# Electron Cooler for Low-Energy RHIC Operation

November 19, 2009

## Near-term goals

**FY10:**

- **Start regular physics and engineering meetings**
- **Choose one design (with or without solenoids)**
- **Decide about undulators**
- **Design realistic beam transport**
- **Design appropriate bending magnets**
- **Address many physics and engineering questions**

bi-weekly, Thursday, 11a.m.-noon, until better time is available

**mid FY10:**

- **Start architectural design**

**late FY10:**

- **Start electrical design**
- **Start mechanical design**

# Meeting agenda



- Pelletron and its possible location in RHIC tunnel
- Work scope  and manpower
- Other

# WHITE PAPER-V.1

## Parameters and design issues of
## Electron Cooler for Low-Energy RHIC program

Collider-Accelerator Department, BNL

The goal of this document is to initialize progress towards design of Electron Cooler for cooling of heavy ion in RHIC at energies below nominal injection energy. This is a working document and material will be replaced on continues bases. Most numbers are preliminary and will be corrected as design proceeds. This is not a design document and intended for discussion purpose only.

*Table of Contents*



Details can be found in White Paper.

# Electron Cooler

**Present baseline option:**

**Recycler's Pelletron (FNAL) – 6MV electrostatic electron accelerator**

**main components:**

**1) pressure vessel**

**2) high-voltage insulating support structure**

**3) charging system**

**4) accelerating/decelerating tubes**

**Covers full energy range of interest:**

**Electron kinetic energies**

**0.9-5MeV (for ions beam energies 2.5-10GeV/n)**

## Disassembly & Transportation

Disassemble pelletron -labor and travel **1M**

Electrical disconnect of equipment & load centers

Rigging services to load

Transportation - 8 loads at 5000$

## Site Preparation at BNL

Design & layout - architectural

Design & layout - electrical

Design & layout - mechanical

Prepare site access road & fence

Modify 4:00 wall, install blockhouse

Fabricate & install upper walls & roof

Insulate & seal blockhouse

Fabricate stairs, platforms and lifts

Install service building

Install SF6 tank foundation **1.2M**

Power to load centers

Lights & utility power

Blockhouse & service bldg AC

Compressed air extension

Fire Alarm & sprinklers

Network & communications

Sesmic consulting

## Installation

Assemble Pelletron in blockhouse (thru roof)

Place aux. equipment, stairs & platforms

Run tray to cooling section

Power equipment

Hookup Pelletron, e- transport & cooling section **0.6M (non C-AD)**

Design & fabricate undulators

Install undulators

Design of cooling section

Design of magnets for additional bends

Fabricate U bend +6 -90 degree bends

Controls modifications & adaption

Ion pumps, power supplies, cabling

Vacuum beam pipe modifications

Instrumentation modifications

Power supplies for additional magnets

New power supplies (if needed)

Cooling section modifications (stands, etc,)

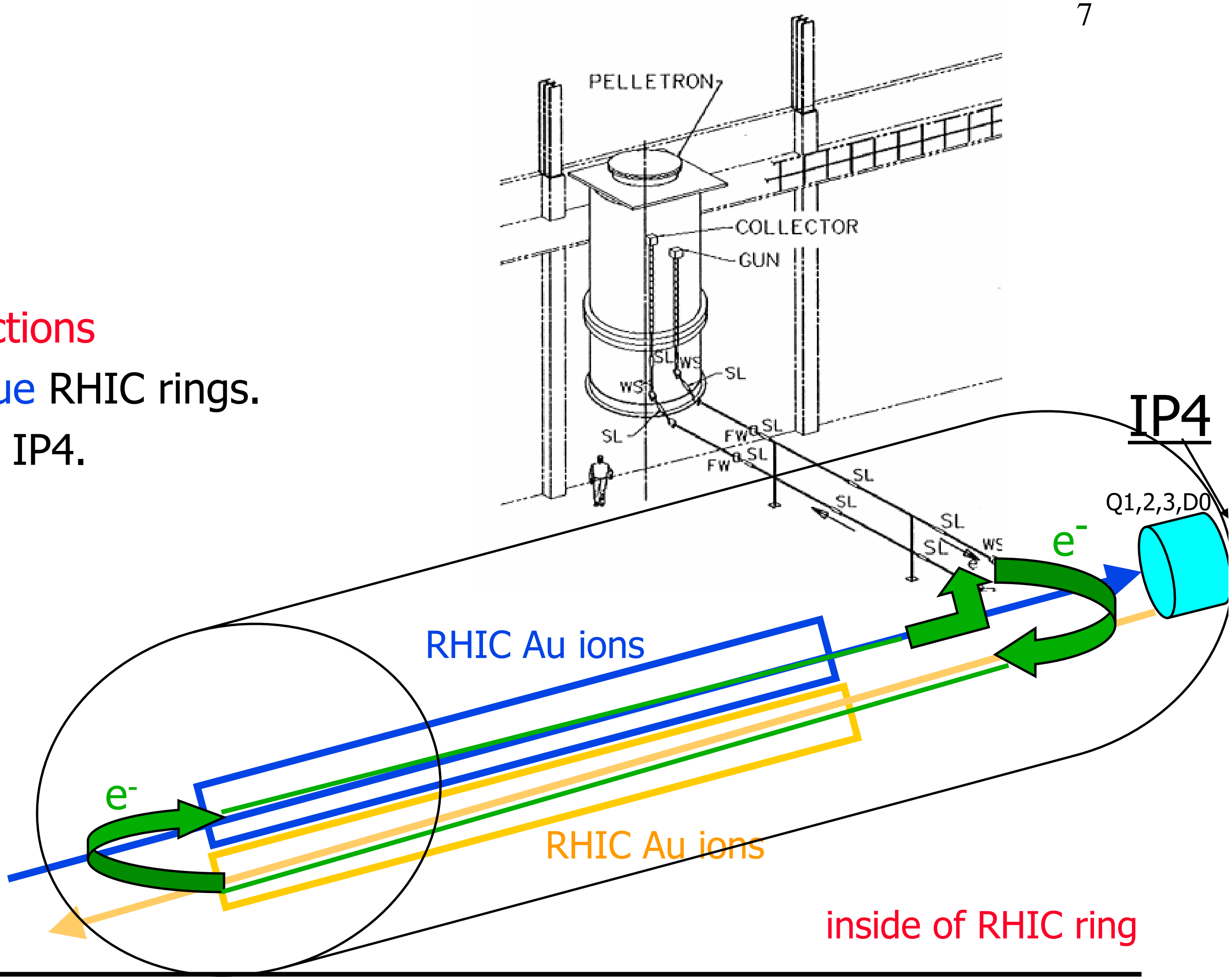
**Preliminary cost estimate October 2009**

