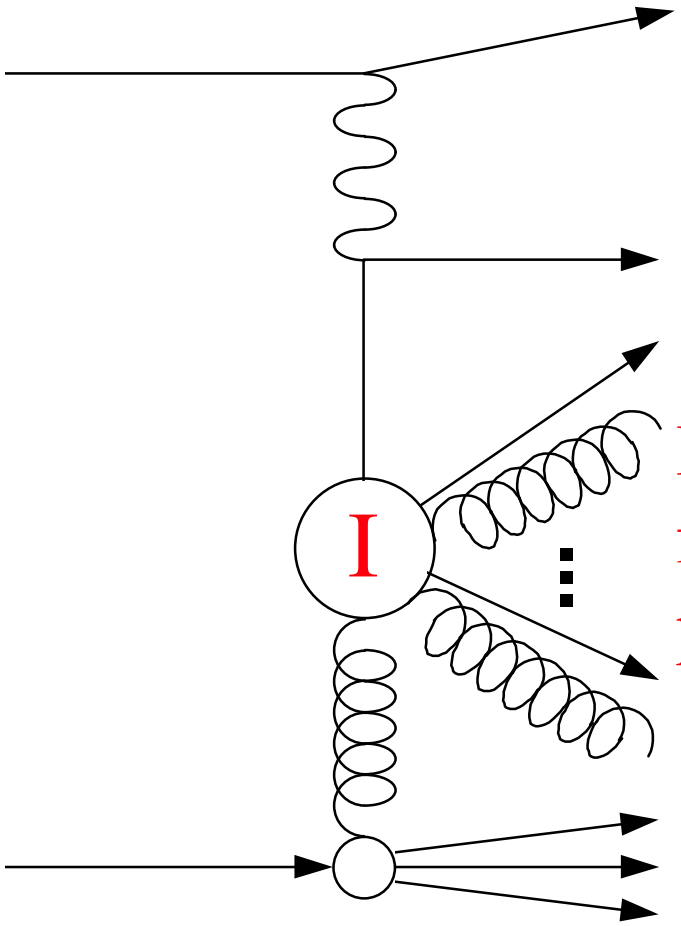
Instantons



- Induce B+L number violation in electroweak sector of SM.
- QCD analogue, chirality violation.
- Cross-section predictions for DIS available.
- Upgraded HERA will see instantons if predictions correct.
- Fundamental test of previously unexplored region of SM.

QCD instantons

- Final state in DIS



Isotropic (in I c-of-m), flavour democratic particle production.

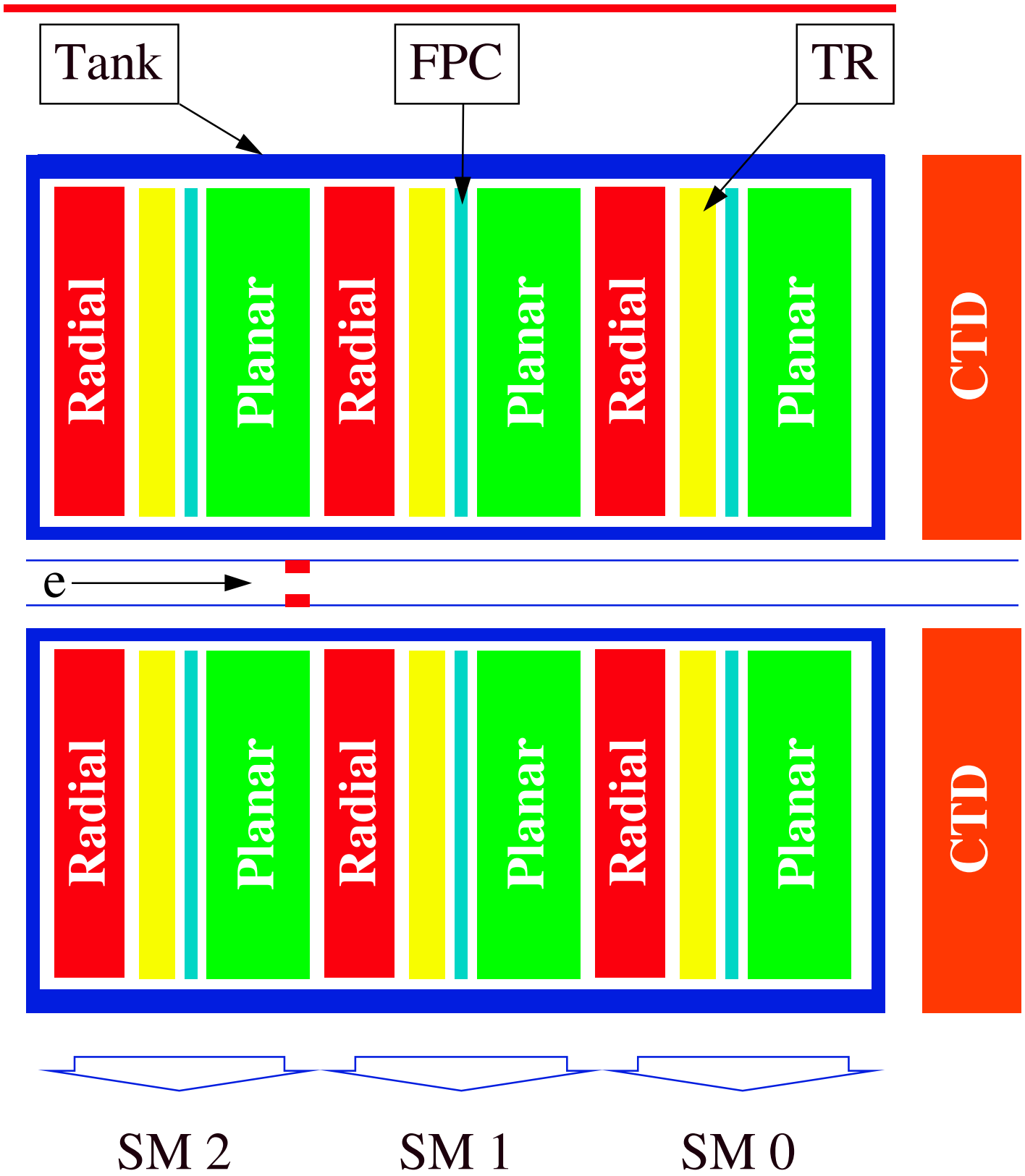
- Look for beauty, charm, strangeness... with increased efficiency in upgraded FTD.

