Zero Degree Calorimeters for ATLAS

ZDC Physics

Installation scenario

ZDC design

ATLAS TDAQ integration

ZDC performance (simulation,
 rad damage, testbeam)

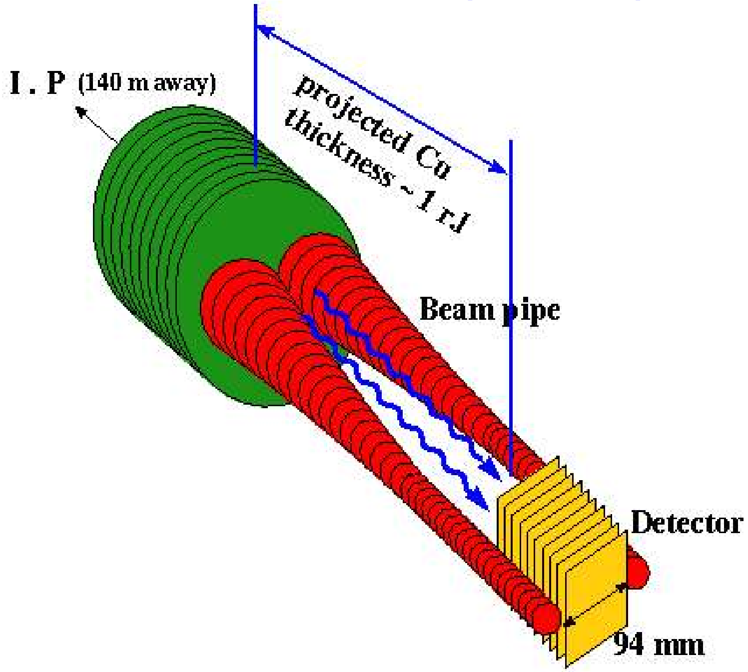
Planning

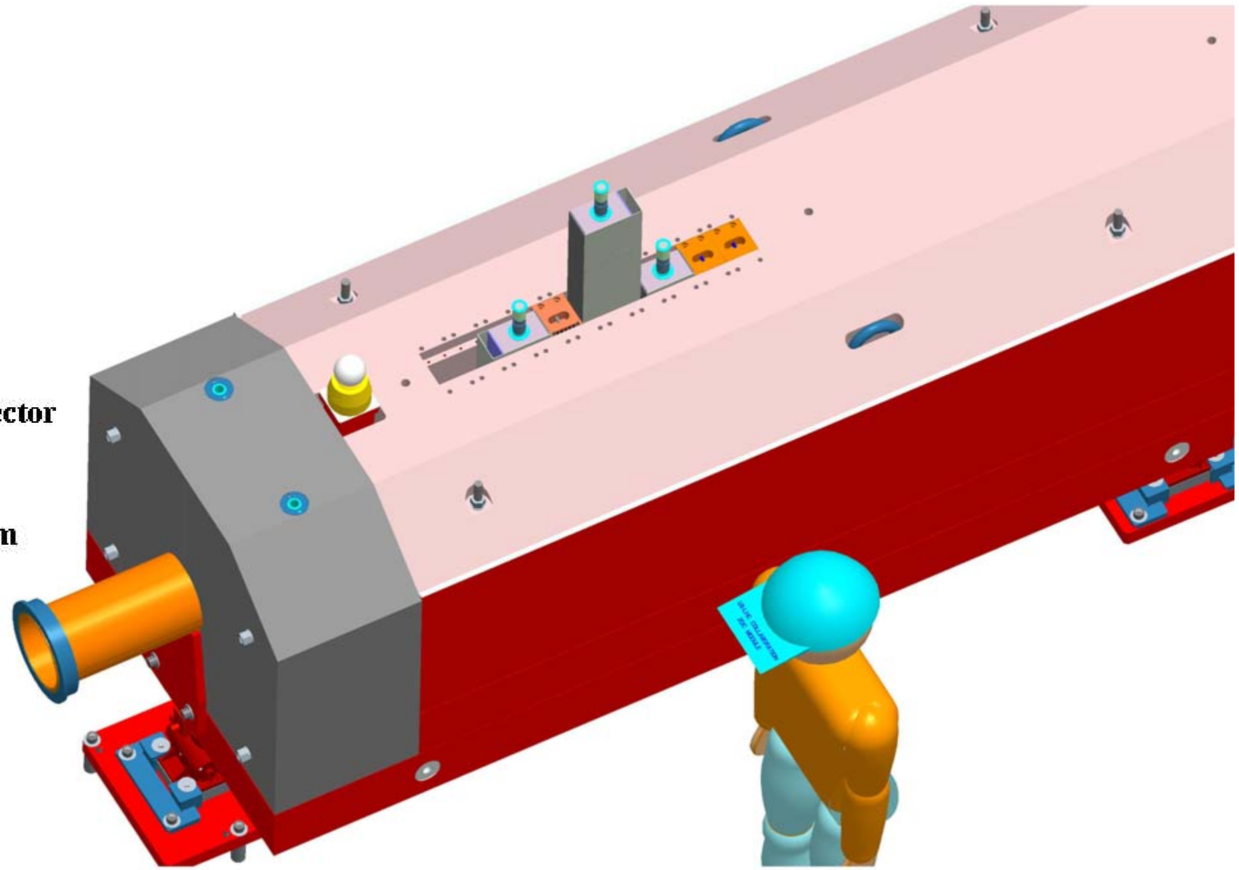
Sebastian White, Brookhaven Lab

LHCC – January 2007

ZDC in ATLAS

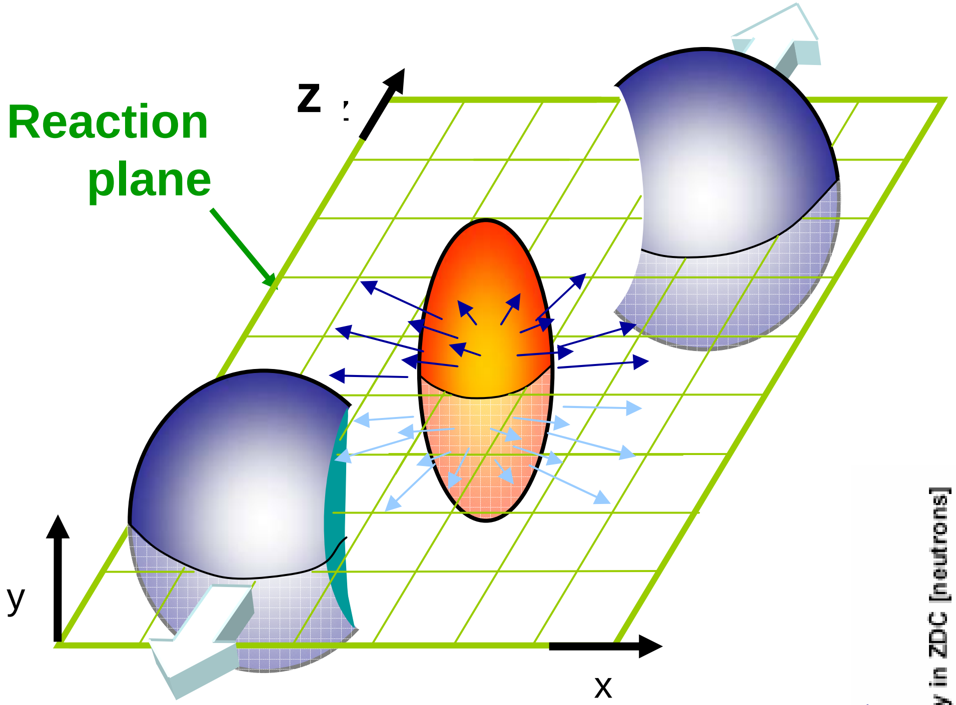
A Zero Degree Calorimeter (ZDC) is a calorimeter that resides at the junction where the two beam pipes of the LHC become one – at 0° from the pp collisions. It is housed in the shielding unit that protects the S.C magnets from radiation, and measures neutral particle production at 0°. It can play many roles.





Event characterization using forward detectors

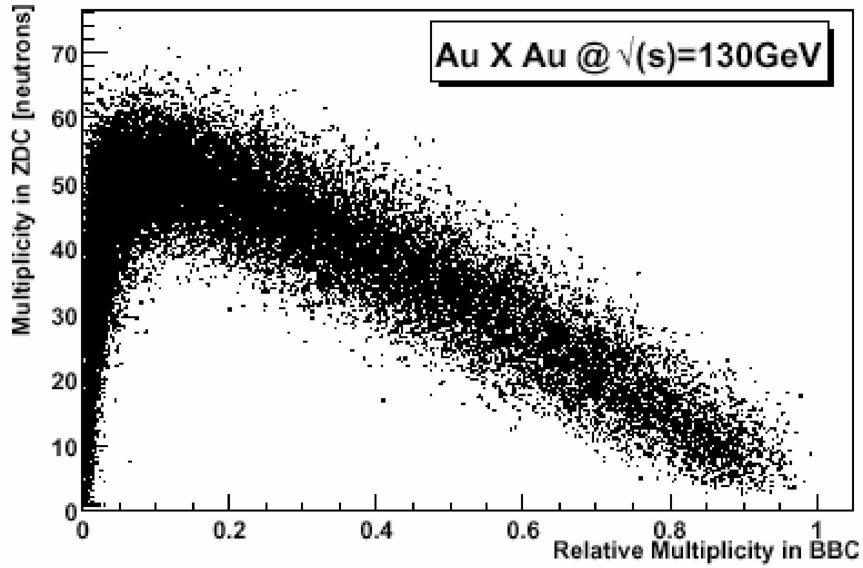
>>Direction and magnitude of impact parameter, b



Spectator neutrons
•measure centrality,
•Min_min_bias trigger

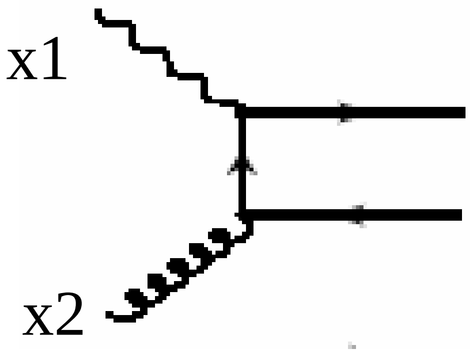
Magnitude from complementary parameters

$N_{participant}=2*A-N_{spectator}$



Beam-Beam Counter Mult/1000

Probing small x structure in the Nucleus with γN->jets, in Ultraperipheral Collisions(UPC)



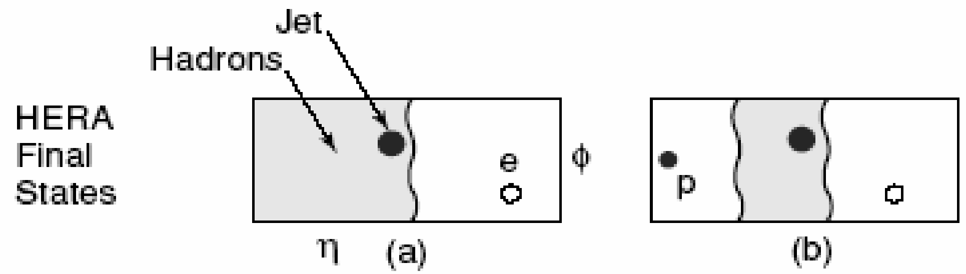
di-jet photoproduction-> parton distributions,x2 by γ with momentum fraction, x1

$4p_t^2/s = x1 * x2$

$<y> \sim -1/2 * \ln(x1/x2)$

Signature: rapidity gap in γ direction(FCAL veto)

ATLAS coverage to $|\eta|<5$ units. P_t ~2 Gev "rapidity gap" threshold



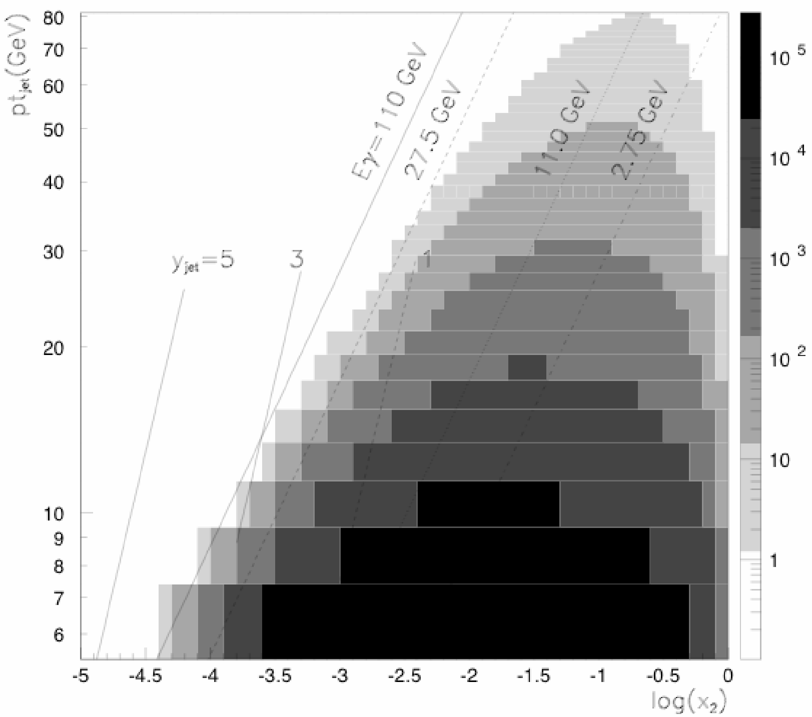
Analogous upc interactions and gap structure

diffractive   Non-diffractive

Rates and Kinematics

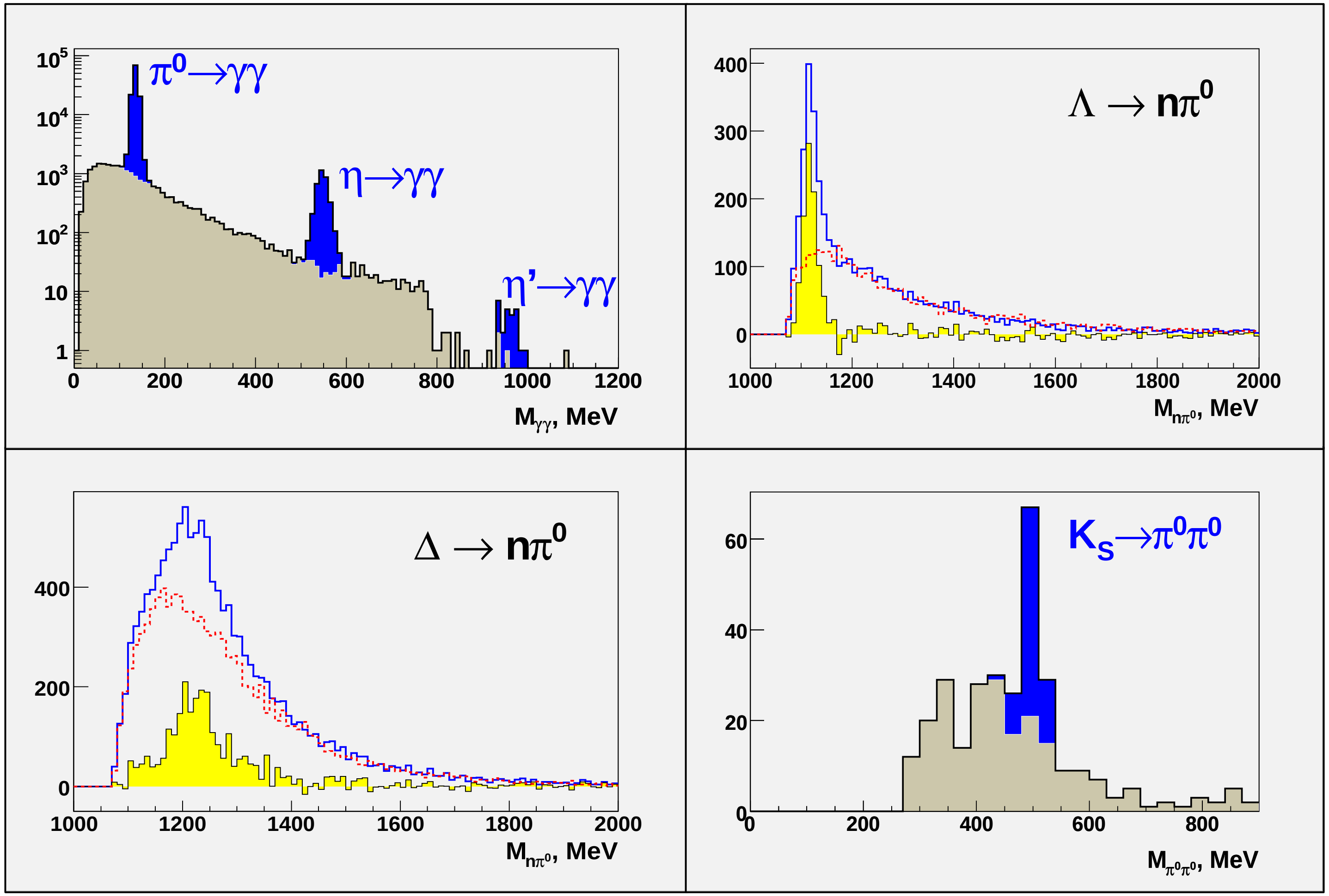
Event yields from a 1 month HI (Pb-Pb) run at nominal Luminosity (4 10^{26} $cm^{-2}s^{-1}$). Counts per bin of δpt=2 GeV $\delta x2/x2$=+/- 0.25