**Total project cost: just under 5M**

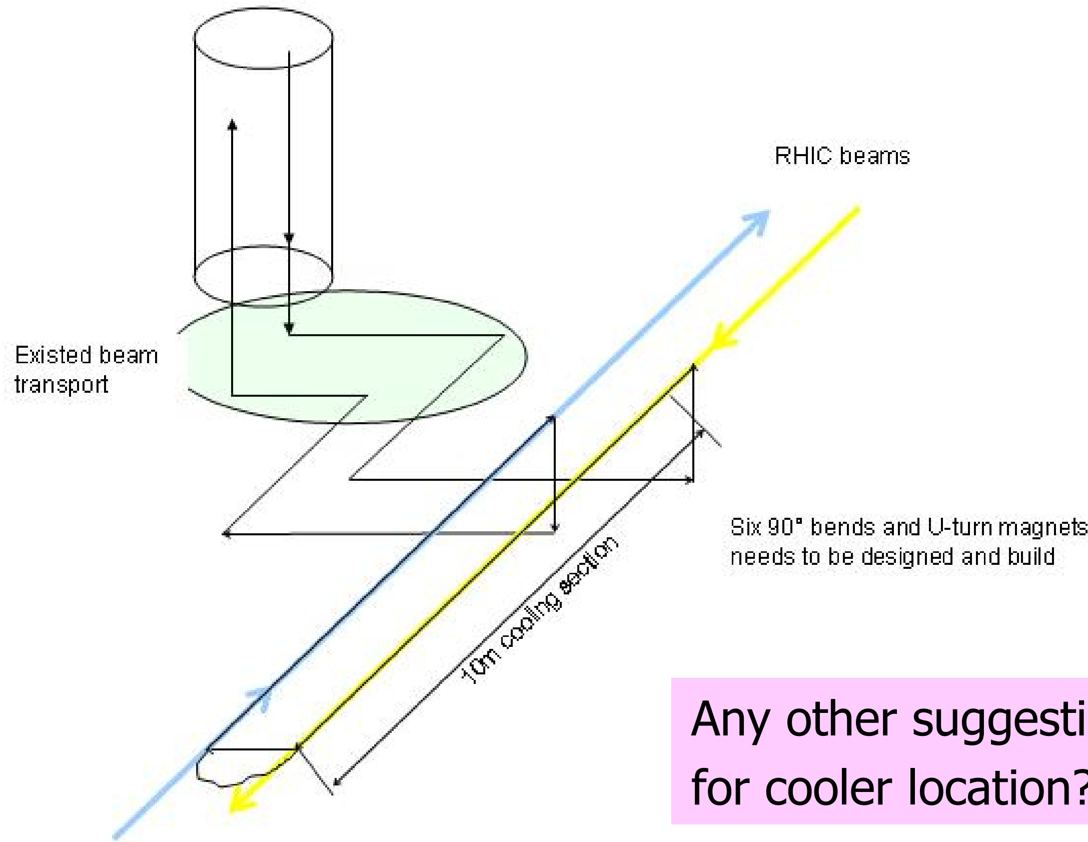
# E-cooler schematics (@ RHIC)



10 m cooling sections
in Yellow and Blue RHIC rings.
Warm section @ IP4.



## Schematics
## of beam transport
## for RHIC




Any other suggestions for cooler location?

-minimize number of needed bends

-careful design of bending magnets

-field stability and control in bends

**All other options, like**

**- on top of the tunnel**

**- removing dirt around beam tunnel**

**result in significant cost increase.**

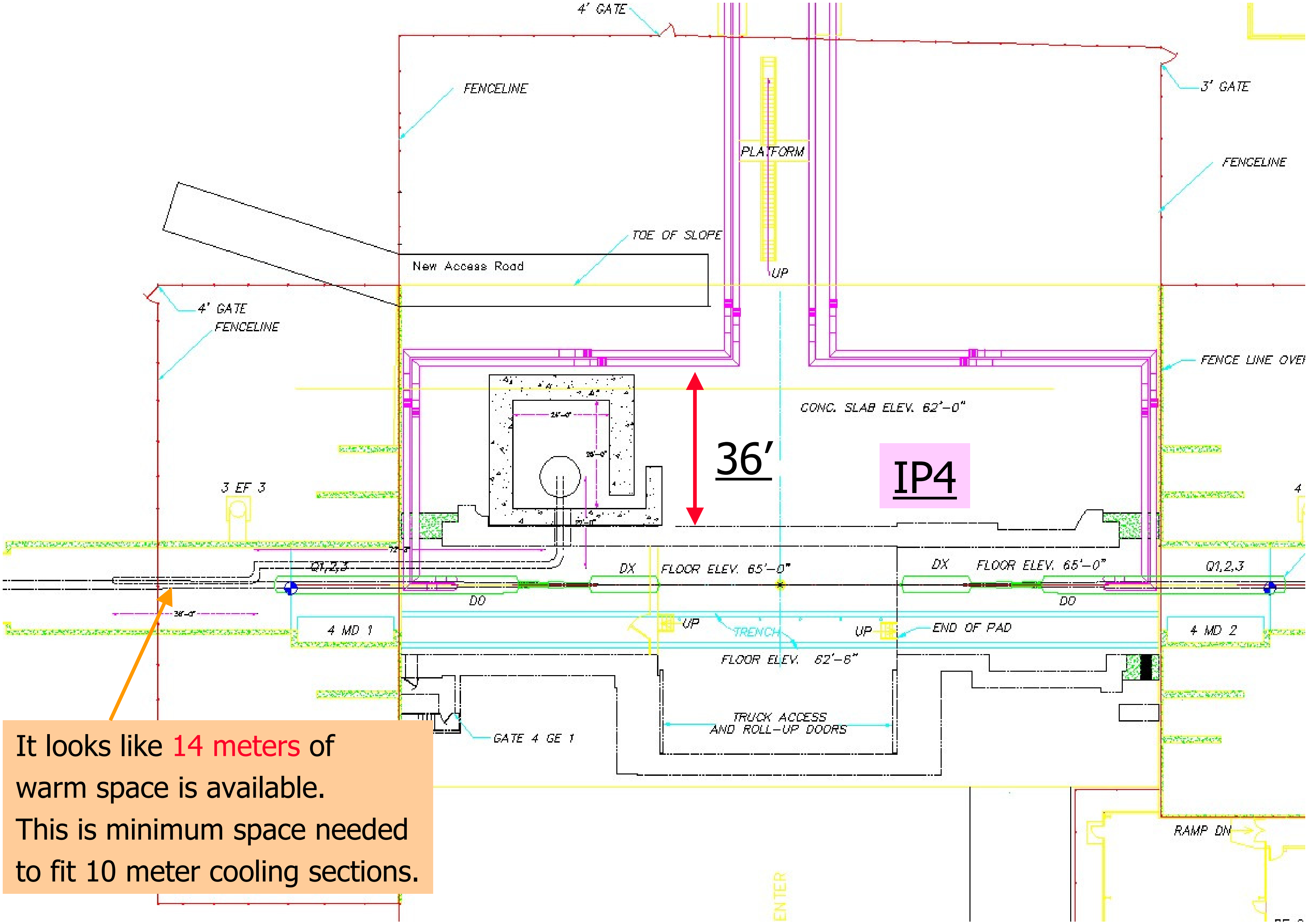
**- inside the ring was also considered**