Instanton induced interactions

- Lab. pseudorapidity at which kaons appear.
- $10 < Q^2 < 70\ \mathrm{GeV}^2$, $0.001 < x < 0.01$.

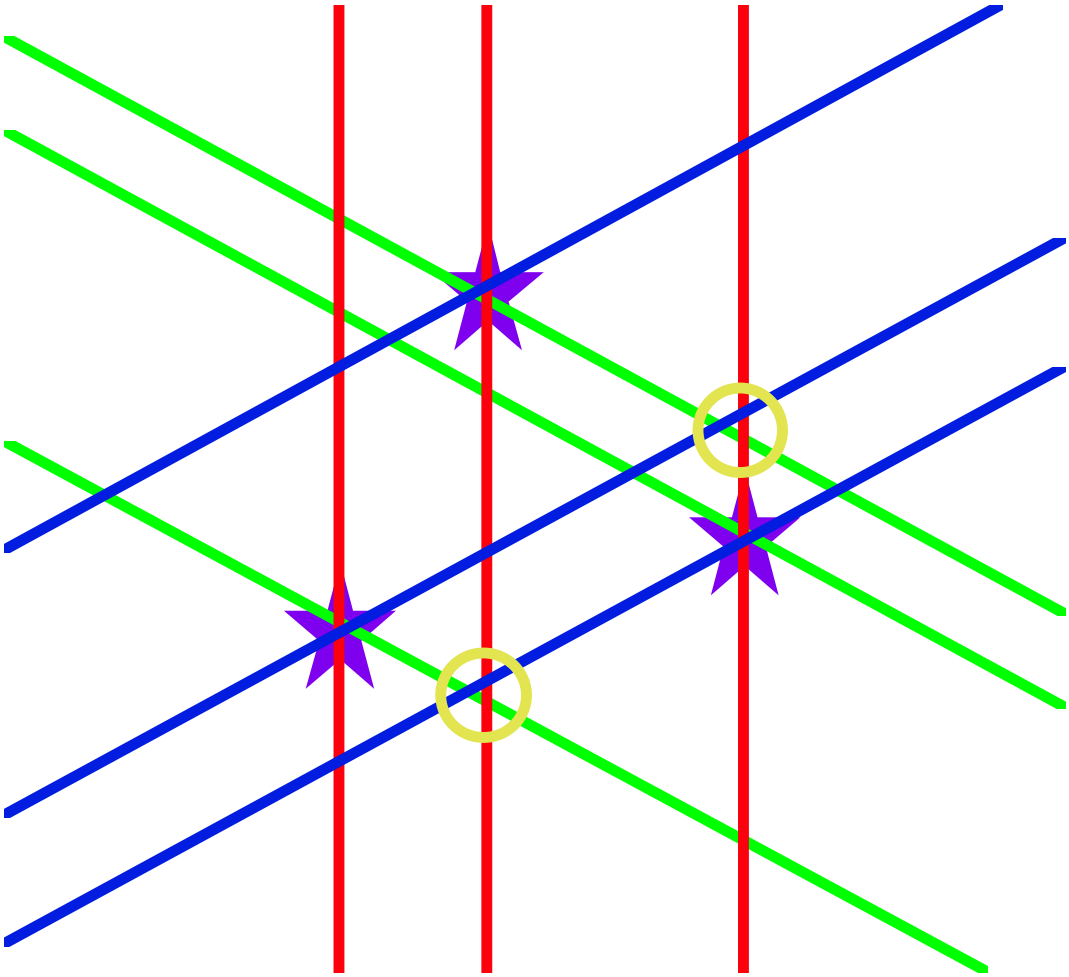
- Current H1 limit, < 1% DIS events induced by instantons.