(with M. Strikman and R. Vogt)



ZDC in pp(Phase II configuration)

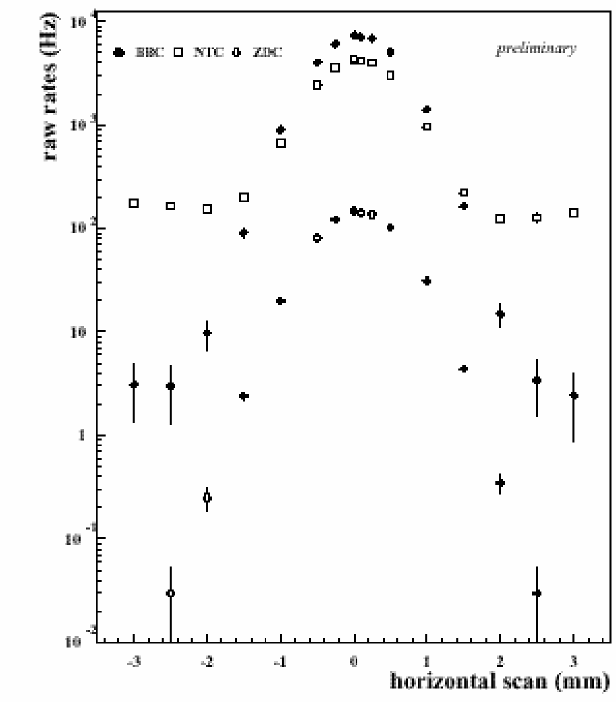
In pp, the ZDC can measure forward production cross sections for several types of particles at very high energies. This will be useful for adjusting parameters for simulations and models, and for cosmic ray physics where the energy in one proton's rest frame is 10^{17} eV – a very interesting energy for extended air showers.



What happens when a high energy proton hits the upper atmosphere?

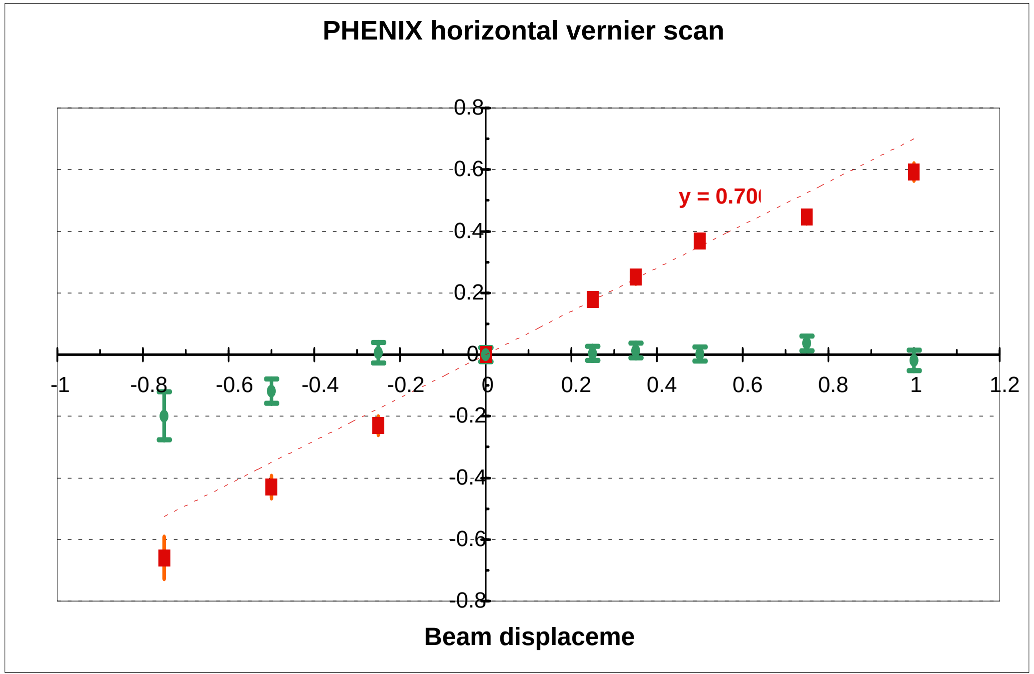
The ZDC can find a pi0 in the midst of several neutrons.

(1M Pythia events analyzed by a ZDC)



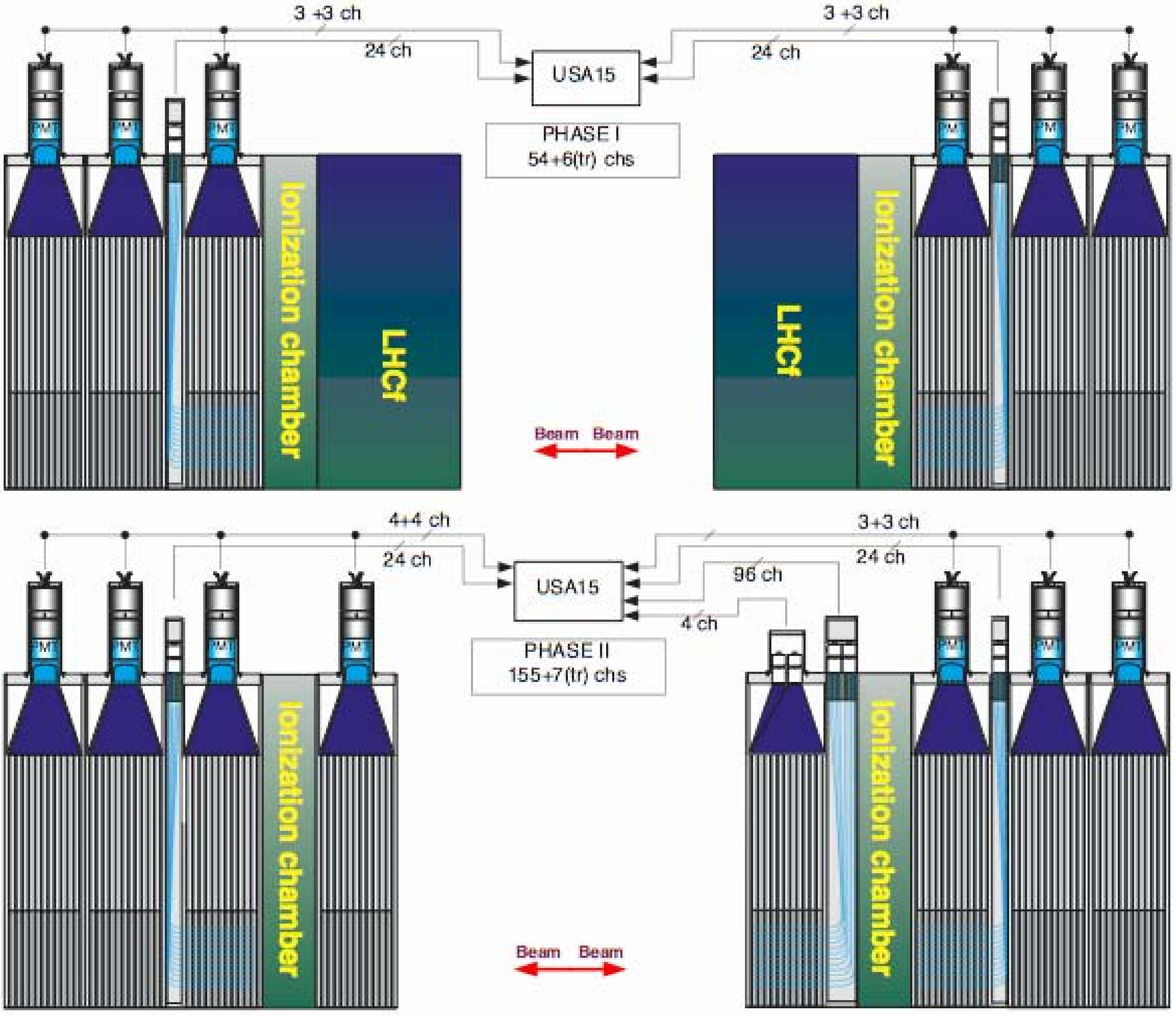
RHIC ZDC as an accelerator tool (in pp)

- •Van derMeer scan (ZDC coincidence rate vs. relative beam position)
- •ZDC (lower curve) bkg free over 4 orders of magnitude



- •ZDC also measures beam displacement (red points)
- •Useful for crossing angle commissioning

ZDC scenarios and cabling

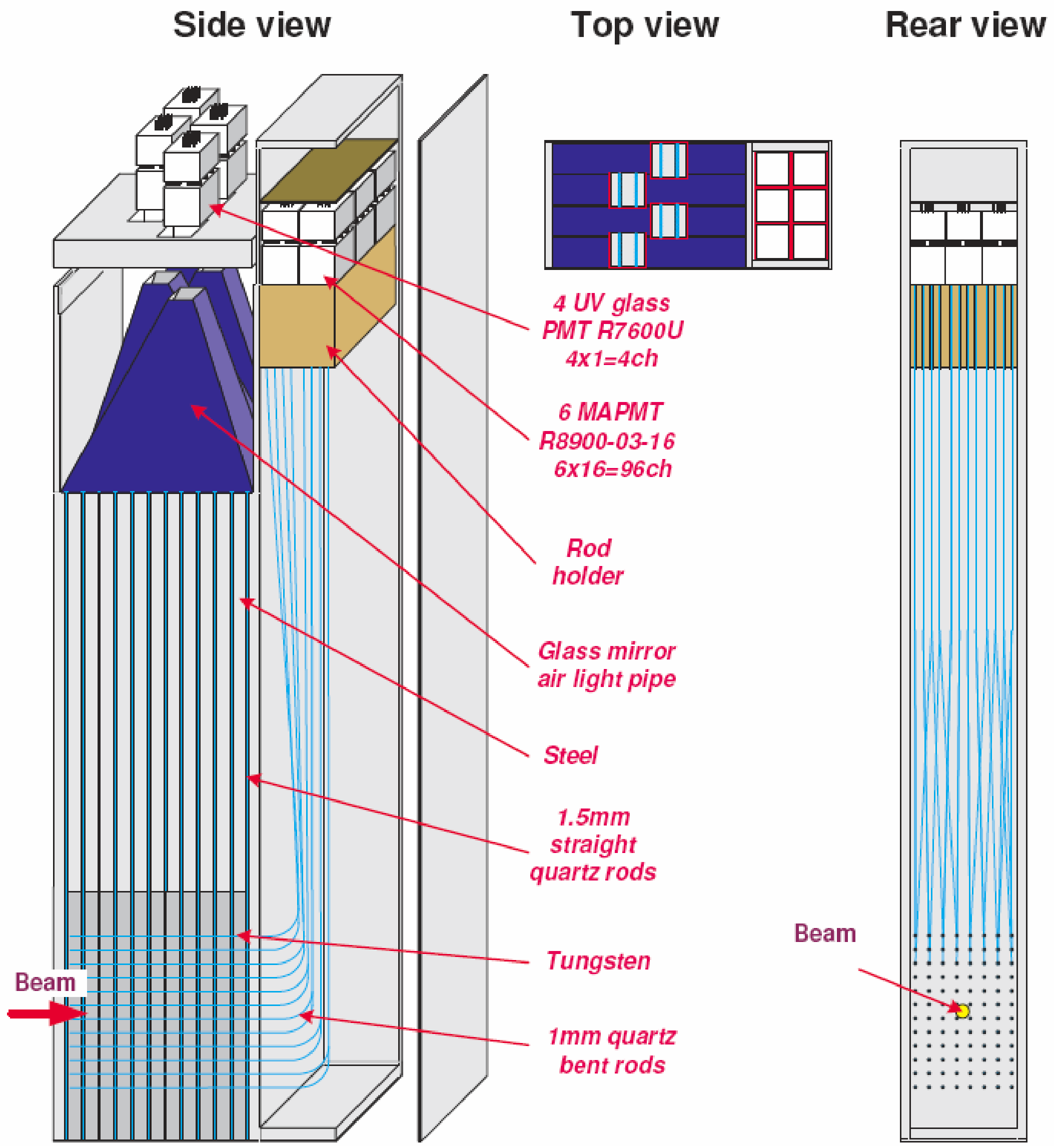


EMCal Module design
(1 module only)

Light collected from
Strips of 1.5 mm quartz
Transverse to beam
(main energy and timing)

And 1 mm quartz rods
Projective to beam

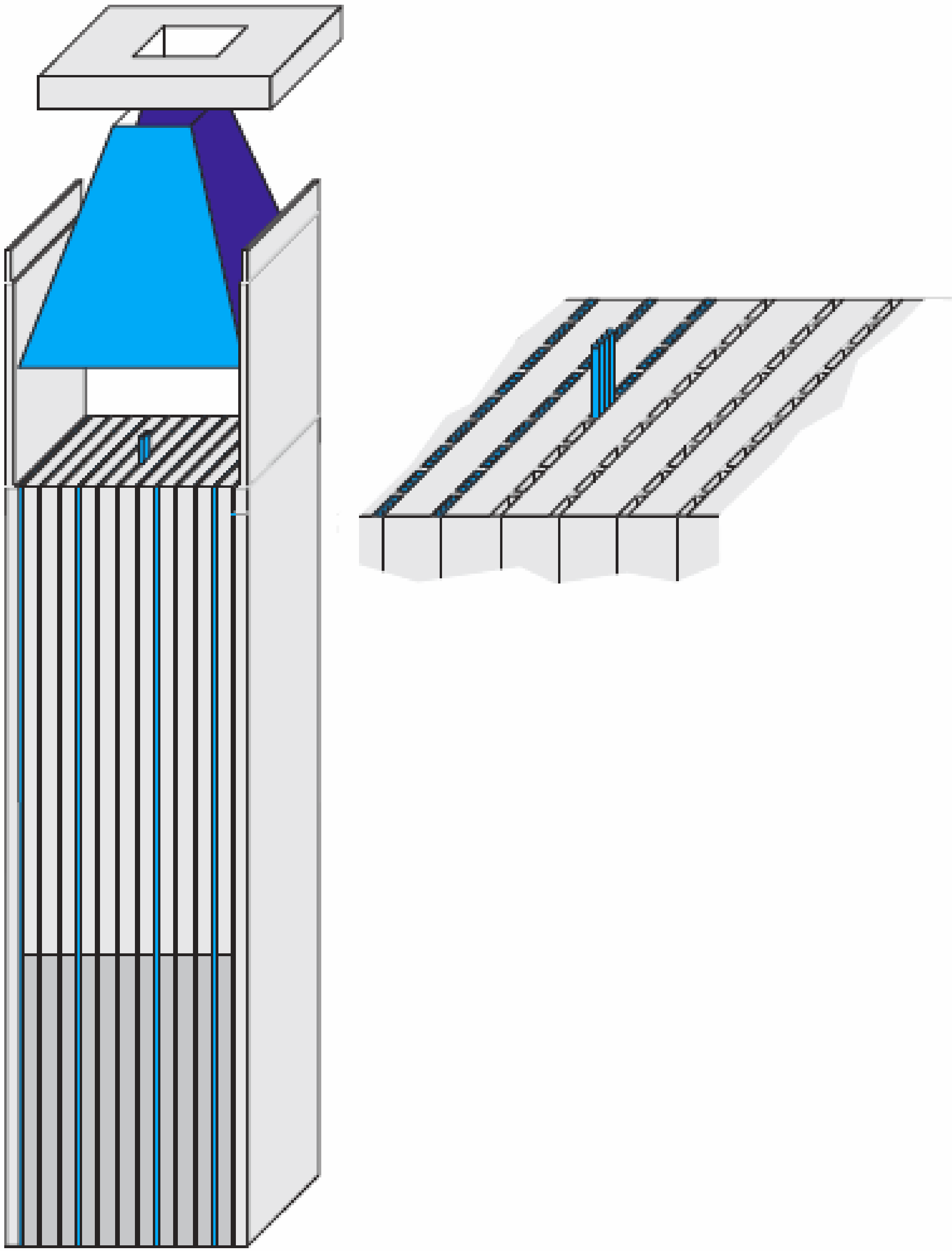
Latter measure coordinate
Of showers.