**To keep cost at present level will have to penetrate through the block-wall at the IR, and then transport beam towards warm section.**

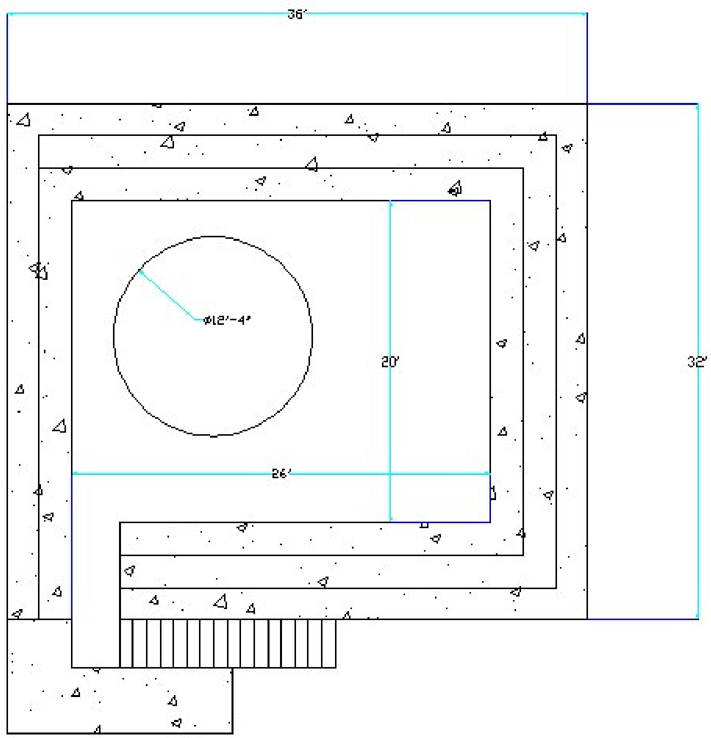
**Two options:**

**near IR4**

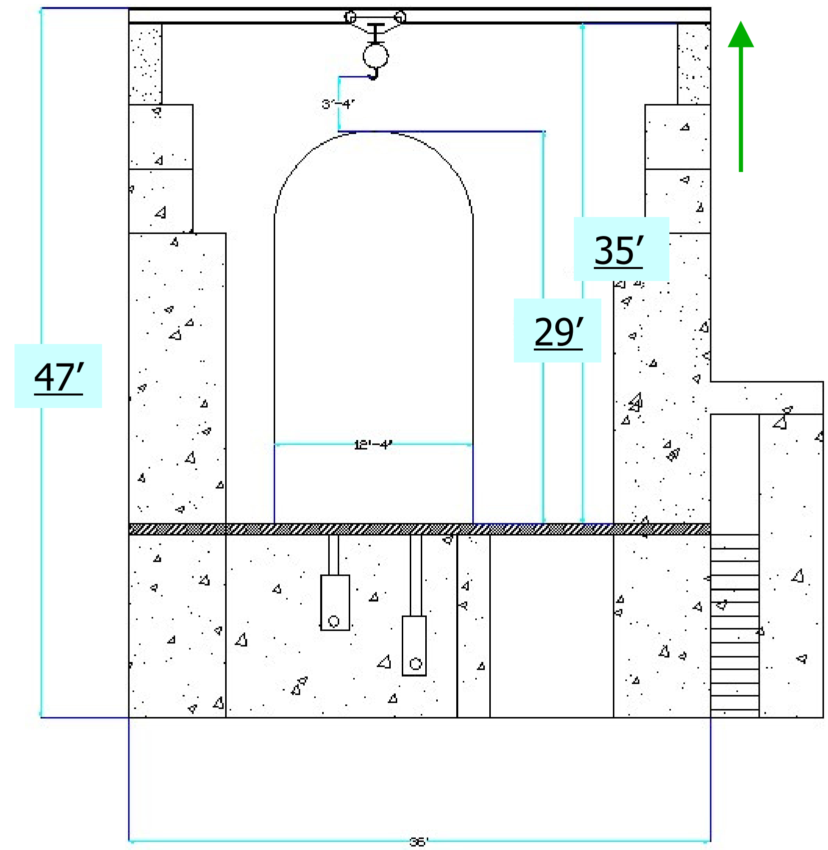
**near IR12**




It looks like 14 meters of warm space is available.
This is minimum space needed to fit 10 meter cooling sections.