The current FTD



Track finding in FTD

- Find “clusters” in planar chambers.
- Find sets of three clusters in planar module compatible with coming from one track.



Track finding in FTD

- Form “planar segments” from optimal groupings of three clusters.
- Find “radial segment” in radial chambers.
- Link segments to form tracks.
- Good tracks must have planar segments to tie down θ.
- Planar segment finding efficiency drives FTD efficiency.
- Inability to resolve hodoscope ambiguities leads to loss of planar segments.
- Cluster loss leads to loss of segment.

Problem for FTD

- At high Q^2 average of 9 primary hadrons in FTD.
- Secondaries generated in CTD end-wall (0.5 X_0) and interactions in beam-pipe and collimators.
- Four secondaries produced for every primary particle.
- 13% of primary hadrons have particle within 2mm in drift in planar cell.
- Problem compounded by ~ 12% probability per hadron per planar wall of δ-ray production.

FTD efficiency from MC

- Low Q^2 DIS, (removing effect of dead wires)

Track selection	Effic. (%)	FWHM $\Delta(q/p)$ (GeV^{-1})	Prop. well measured (%)
1R or 1P(p or s)	97	0.076	50
1P(p)	77	0.070	66
1P(p) and V	70	0.068	75
1P(p) and V and (1P or 1R)	66	0.063	89
1P(p) and V and F and (1P or1R) *	60	0.057	92

- For high Q^2 DIS * becomes 42%

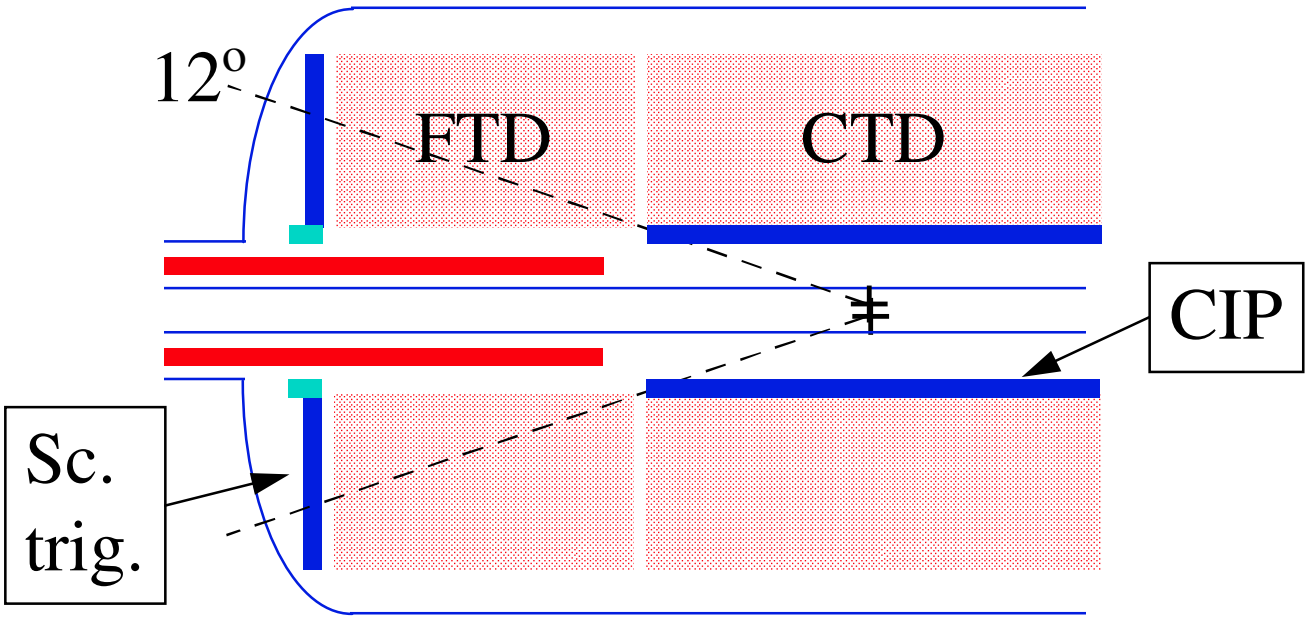
(1R $\Rightarrow \geq$ 1 rad seg, 1P $\Rightarrow \geq$ 1 plan seg,
V $\Rightarrow$ good vertex fit, F $\Rightarrow$ good fit quality)

Proposed upgrade

- Remove transition radiators and MWPCs to make space for...
- Three new planar chambers.
- Rebuild FTD including new planar chambers oriented in modules so $\phi = +60^{o}$, -60^{o}, 90^{o} and 0^{o}.

Removal of TR/MWPCs

- TR unusable in electromagnetic shower surrounding high energy electron.
- MWPCs form part of z-vertex trigger and forward ray traigger.
- New CIP takes over z-vertex function.
- Add scintillators to maintain forward ray capability for $\theta < 12^{o}$.



Cost

Units k£