Strip detail and air
Lightguide

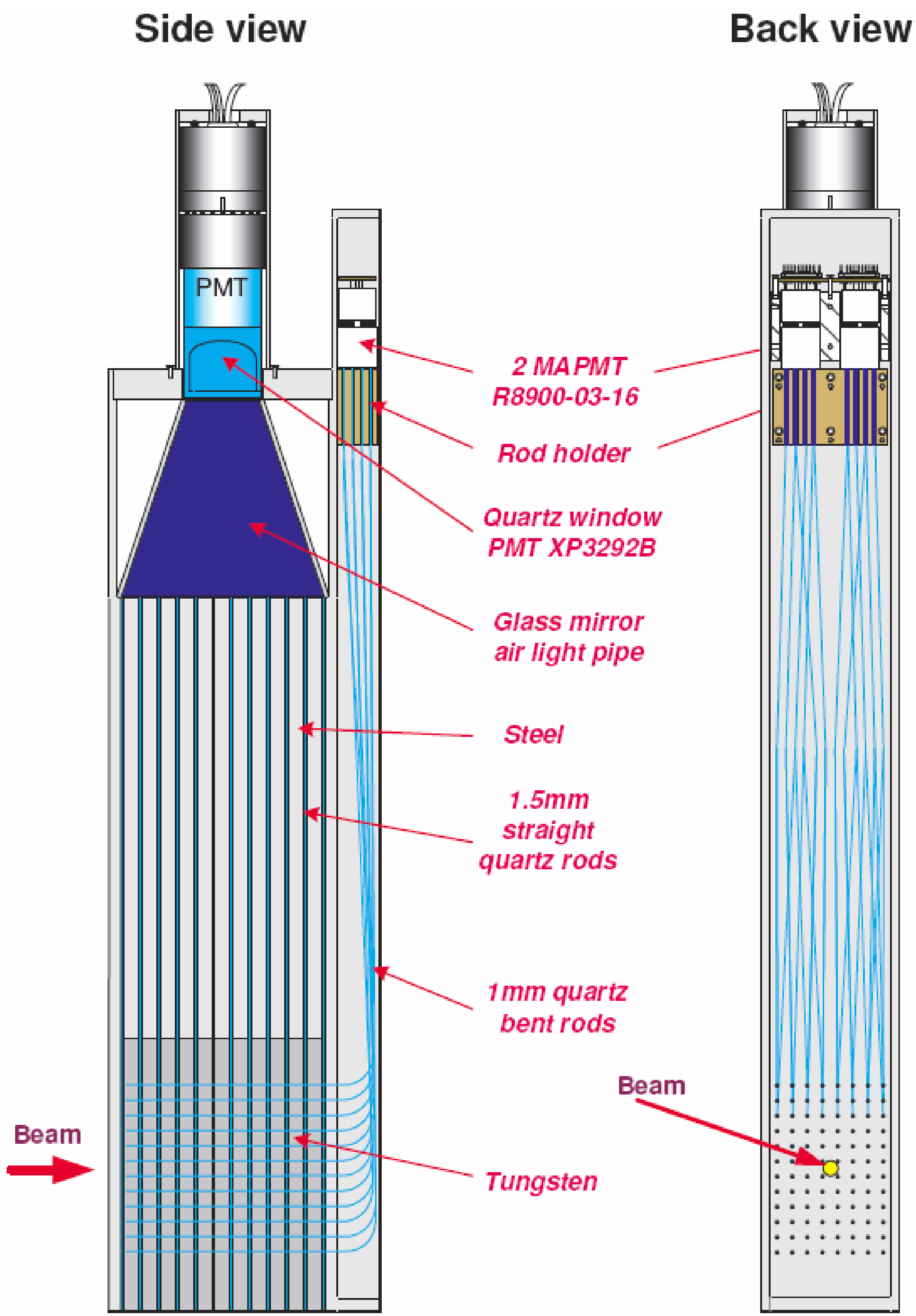
648 1.5 mm diameter rods

Provides main energy and
Timing measurement



Hadronic module with
Coordinate readout
(1 module per arm)

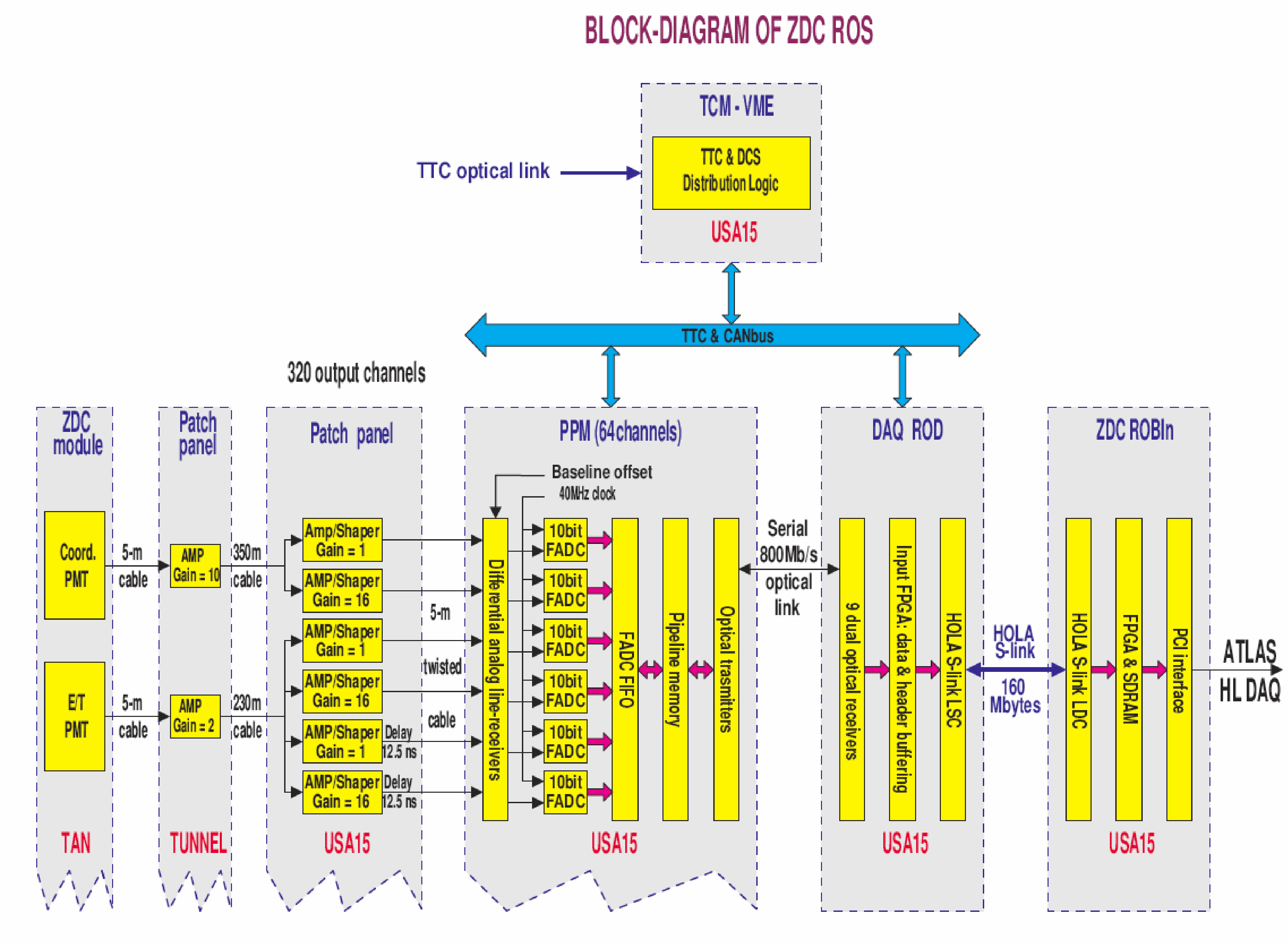
Rods are grouped into
4 per readout pixel



Inserting coord readout fibers

Summary of ZDC module parameters

	Hadronic	Electromagnetic
Number of modules	3 on each arm	1 on each arm
x-y sensing modules	1 on each arm	1 on 1 arm
Energy measuring tubes	3 on each arm	4 on 1 arm, 1 on 1 arm
Tube type	MAPMT: R8900-03-16	Same
	Single channel: XP3292B	Single channel: R7600U
Tot. Int. depth	4.6 λ_{int} on each arm	$29X_0$
	(with EM module)	
Module size (mm)	93.8 wide, 738 high, 150 deep	Same
Tungsten plate size (mm)	91.4 wide, 180 high, 10 deep	Same
11 plates/module		
Module weight (kg)	80	Same
Number of strip (1.5 mm) rods	648	Same
Number of pixel (1 mm) rods	96	Same
Number of pixel readout		
channels	24 (in each arm)	96 (one arm only)


BLOCK-DIAGRAM OF ZDC ROS
TCM - VME
TTC & DCS Distribution Logic
USA15
TTC optical link
TTC & CANbus
320 output channels
ZDC module
Coord. PMT
E/T PMT
TAN
5-m cable
5-m cable
Patch panel
AMP Gain = 10
AMP Gain = 2
TUNNEL
350m cable
230m cable
Patch panel
Amp/Shaper Gain = 1
AMP/Shaper Gain = 16
AMP/Shaper Gain = 1
AMP/Shaper Gain = 16
AMP/Shaper Gain = 1
AMP/Shaper Gain = 16
Delay 12.5 ns
Delay 12.5 ns
USA15
5-m twisted cable
PPM (64channels)
Baseline offset
40MHz clock
Differential analog line-receivers
10bit FADC
FADC FIFO
Pipeline memory
Optical trasmitters
USA15
Serial 800Mb/s optical link
DAQ ROD
9 dual optical receivers
Input FPGA: data & header buffering
HOLA S-link LSC
USA15
HOLA S-link
160 Mbytes
ZDC ROBIn
HOLA S-link LDC
FPGA & SDRAM
PCI interface
USA15
ATLAS HL DAQ

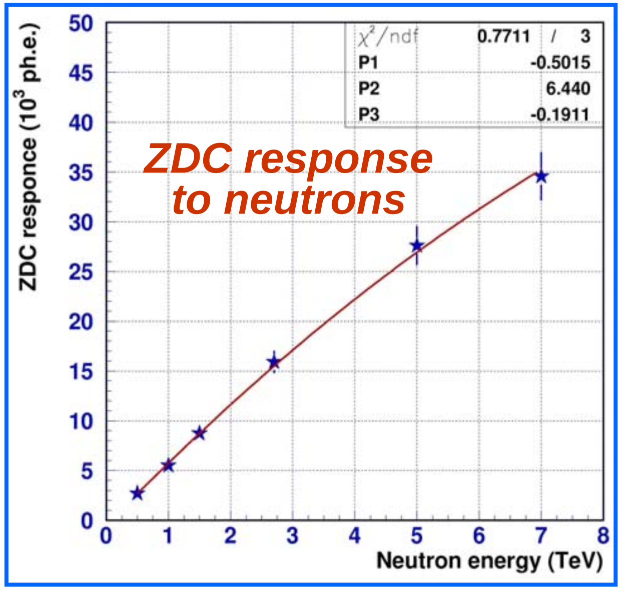
L1 Calo boards

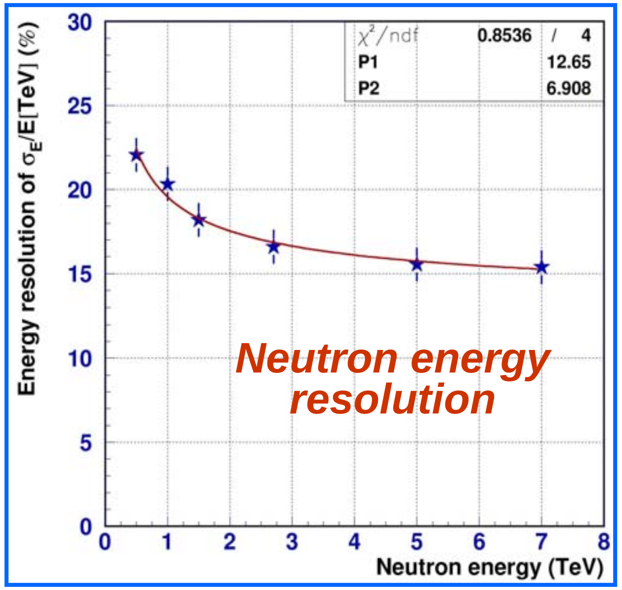
- We require 5 PreProcessor modules
- Current production is for 180 modules of which 120 modules needed for L1calo system (KarlHeinz Meier, Heidelberg)
- Project would be charged for cost of materials (~10k euro/module)
- 1 ROD sufficient

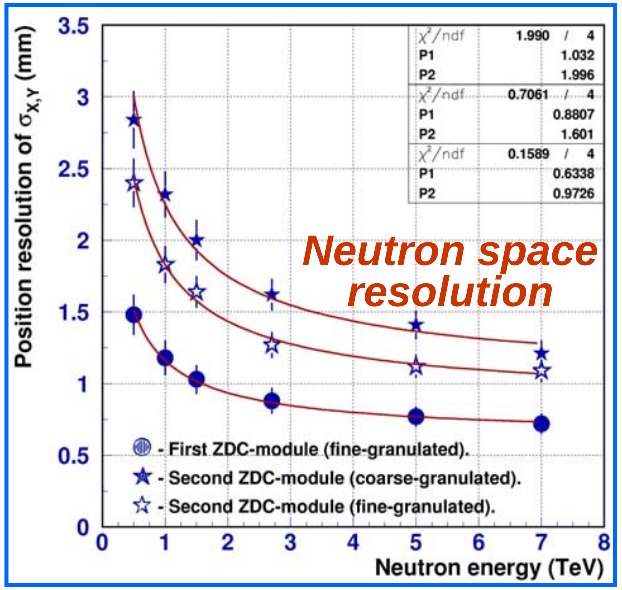
ZDC L1 trigger

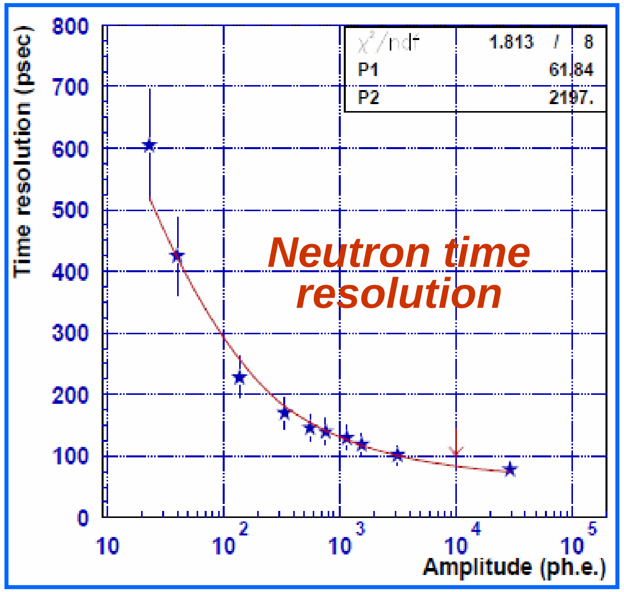
- The ZDC trigger will be used primarily as a 2-arm coincidence (each arm above a preset threshold) in Heavy ion runs
- Trigger bits assigned in Central trigger Processor board ctp_cal
- Ctp_cal is designed to accept calib triggers as well as trigger from small systems like the ZDC