36'
ø12'-4"
20'
32'
26'

3'-4"
35'
29'
47'
12'-4"
36'


SULFUR HEXAFLUORIDE (SF6)

# Issues for IR4



Option#1:

1) Steep slope

dirt will be removed to make flat road access

2) need to assemble Pelletron over the cryo lines

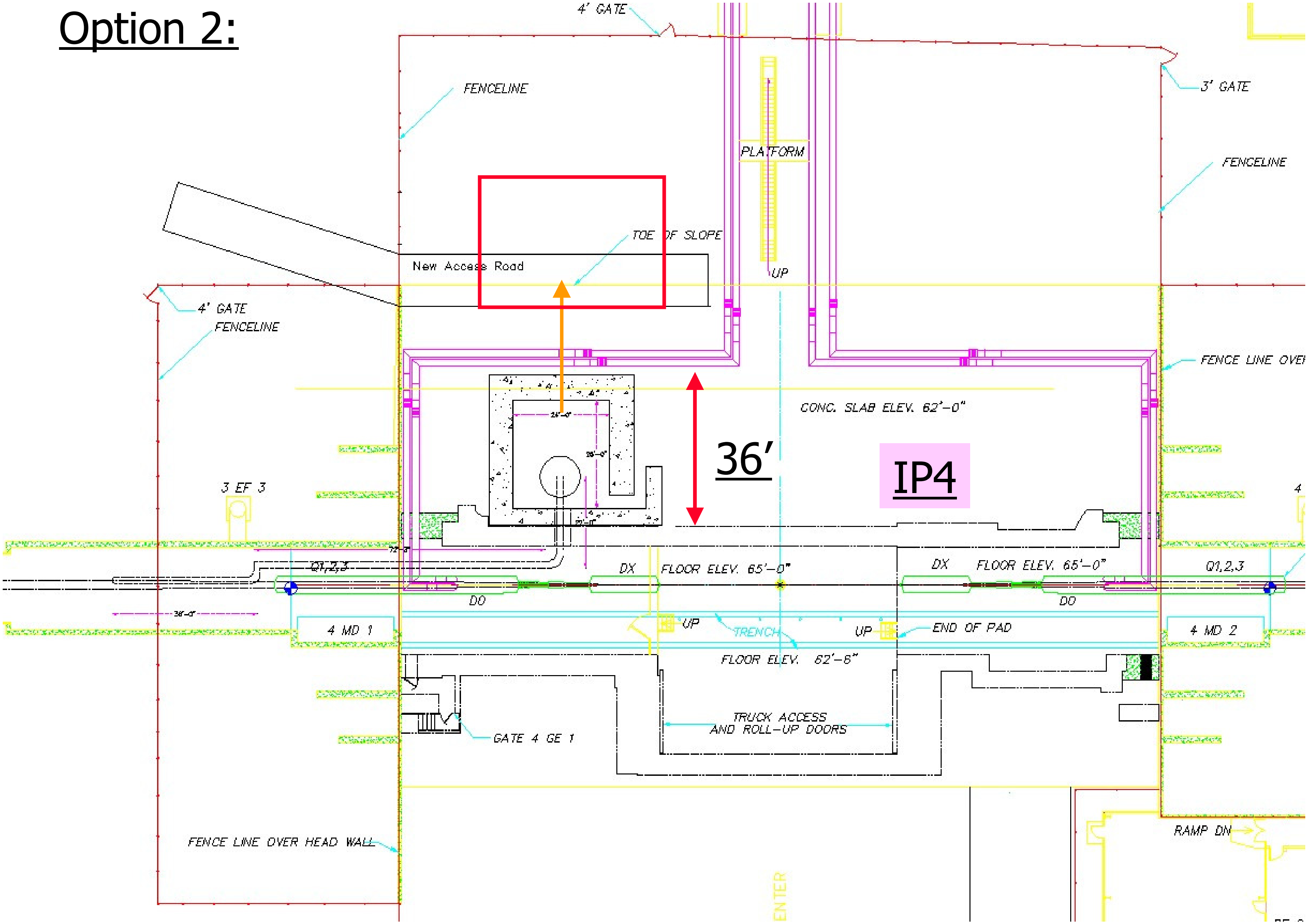
it was done before and should not be a problem

3) Building of blockhouse should be done during RHIC shutdown, since this area is behind the fence. But once Pelletron is installed one can move the fence to allow access to blockhouse during RHIC operation.

Option#2: Blockhouse can be assembled outside cryo pipes:

- this makes longer beam transport by 36'
- but allows assembly during RHIC operation; easier access.
- construction during RHIC operation?

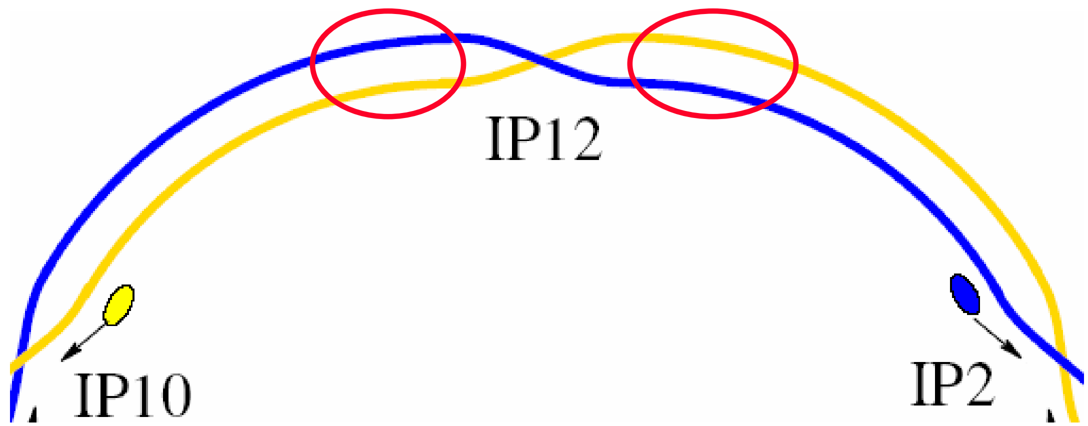
# Option 2:



4' GATE
FENCELINE
3' GATE
PLATFORM
FENCELINE
TOE OF SLOPE
New Access Road
UP
4' GATE
FENCELINE
FENCE LINE OVER
CONC. SLAB ELEV. 62'-0"
36'
IP4
3 EF 3
Q1,2,3
DX
FLOOR ELEV. 65'-0"
DX
FLOOR ELEV. 65'-0"
Q1,2,3
DO
DO
4 MD 1
UP
TRENCH
UP
END OF PAD
4 MD 2
FLOOR ELEV. 62'-6"
TRUCK ACCESS
AND ROLL-UP DOORS
GATE 4 GE 1
FENCE LINE OVER HEAD WALL
RAMP DN
CENTER

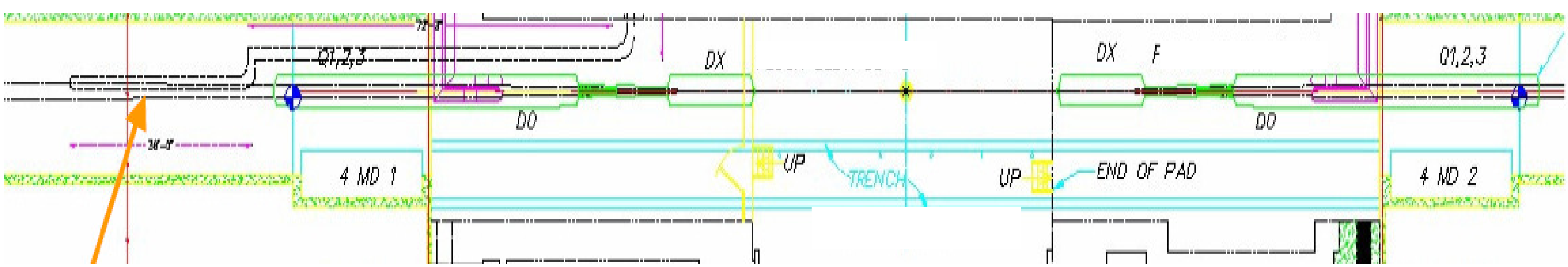
# At IR12?






about 25m available

about 25m available




<u>Significant warm space is available in Sectors 11 & 12</u>

# IR12



**Advantages:**

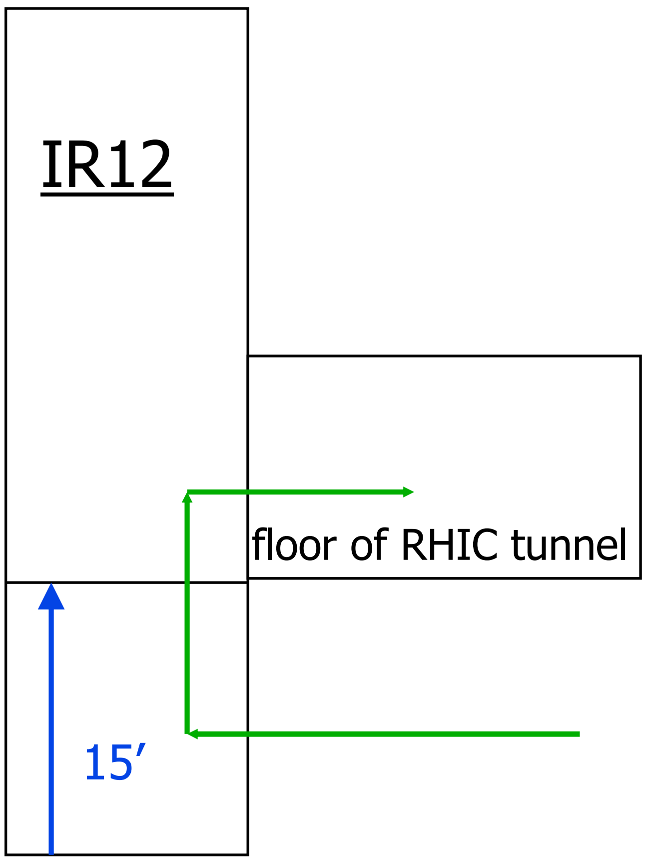
- No need to assemble over cryo lines
- Gives more "warm" space, which allows easier beam turn around and cooling section installation.
- Can be moved further from Q3 (compared to IR4) which gives larger distance between beam pipes – this is very important for U-turn of electron beam