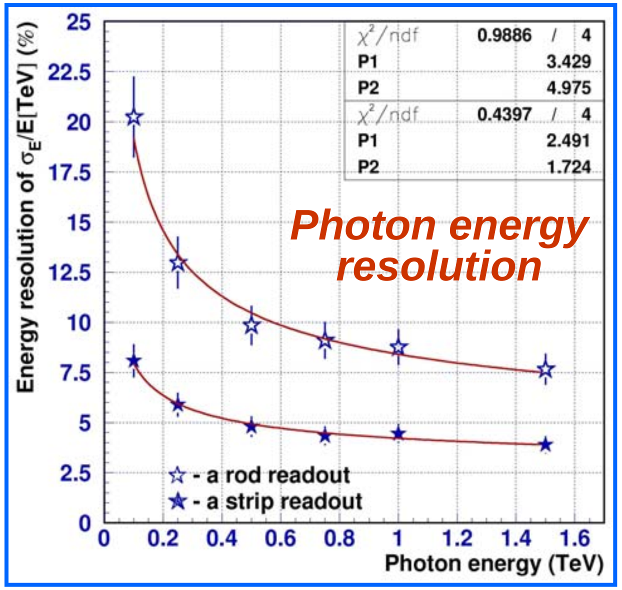
ZDC time, space and energy resolution (Average over active area)

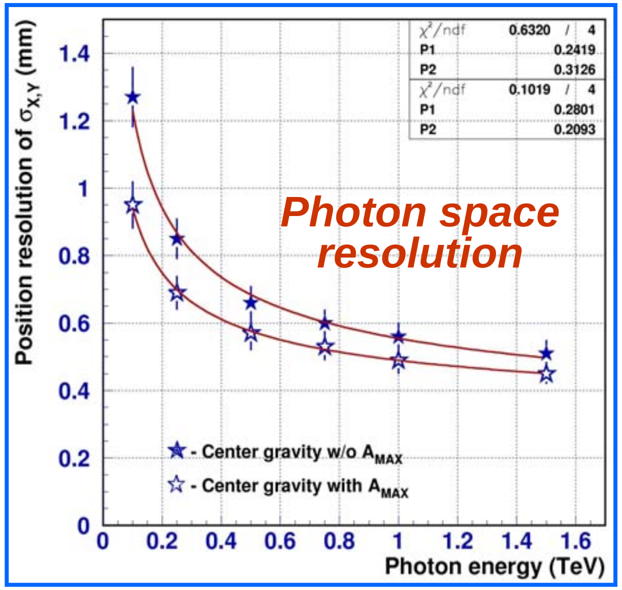




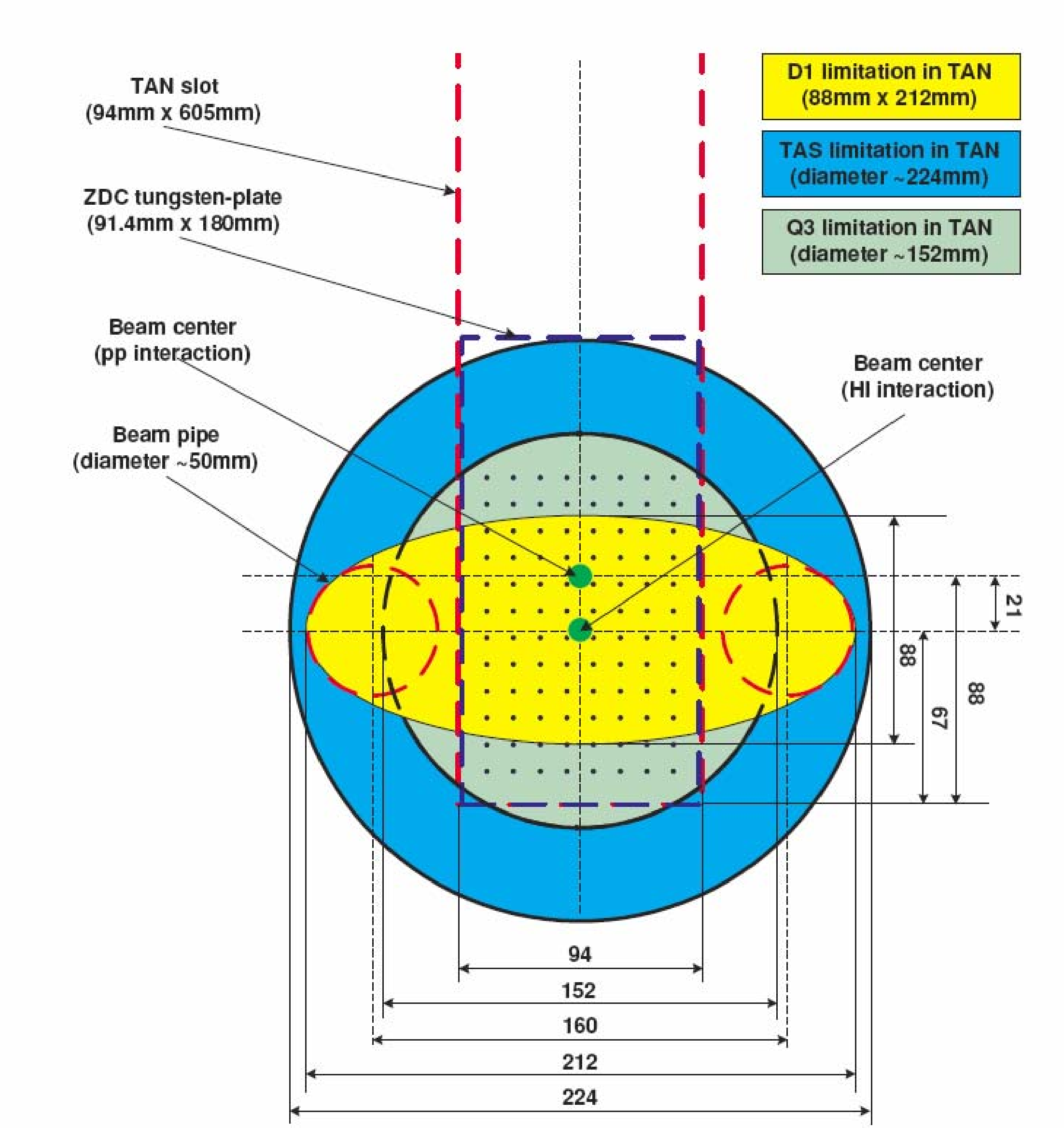




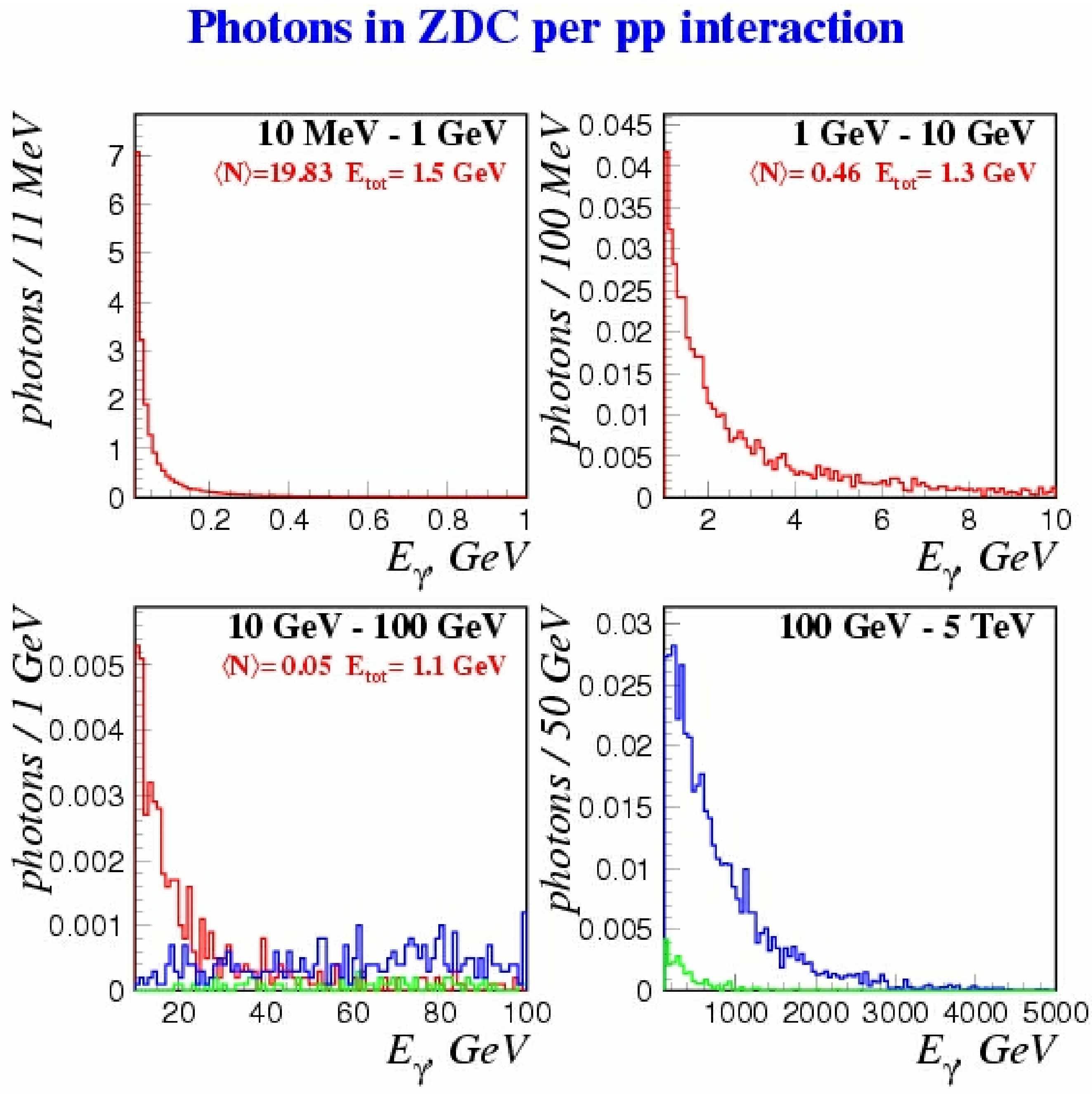




Aperture limitations from upstream components of the machine



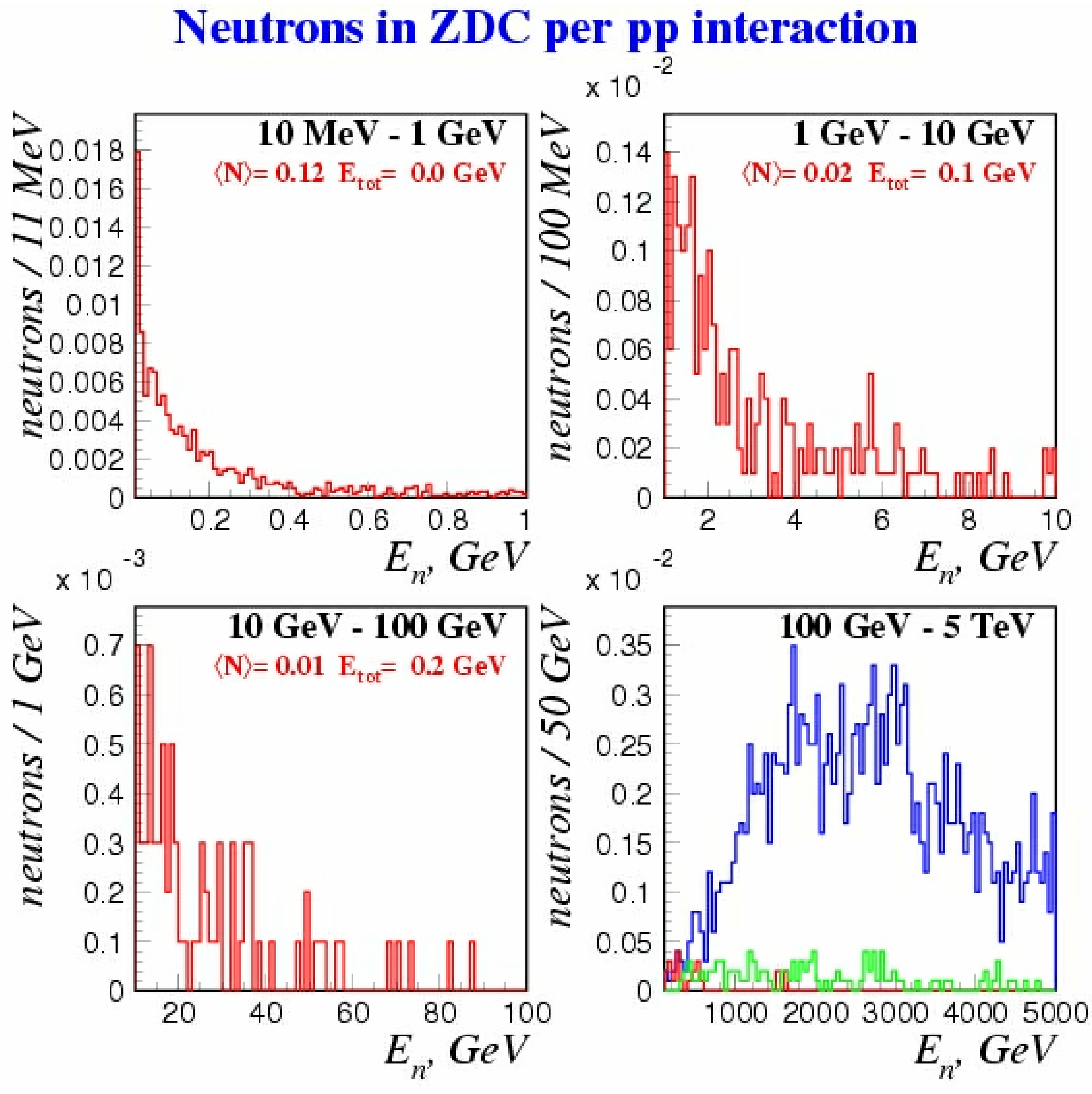
Background *(PYTHIA* / GEANT-FLUKA simulation)