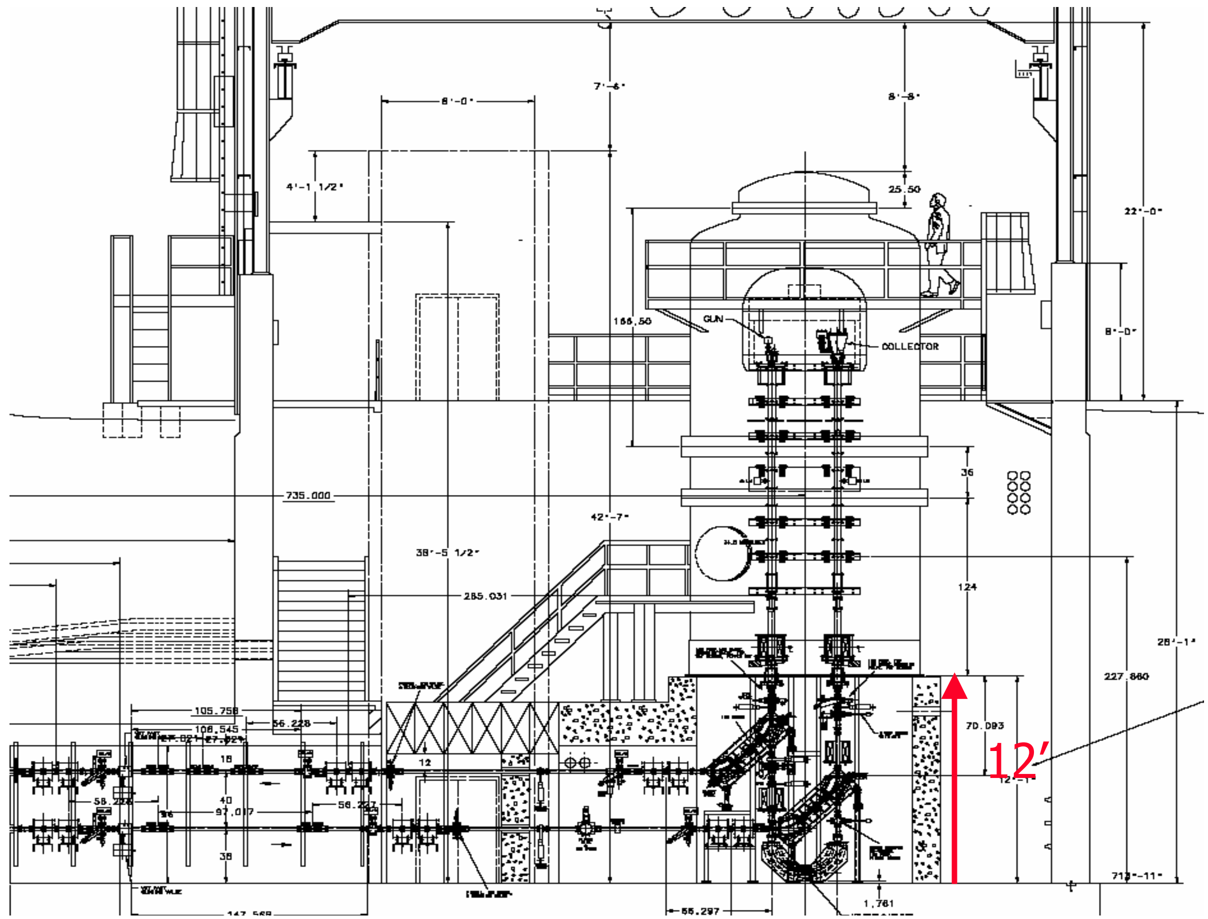
**Disadvantages:**

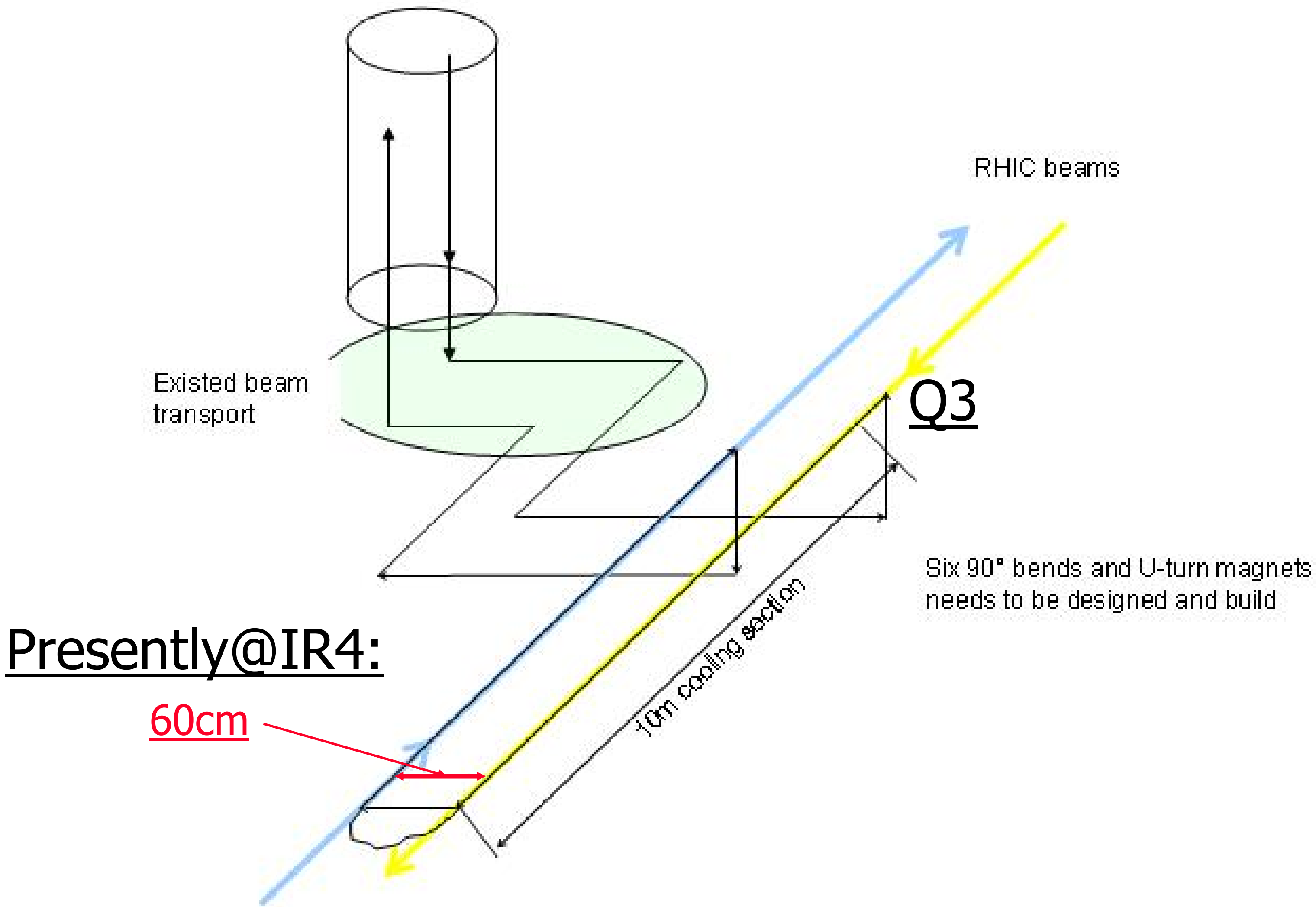
- Elevation - requires additional vertical bend. This may be not a problem since one has plenty of space to make a smooth bend.
- More complicated wall modifications due to cryo pipes on top.