Sources of signal and Background

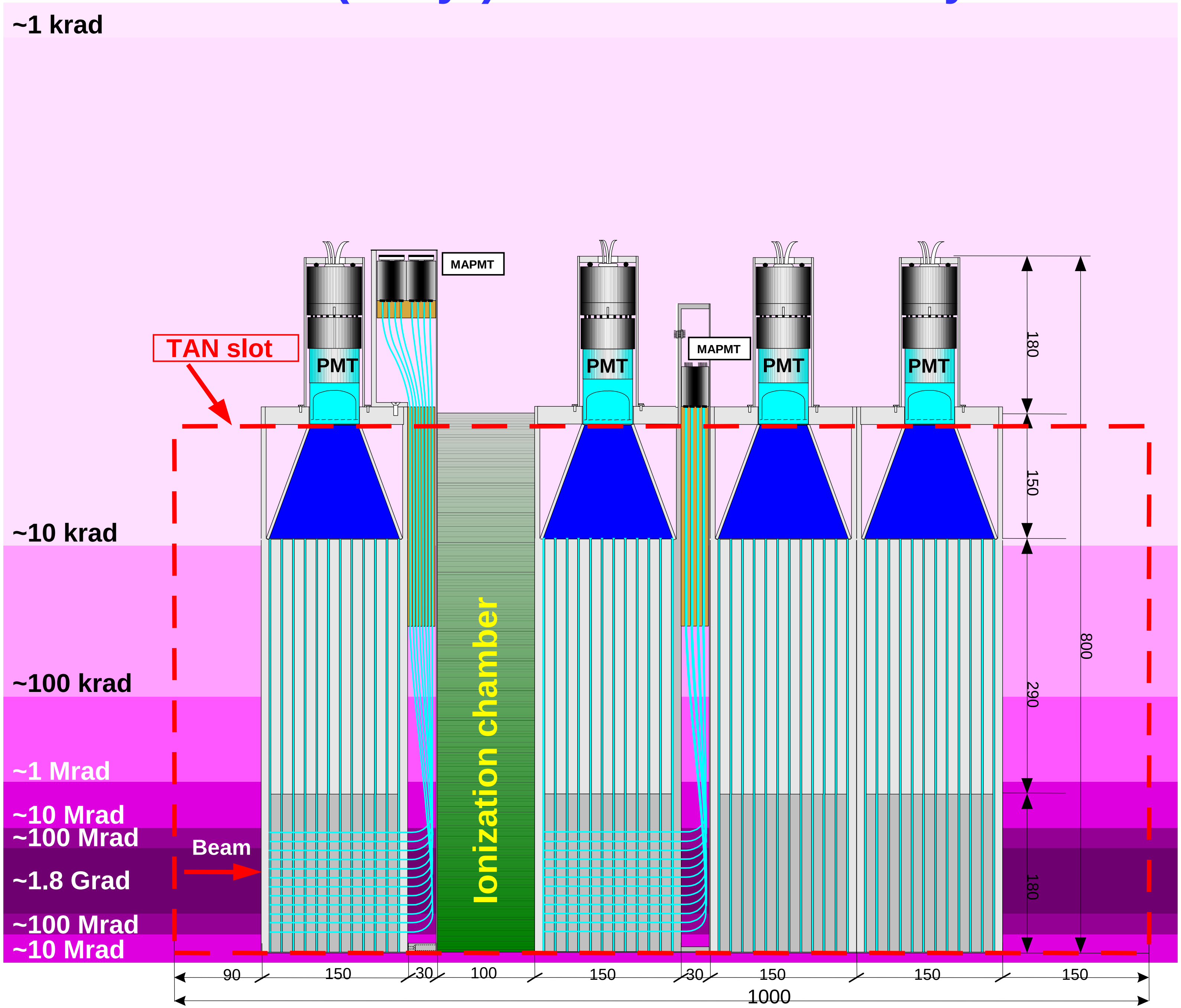
- Interaction Point
- Decays in Flight
- “Walls”

Background (PYTHIA / GEANT-FLUKA simulation)



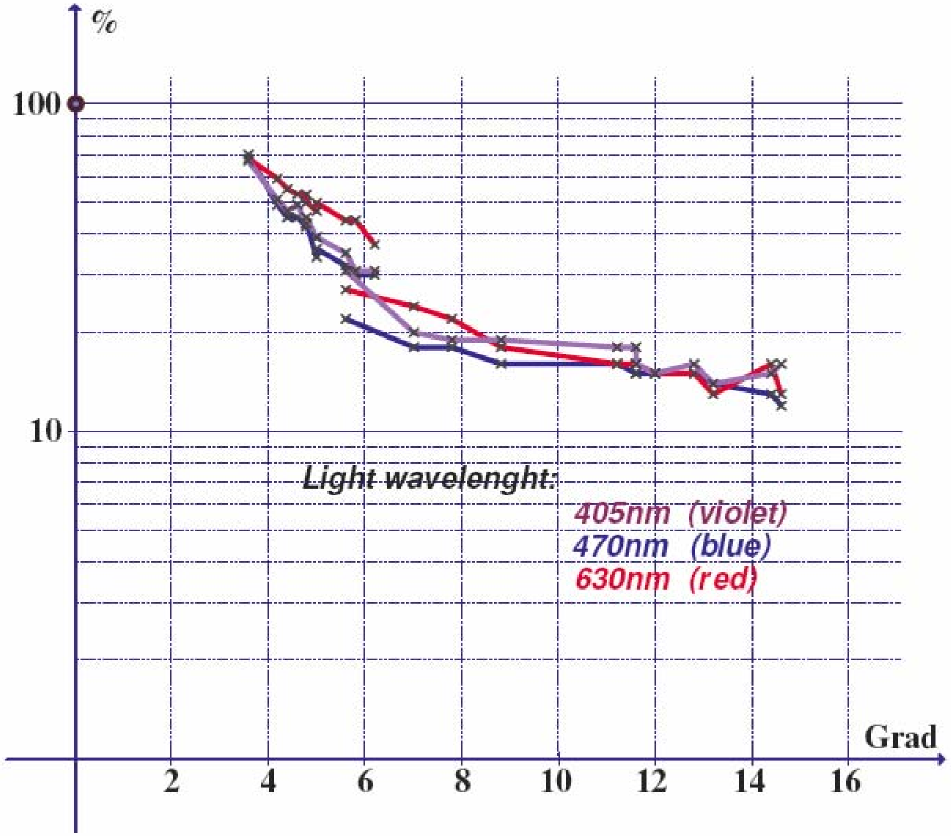
Sources of Signal and Background

Absorbed dose (rad/yr) in TAN at luminosity 10^{33} $cm^{-2}sec^{-1}$



We exposed quartz rods at the BNL linac Isotope Producer facility

At 5 Grad absorbed dose
Light loss corresponds to
A 30% deterioration in
Resolution of coord measurement

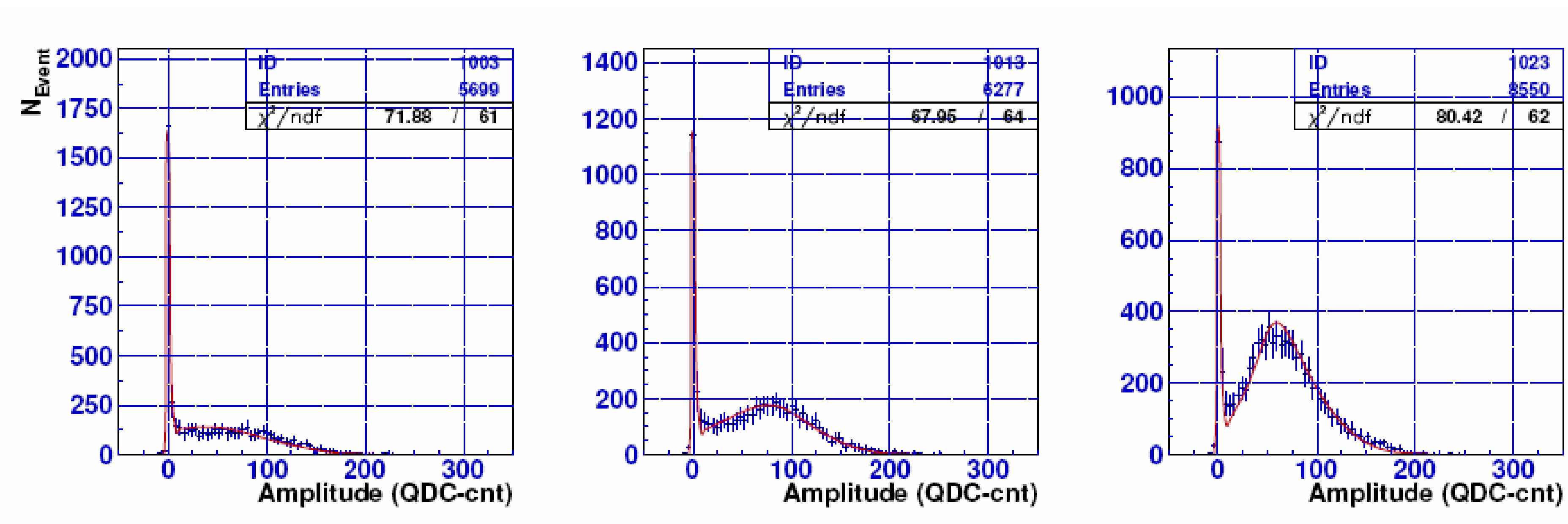


Test beam exposure in SPS North area parasitic with RP (Oct. '06)

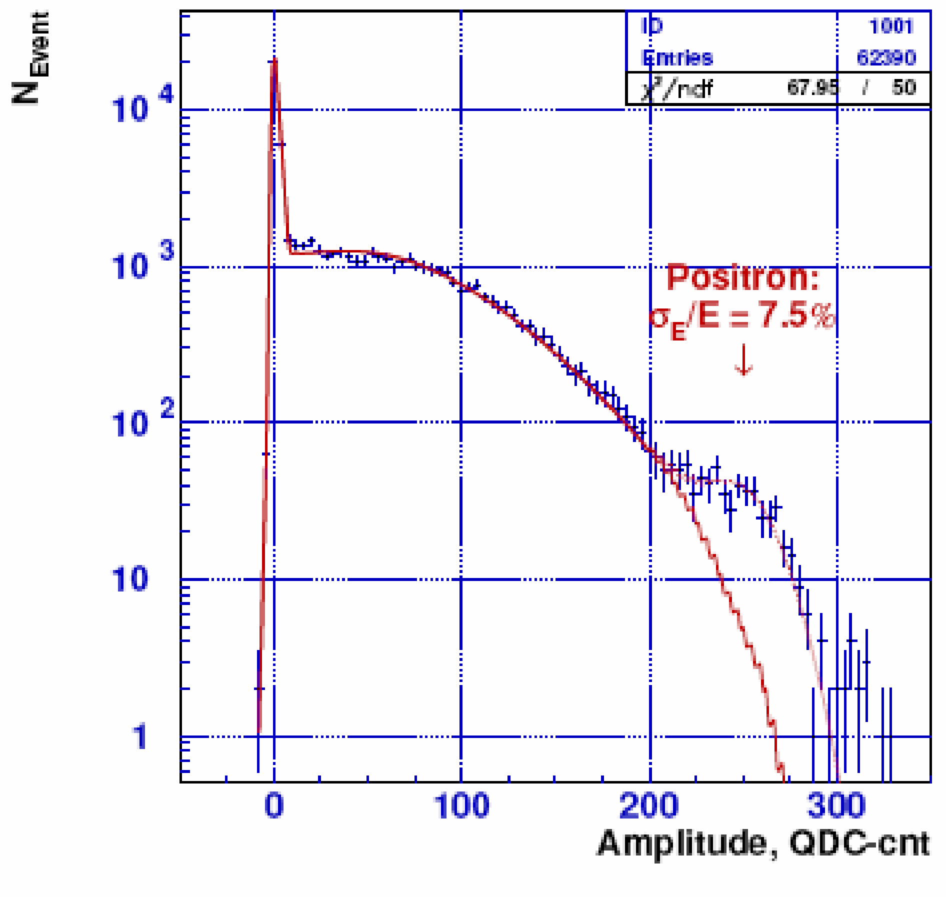
Single module exposed to 230 GeV proton beam

Spectra with 0, 10 and 20 cm steel blocks inserted in the beam

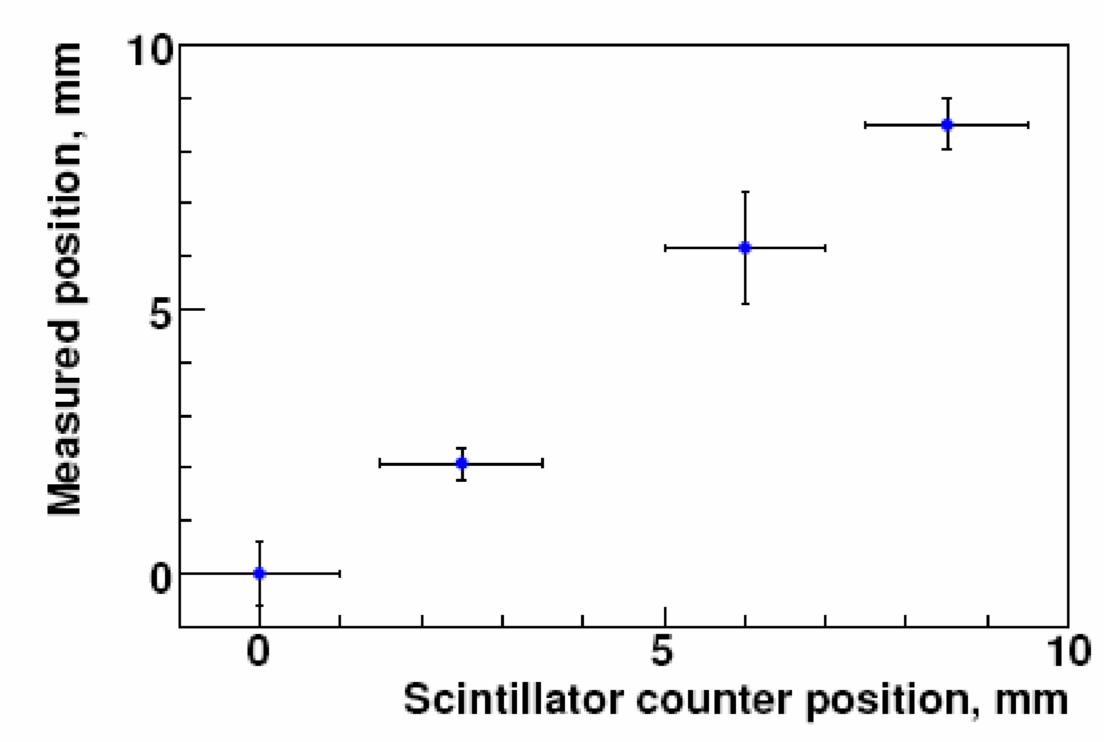
Comparison to simulation (note same energy scale used in all Simulations)



Beam tuned to enrich positron component
Peak used to confirm light yield and agreement
With simulations



Tested correlation between coordinate measurement and
Position of 2 mm high beam scintillation counters



Summary of cables to USA15

cable use	cable type	no. of cables	length(m)
fast trigger signals	C-50-6-1 50 Ω	4	230
fast signals to WFD's	C-50-3-1 50 Ω	6	230
coordinate readout	C-50-3-1 50 Ω	24	350
extra coordinate readout (1 side)	C-50-3-1 50 Ω	24	350
test signal	C-50-3-1 50 Ω	2	350
PMT HV cable	RG 59 equiv	6	350
extra HV (1-side)	RG 59 equiv	7	350
low voltage	power cable	2	350
EM coordinate readout (1 side)	C-50-3-1 50 Ω	96	350

Risetime of fast signals τ_r= 5 nsec
Attenuation 50%

What we are planning

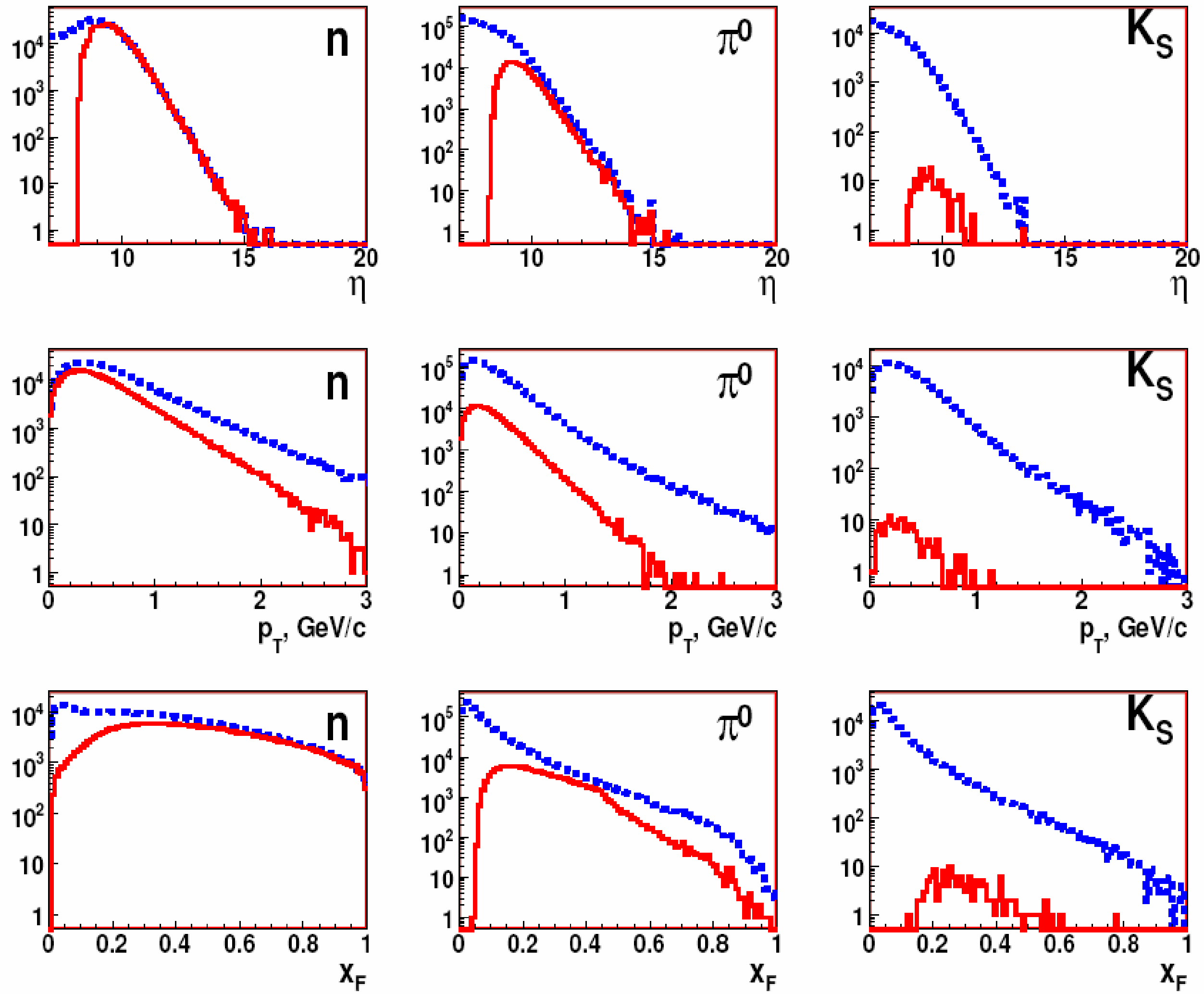
- Install full (8 module) ZDC phased with the LHCf run plan
- Integrate ZDC into ATLAS DAQ and provide a level1 trigger
- Will remove ZDC for highest Luminosity pp runs
- Provide a critical role in Heavy Ion program
- Important measurements of forward particle production in pp collisions over full acceptance permitted by TAN constraints
- Funding from US Nuclear Physics program

Schedule

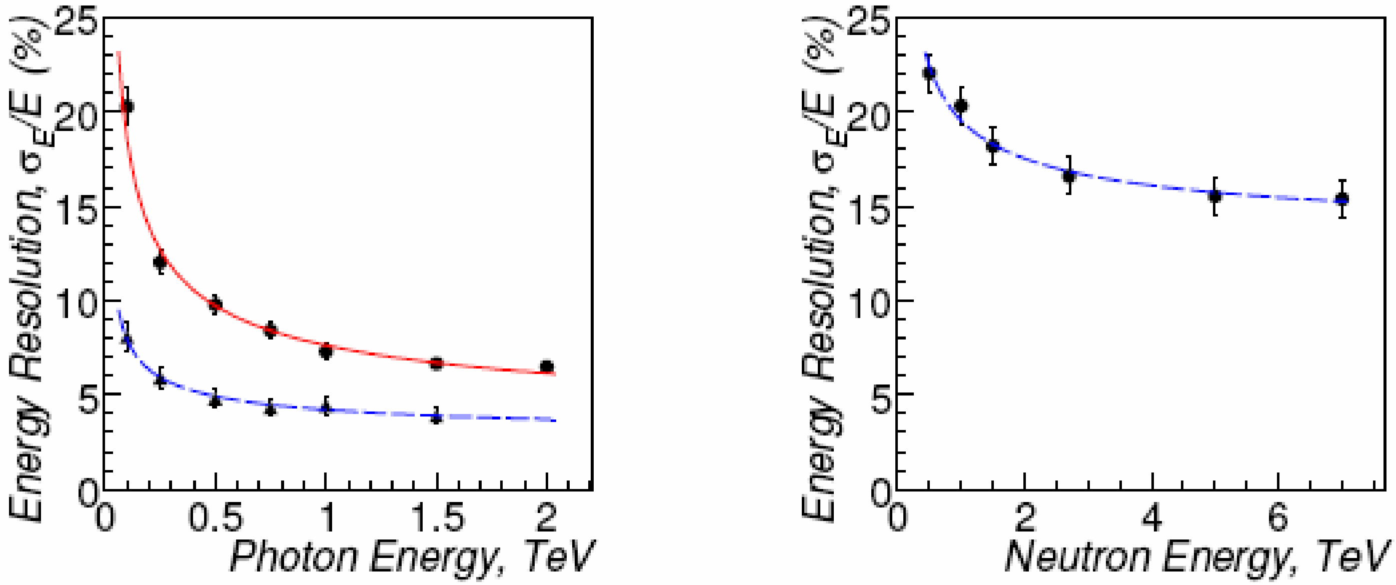
- 1st module completed and tested in beam-no design changes planned
- Construction of mechanical modules can begin 2/07 expect completion in 6/07
- Remaining cables installed this spring
- Main schedule uncertainty is window for installation of cables and modules
- Operation possible at end of '07 in conjunction with LCHf detector

Extra slides

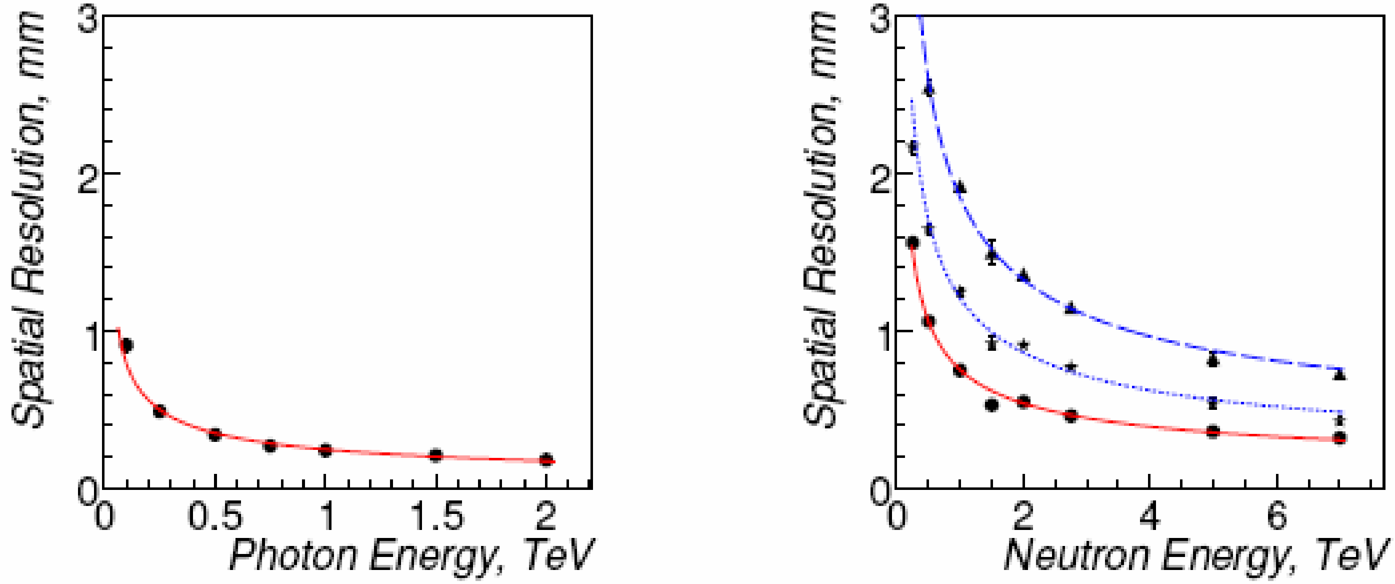
Simulation of kinematic acceptance



Energy resolution for Photons and neutrons (GEANT simulation)

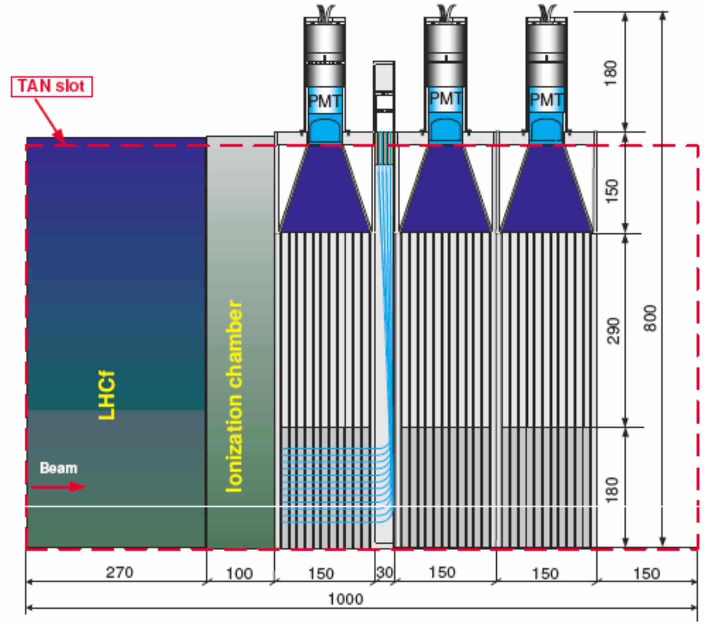


Coordinate resolution for photons and neutrons

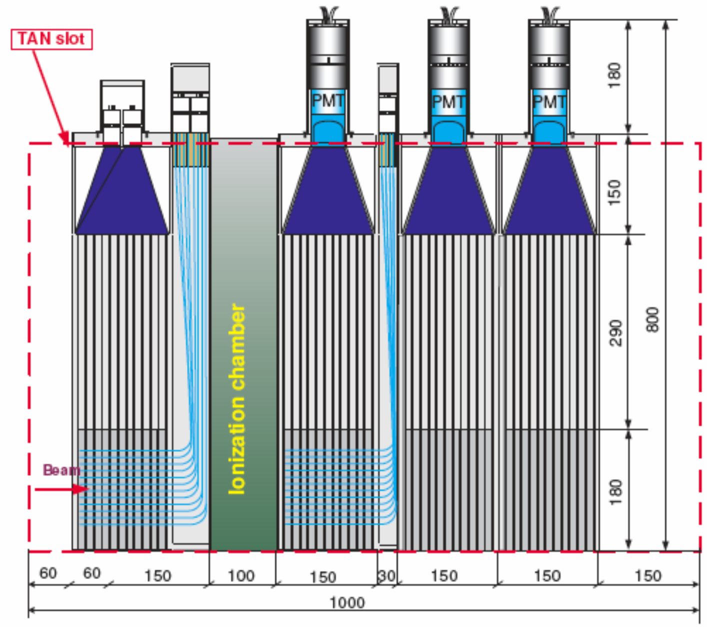


Phasing with LHCf run

Phase I



Phase II



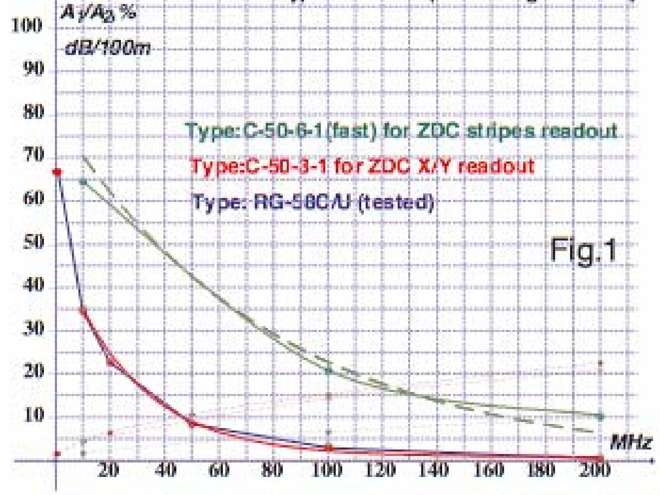
For transport the signals from ZDC modules to USA15 room we are using two type of coaxial cables:

1. the fast C-50-6-1 cable for stripe readout and
2. the cheap C-50-3-1 cable for X/Y readout.

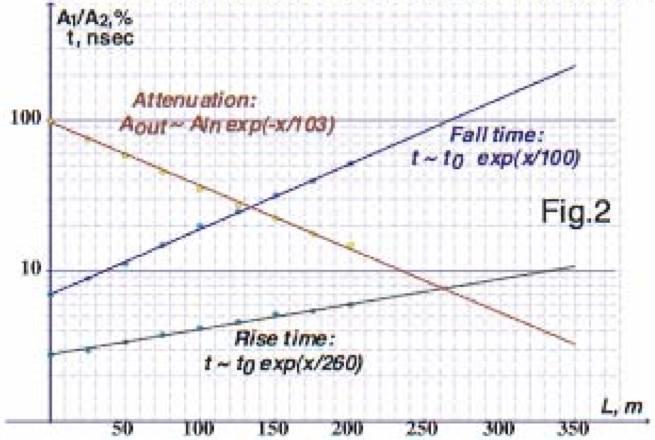
I used the coaxial cable (type RG 58C/U) what have close to C-50-3-1 characteristics (see Fig.1) for measurement the attenuation and shapes of signals from PMT versus the length of cable (see Fig2).

I show the expected values for fast C-50-6-1 cable in Fig.3 (I'm sure about the attenuation curve, but about fall and rise time need additional research).

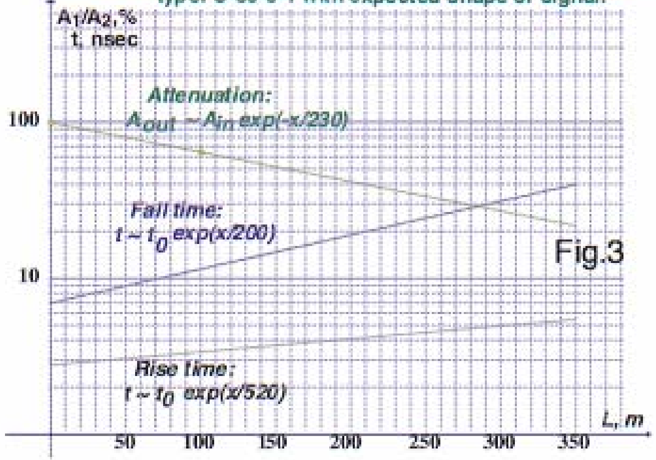
Attenuation of amplitude vs MHz
for different type of cables (same length ~100m)



Attenuation of amplitude, rise and fall time vs length of cable
type: RG-58C/U (like C-50-3-1) with expected shape of signal.