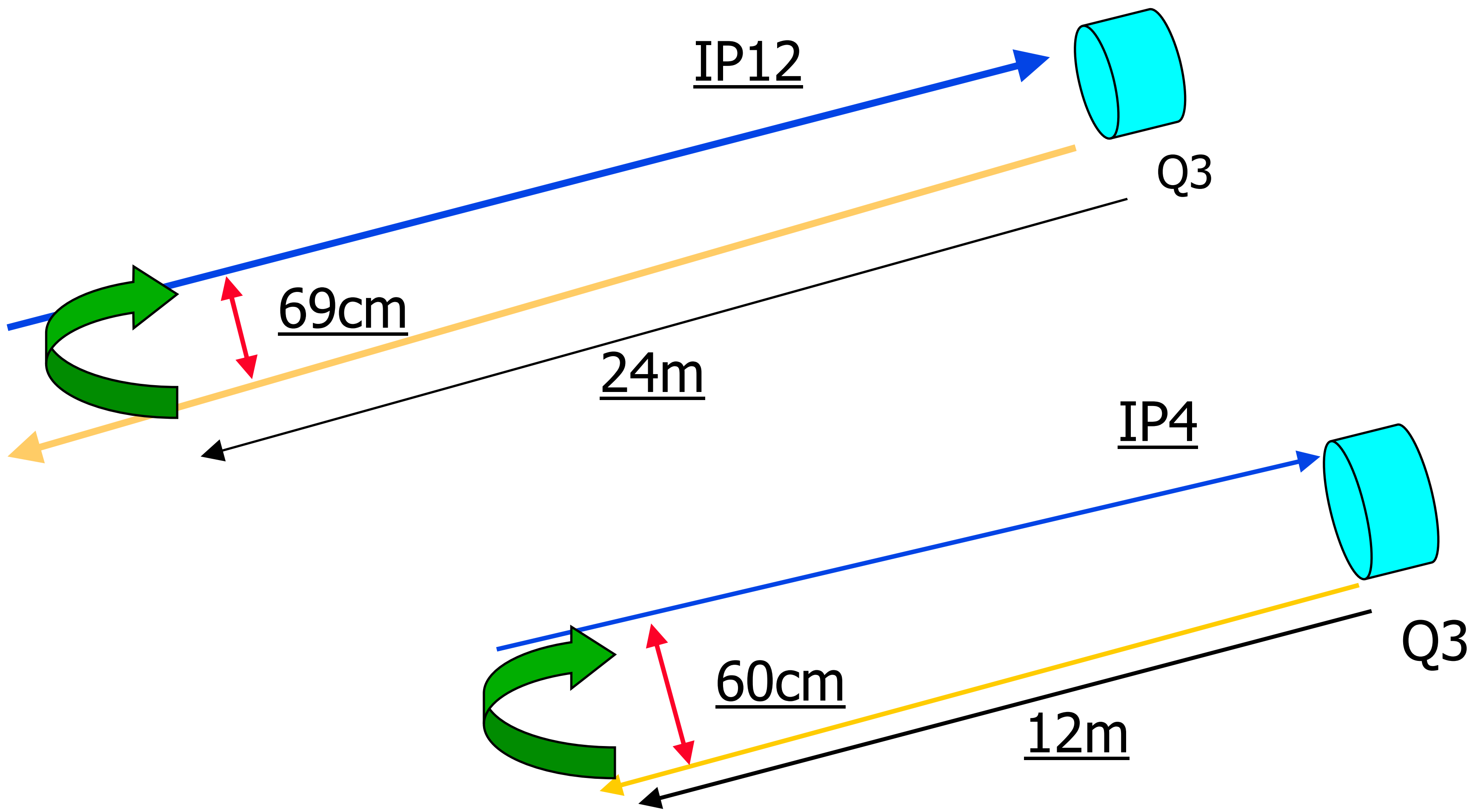
# Elevation @IR12






RHIC beams
Existed beam
transport
Q3
Six 90° bends and U-turn magnets
needs to be designed and build
10m cooling section
Presently@IR4:
60cm