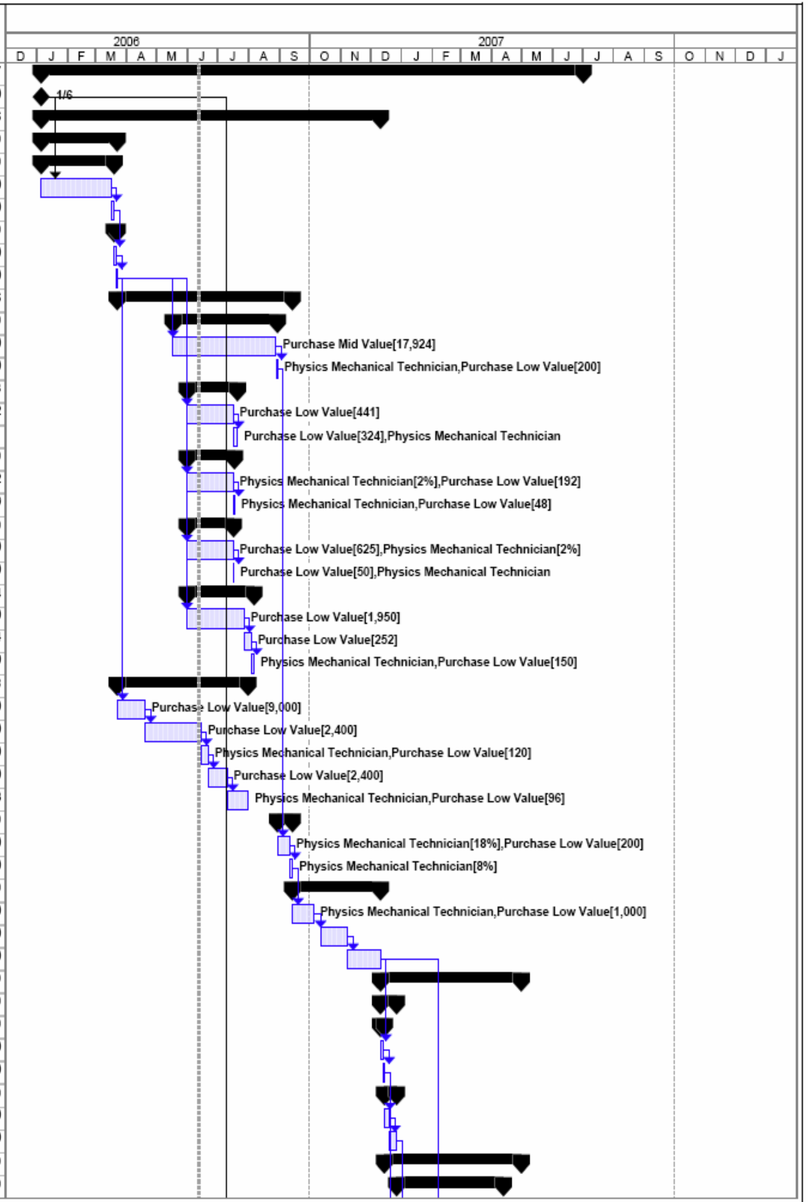


Attenuation of amplitude, rise and fall time vs length of cable
type: C-50-6-1 with expected shape of signal.



ZDC Project file (p.1) including Phase II eqpt and labor costs

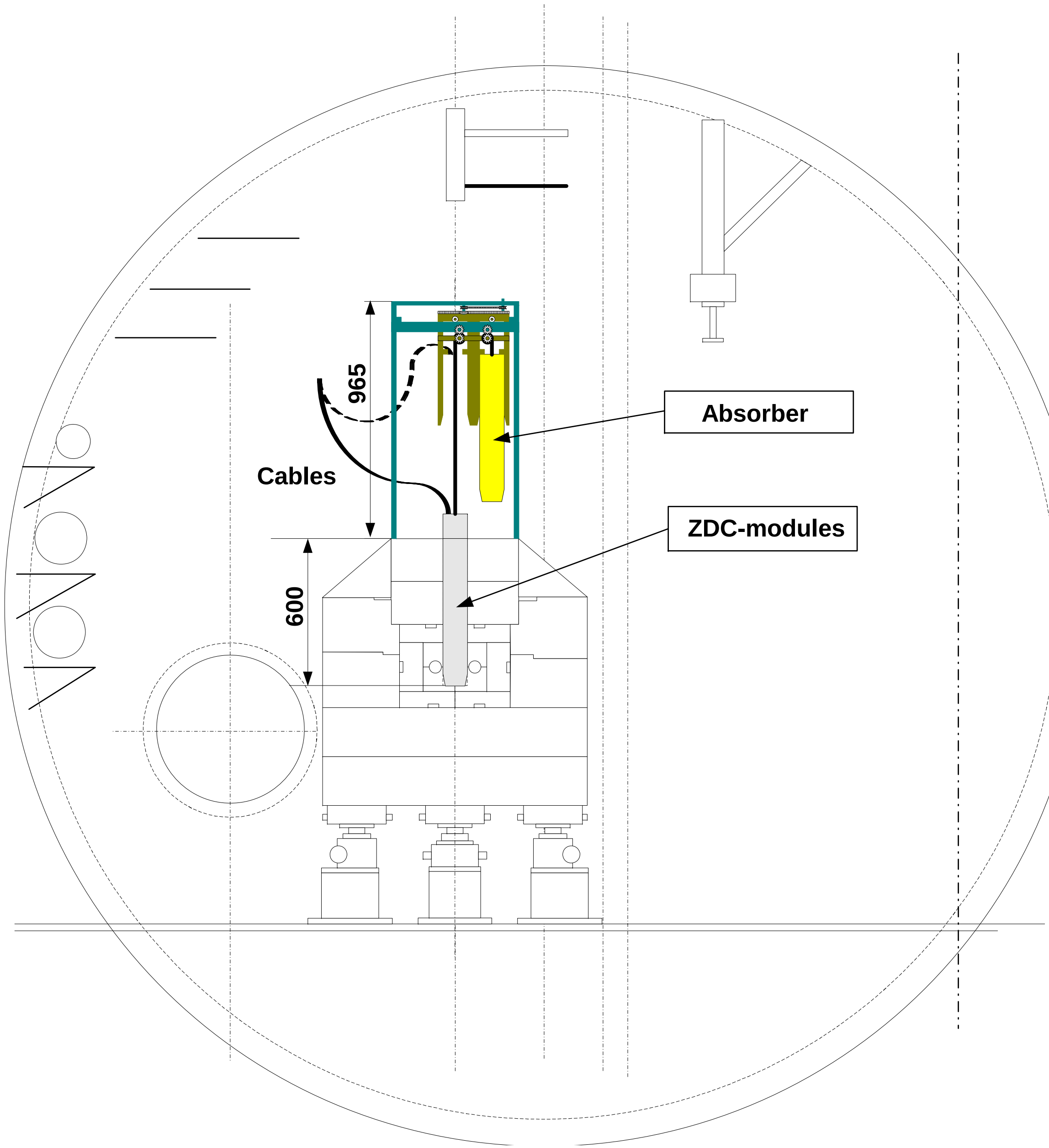
ID	WBS	Task Name	Duration	Start	Finish	Pred'sor	Cost	Contingency Cost	Base Cost + Contingency Cost
1	**1**	**Project Summary**	**372 days**	**Fri 1/6/06**	**Mon 7/2/07**		**$381,066.88**	**$64,847.29**	**$445,914.17**
2	1.1	Project Start	0 days	Fri 1/6/06	Fri 1/6/06		$0.00	$0.00	$0.00
3	**1.2**	**ZDC Prototype**	**232.25 days**	**Fri 1/6/06**	**Mon 12/11/06**		**$44,211.04**	**$7,429.12**	**$51,640.16**
4	**1.2.1**	**Prototype Design**	**52 days**	**Fri 1/6/06**	**Thu 3/23/06**		**$0.00**	**$0.00**	**$0.00**
5	**1.2.1.1**	**Conceptual Design**	**49 days**	**Fri 1/6/06**	**Mon 3/20/06**		**$0.00**	**$0.00**	**$0.00**
6	1.2.1.1.1	Development (simulation, sketching, material	48 days	Fri 1/6/06	Fri 3/17/06	2	$0.00	$0.00	$0.00
7	1.2.1.1.2	Final Design Review	1 day	Fri 3/17/06	Mon 3/20/06	6	$0.00	$0.00	$0.00
8	**1.2.1.2**	**Technical Design**	**3 days**	**Mon 3/20/06**	**Thu 3/23/06**		**$0.00**	**$0.00**	**$0.00**
9	1.2.1.2.1	Development (technical drawings)	2 days	Mon 3/20/06	Wed 3/22/06	7	$0.00	$0.00	$0.00
10	1.2.1.2.2	Final Design Review	1 day	Wed 3/22/06	Thu 3/23/06	9	$0.00	$0.00	$0.00
11	**1.2.2**	**Prototype Production**	**121.25 days**	**Thu 3/23/06**	**Thu 9/14/06**		**$42,443.04**	**$7,075.52**	**$49,518.56**
12	**1.2.2.1**	**Module production**	**71.25 days**	**Thu 5/18/06**	**Wed 8/30/06**		**$18,764.00**	**$3,752.80**	**$22,516.80**
13	1.2.2.1.1	Fabrication/Procurement	70 days	Thu 5/18/06	Tue 8/29/06	10FS+40 c	$17,924.00	$3,584.80	$21,508.80
14	1.2.2.1.2	Delivery/Test	1.25 days	Tue 8/29/06	Wed 8/30/06	13	$840.00	$168.00	$1,008.00
15	**1.2.2.2**	**Quartz-optic production (for strips)**	**34.05 days**	**Thu 6/1/06**	**Fri 7/21/06**		**$2,838.60**	**$340.63**	**$3,179.23**
16	1.2.2.2.1	Fabrication/Procurement	30 days	Thu 6/1/06	Mon 7/17/06	10FS+49 c	$441.00	$52.92	$493.92
17	1.2.2.2.2	Delivery/Test	4.05 days	Mon 7/17/06	Fri 7/21/06	16	$2,397.60	$287.71	$2,685.31
18	**1.2.2.3**	**Quartz-optic production (for rods)**	**31.2 days**	**Thu 6/1/06**	**Tue 7/18/06**		**$1,223.04**	**$146.76**	**$1,369.80**
19	1.2.2.3.1	Fabrication/Procurement	30 days	Thu 6/1/06	Mon 7/17/06	10FS+49 c	$560.64	$67.28	$627.92
20	1.2.2.3.2	Delivery/Test	1.2 days	Mon 7/17/06	Tue 7/18/06	19	$662.40	$79.49	$741.89
21	**1.2.2.4**	**Guide-optic production (for a strip's readout)**	**30.13 days**	**Thu 6/1/06**	**Mon 7/17/06**		**$1,091.00**	**$218.20**	**$1,309.20**
22	1.2.2.4.1	Fabrication/Procurement	30 days	Thu 6/1/06	Mon 7/17/06	10FS+49 c	$977.00	$195.40	$1,172.40
23	1.2.2.4.2	Delivery/Test	0.13 days	Mon 7/17/06	Mon 7/17/06	22	$114.00	$22.80	$136.80
24	**1.2.2.5**	**Module instrumentation (strip's photodetectors**	**45 days**	**Thu 6/1/06**	**Mon 8/7/06**		**$2,544.00**	**$332.64**	**$2,876.64**
25	1.2.2.5.1	Fabrication/Procurement of PMT-XP3292B	39 days	Thu 6/1/06	Fri 7/28/06	10FS+49 c	$1,950.00	$234.00	$2,184.00
26	1.2.2.5.2	Fabrication/Procurement of a PMT Base (VD:	5 days	Fri 7/28/06	Fri 8/4/06	25	$252.00	$30.24	$282.24
27	1.2.2.5.3	Delivery/Test (PMT&Base)	0.38 days	Fri 8/4/06	Mon 8/7/06	26	$342.00	$68.40	$410.40
28	**1.2.2.6**	**Module instrumentation (rod's photodetectors)**	**90 days**	**Thu 3/23/06**	**Tue 8/1/06**		**$15,014.40**	**$2,090.88**	**$17,105.28**
29	1.2.2.6.1	Fabrication/Procurement of PMT-R7600-06-M	20 days	Thu 3/23/06	Thu 4/20/06	10	$9,000.00	$1,080.00	$10,080.00
30	1.2.2.6.2	Fabrication/Procurement of a PMT base (???	39 days	Thu 4/20/06	Thu 6/15/06	29	$2,400.00	$288.00	$2,688.00
31	1.2.2.6.3	Delivery/Test (PMT&Base)	0.75 days	Thu 6/15/06	Thu 6/22/06	30	$504.00	$100.80	$604.80
32	1.2.2.6.4	Fabrication/Procurement (Preamp& Analog-s	11 days	Thu 6/22/06	Tue 7/11/06	31	$2,400.00	$480.00	$2,880.00
33	1.2.2.6.5	Delivery/Test (Preamp& Analog-sum)	1.2 days	Tue 7/11/06	Tue 8/1/06	32	$710.40	$142.08	$852.48
34	**1.2.2.7**	**Module Assembling & Lab. Test**	**10 days**	**Wed 8/30/06**	**Thu 9/14/06**		**$968.00**	**$193.60**	**$1,161.60**
35	1.2.2.7.1	Assembling	7 days	Wed 8/30/06	Mon 9/11/06	14	$840.00	$168.00	$1,008.00
36	1.2.2.7.2	Optical Test	3 days	Mon 9/11/06	Thu 9/14/06	35	$128.00	$25.60	$153.60
37	**1.2.3**	**Beam Test & Study**	**59 days**	**Thu 9/14/06**	**Mon 12/11/06**		**$1,768.00**	**$353.60**	**$2,121.60**
38	1.2.3.1	Shipping	1.5 days	Thu 9/14/06	Thu 10/5/06	36	$1,768.00	$353.60	$2,121.60
39	1.2.3.2	Beam test	19 days	Thu 10/12/06	Wed 11/8/06	38FS+5 da	$0.00	$0.00	$0.00
40	1.2.3.3	Data analysis	20 days	Wed 11/8/06	Mon 12/11/06	39	$0.00	$0.00	$0.00
41	**1.3**	**ZDC detector**	**96.5 days**	**Mon 12/11/06**	**Tue 5/1/07**		**$158,725.64**	**$28,697.75**	**$187,423.39**
42	**1.3.1**	**ZDC Design**	**11 days**	**Mon 12/11/06**	**Wed 12/27/06**		**$0.00**	**$0.00**	**$0.00**
43	**1.3.1.1**	**Conceptual Design**	**4 days**	**Mon 12/11/06**	**Fri 12/15/06**		**$0.00**	**$0.00**	**$0.00**
44	1.3.1.1.1	Development (simulation, sketching, material	3 days	Mon 12/11/06	Thu 12/14/06	40	$0.00	$0.00	$0.00
45	1.3.1.1.2	Final Design Review	1 day	Thu 12/14/06	Fri 12/15/06	44	$0.00	$0.00	$0.00
46	**1.3.1.2**	**Technical Design**	**7 days**	**Fri 12/15/06**	**Wed 12/27/06**		**$0.00**	**$0.00**	**$0.00**
47	1.3.1.2.1	Development (technical drawings)	3 days	Fri 12/15/06	Wed 12/20/06	45	$0.00	$0.00	$0.00
48	1.3.1.2.2	Final Design Review	4 days	Wed 12/20/06	Wed 12/27/06	47	$0.00	$0.00	$0.00
49	**1.3.2**	**ZDC Production**	**92.5 days**	**Fri 12/15/06**	**Tue 5/1/07**		**$158,725.64**	**$28,697.75**	**$187,423.39**
50	**1.3.2.1**	**Module production**	**73.75 days**	**Wed 12/27/06**	**Fri 4/13/07**		**$101,808.00**	**$20,361.60**	**$122,169.60**

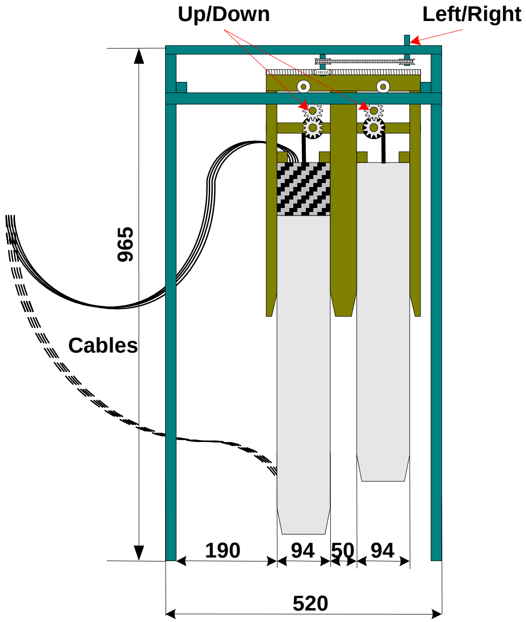


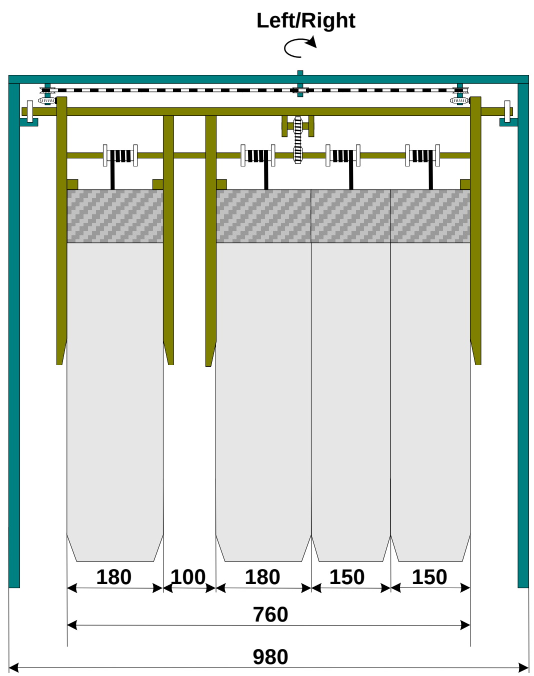
Project: ZDC June 12 2006
Date: Mon 6/12/06

Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone

Concept for remote module replacement







Background

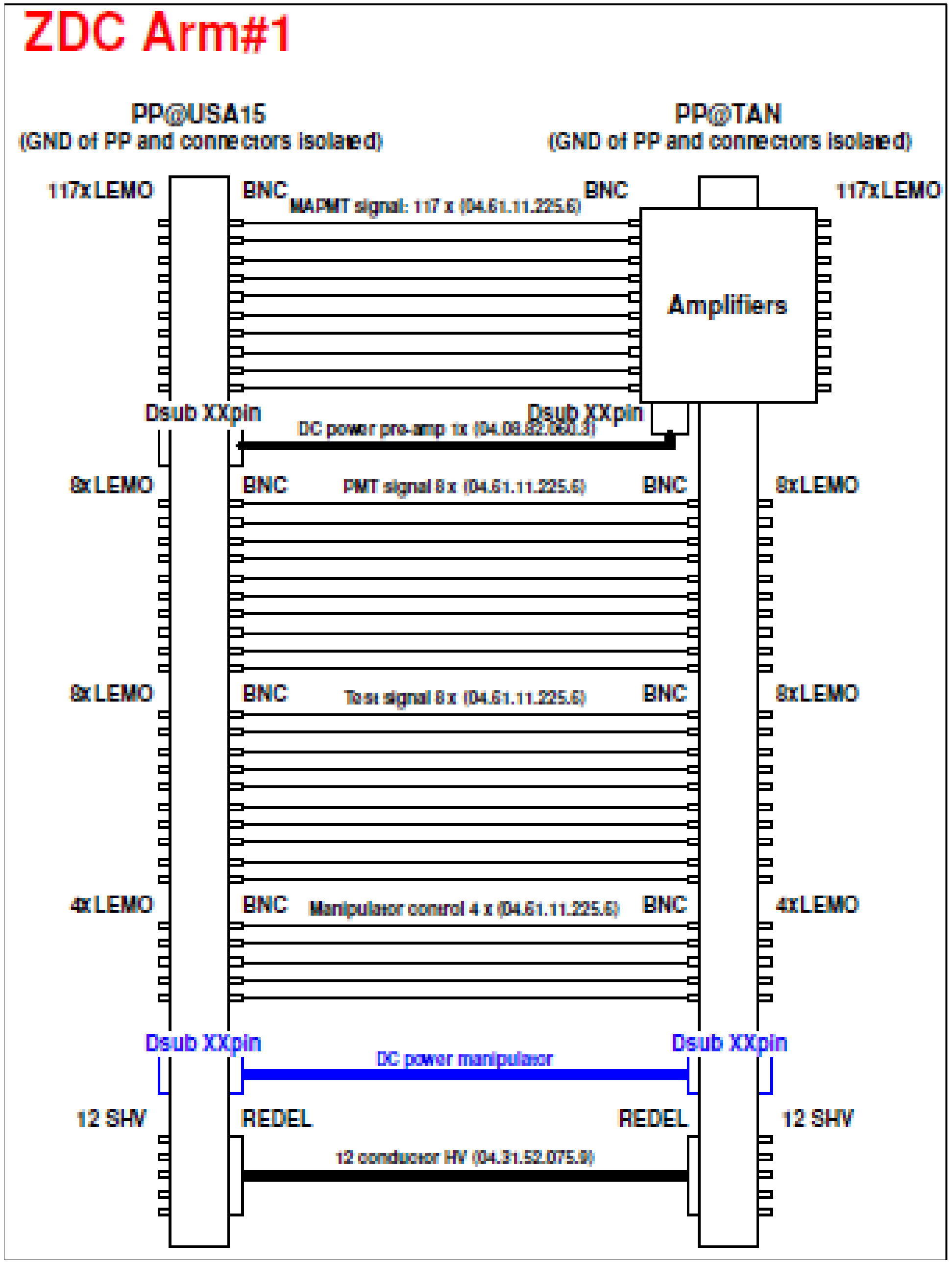
MARS15:Radiation in TAN, LHCf & ZDC – N.Mokhov **TAN Integration – CERN, Mar.10, 2006**

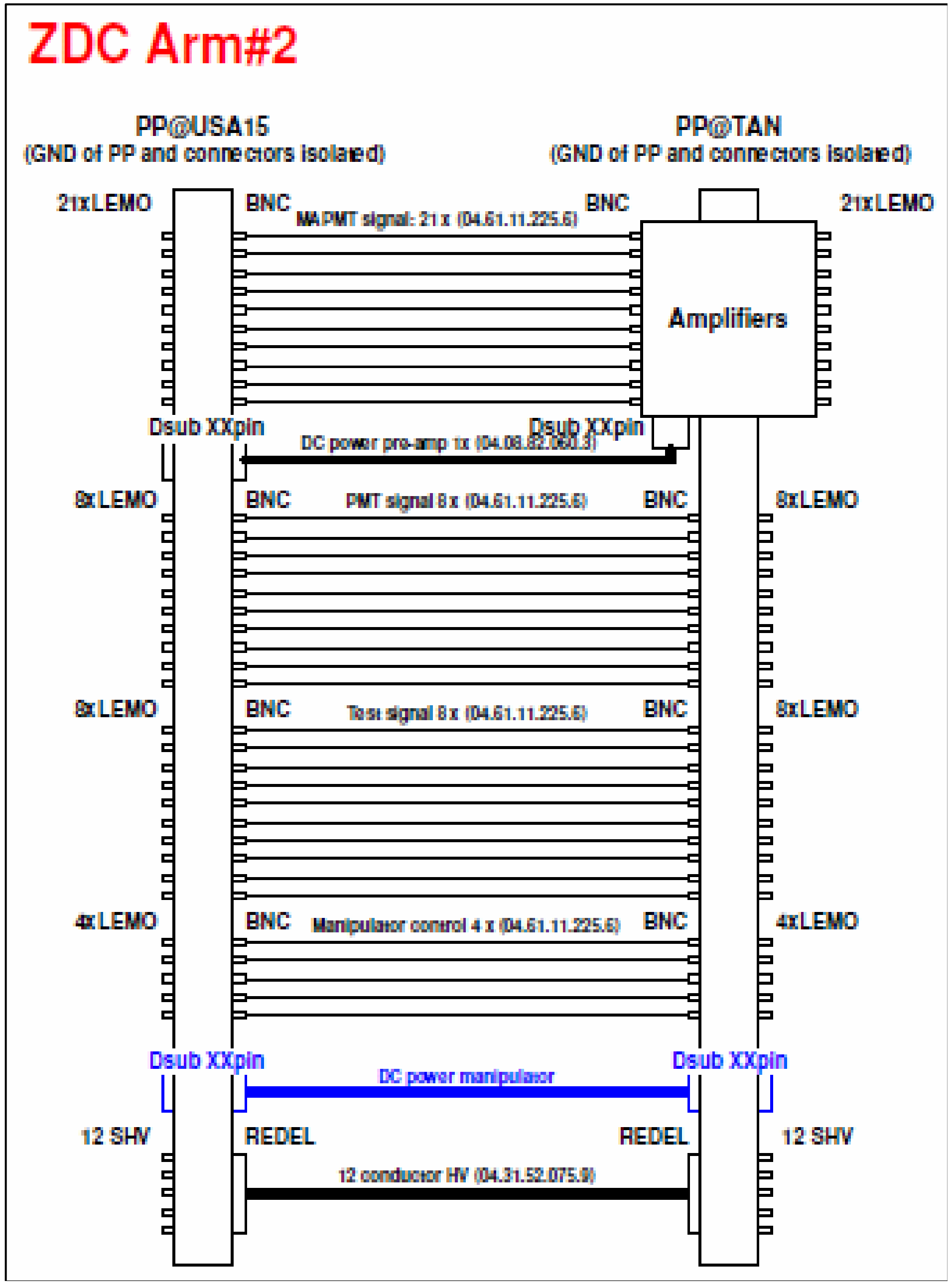
SOURCE TERM AT TAN at -5.5 < x, y < 5.5 cm

	FROM IP		NON-IP		TOTAL	
	<N>	<E> (GeV)	<N>	<E> (GeV)	<N>	<E> (GeV)
p	7.8106E-06	1.3928E+03	7.3854E-02	1.5650E+02	7.3862E-02	1.5663E+02
n	1.8278E-01	2.9556E+03	3.0651E-01	1.0426E+02	4.8929E-01	1.1694E+03
π+	3.9053E-05	1.4448E+03	1.8044E-01	2.6252E+01	1.8048E-01	2.6559E+01
π-	1.2583E-03	2.5358E+03	2.0158E-01	3.3929E+01	2.0284E-01	4.9450E+01
K+	3.9053E-05	1.5920E+03	1.3593E-02	1.8641E+01	1.3632E-02	2.3149E+01
K-	1.8779E-04	2.6675E+03	1.1495E-02	1.4602E+01	1.1683E-02	5.7245E+01
μ+	0.0000E+00	0.0000E+00	3.3441E-04	6.3382E+00	3.3441E-04	6.3382E+00
μ-	0.0000E+00	0.0000E+00	7.6302E-04	9.9281E+00	7.6302E-04	9.9281E+00
γ	6.4190E+00	7.9219E+01	8.9348E+01	1.9997E-01	9.5767E+01	5.4964E+00
e+	2.3936E-01	3.3844E-01	5.9039E+00	1.5220E-01	6.1432E+00	1.5946E-01
e-	9.6830E-02	1.2591E+00	5.7887E+00	1.6300E-01	5.8856E+00	1.8103E-01
pbar	1.4059E-04	2.8715E+03	5.1247E-03	9.8705E+01	5.2652E-03	1.7274E+02
K^0_L	3.6506E-02	1.2308E+03	1.2349E-02	2.6881E+01	4.8855E-02	9.2650E+02
K^0_S	4.8158E-03	2.2434E+03	2.1740E-04	4.7451E+01	5.0332E-03	2.1485E+03
Λ	2.2313E-02	3.5788E+03	0.0000E+00	0.0000E+00	2.2313E-02	3.5788E+03
Λbar	6.3297E-04	1.8356E+03	0.0000E+00	0.0000E+00	6.3297E-04	1.8356E+03
Σ-	1.5640E-05	2.3074E+03	0.0000E+00	0.0000E+00	1.5640E-05	2.3074E+03
nbar	1.2447E-02	1.1503E+03	6.2474E-03	1.7173E+02	1.8694E-02	8.2330E+02

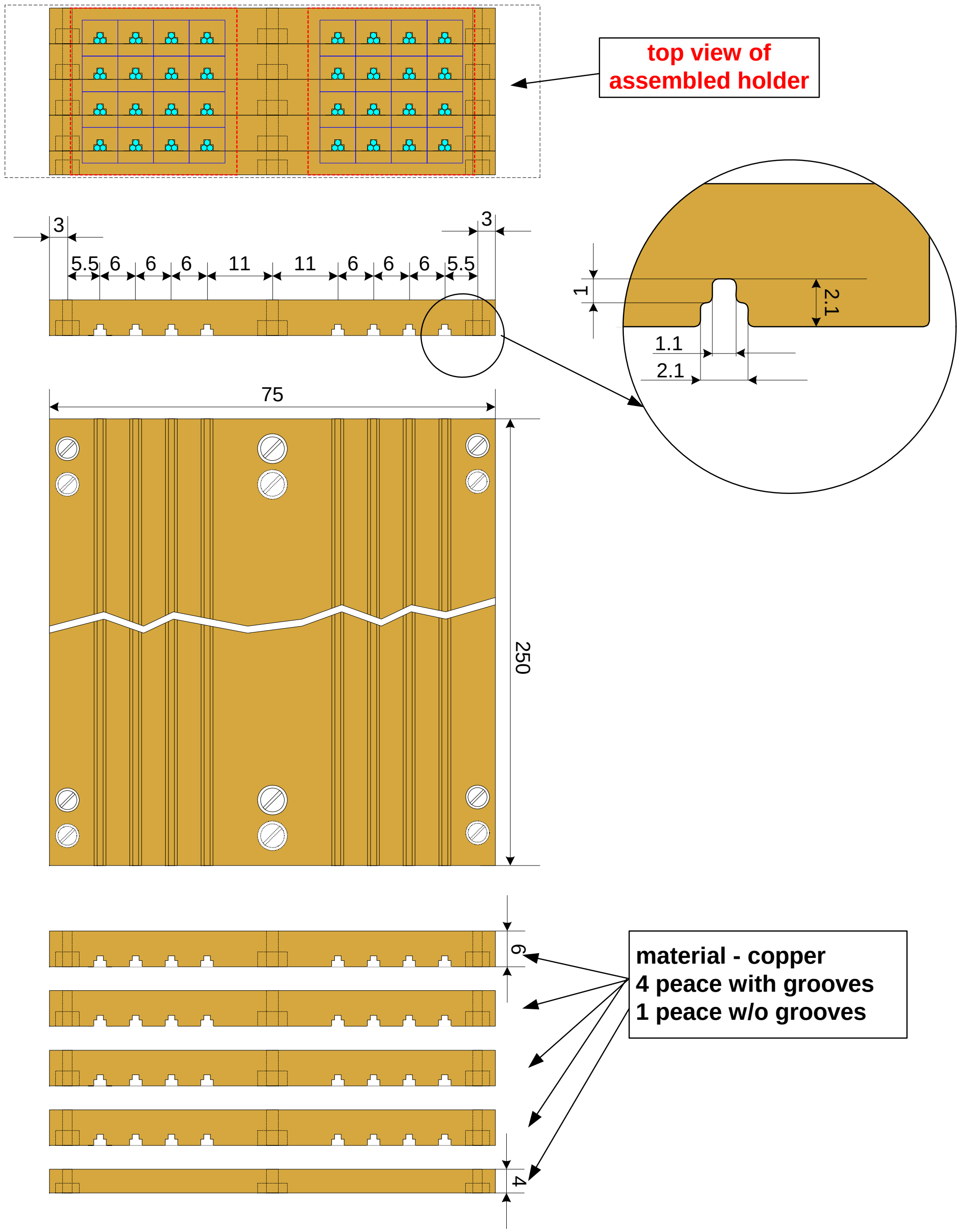
P (W/ 10^{34}) = 154 10 164

ZDC cable detail





X-Y rod holder



Assembling module: installing X-Y rods