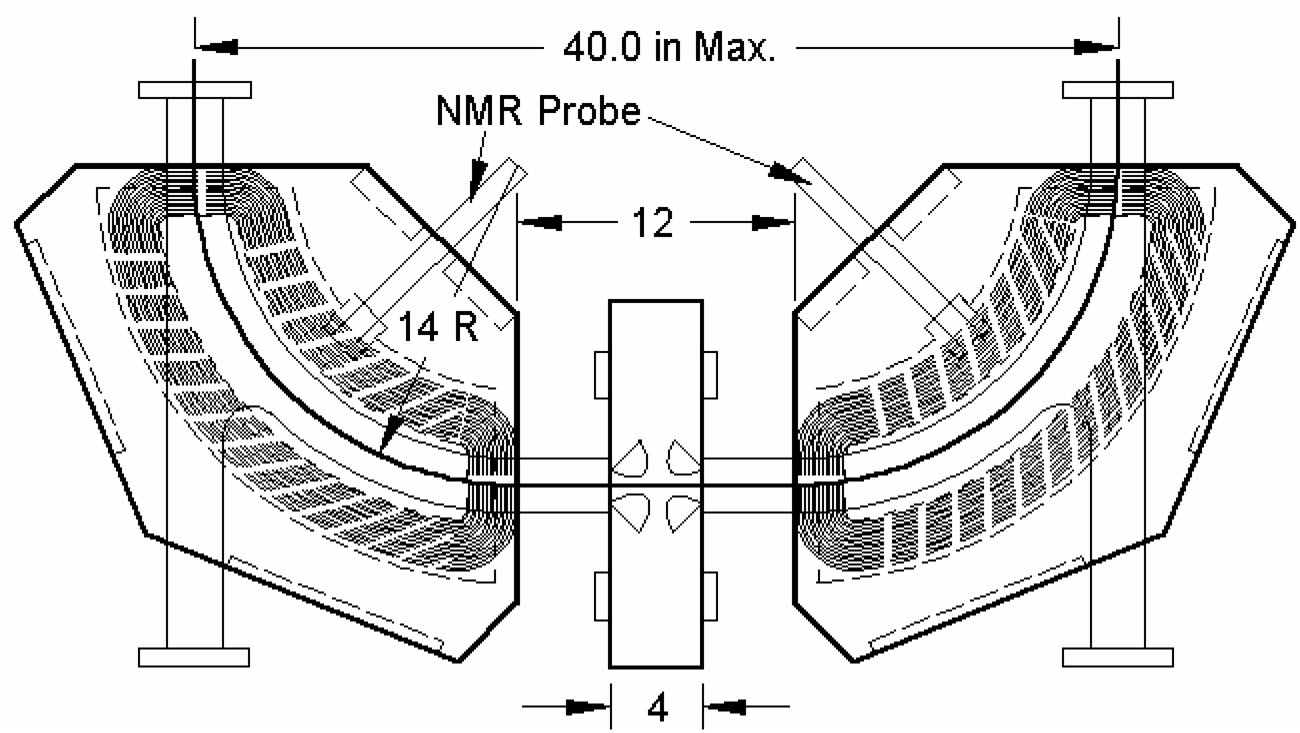

IP12
Q3
69cm
24m
IP4
Q3
60cm
12m

# U-bend at FNAL



@IR4: 24in (Preliminary design D.K., J.B.)

@IR12: 28in



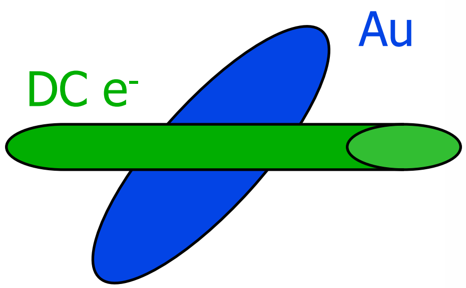
# IR4 or IR12?

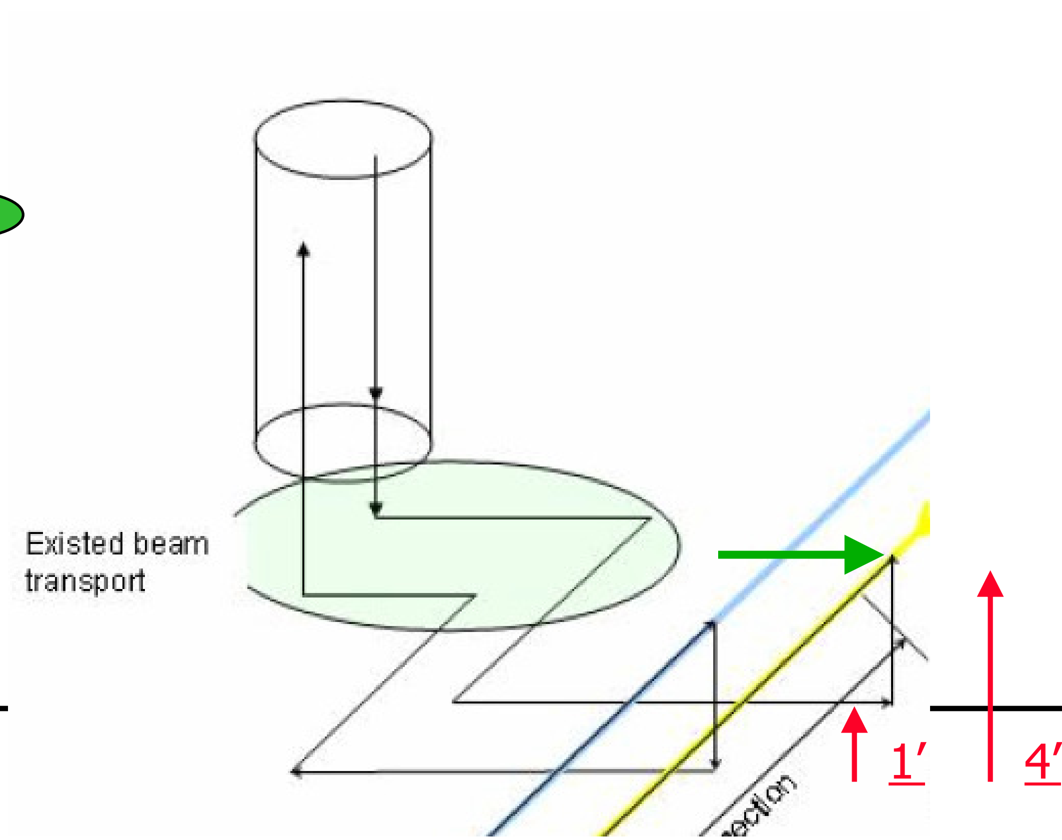


- To proceed with design we need to choose whether cooler location should be in IR4 or IR12

# Minimizing number of bends

- **Presently, the plan is to go with DC electron beam around one ion beam pipe to inject into the other.**
- **Can we consider going right through the ion beam?**



# Project timeline



1. (Assuming FNAL Recycler cooler will be available in October 2011, after Tevatron FY11 run):

| | |
|---|---|
| Preliminary cost estimate of the project – | November 2009 |
| Physics design complete | December 2010 |
| Architectural design & layout | February 2010-February 2011 |
| Electrical design & layout – | June 2010-June 2011 |
| Mechanical design & layout – | June 2010-June 2011 |
| Site preparation – | February 2011- March 2012 (14 month) |
| Recycler's cooler disassembly and transport | October 2011-February 2012 (5 month) |
| Electron cooler installation | March 2012 –January 2013 (10 month) |
| Commissioning | February-June 2013 (5 month) |

Available for FY14 RHIC physics run – November 2013.

## Near-term goals

**FY10:**

- **Start regular physics and engineering meetings**
- **Choose one design (with or without solenoids)**
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- **Design appropriate bending magnets**
- **Address many physics and engineering questions**
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**Spring 2010 – collaboration (FNAL) review?**

**Around December 2010: - formal agreement between BNL and FNAL; decision how to proceed before spending AIP funds**

**December 2010 – design review?**

**January 2011: start spending AIP funds (AIP funds in FY11, FY12, FY13)**

# Needed C-AD manpower projection FY10-FY13 

PROJECTION OF C-AD MANPOWER NEEDED FOR LOW-E RHIC ELECTRON COOLING 11/03/09

| Year | Work scope | Manpower | Hours | Comments |
|---|---|---|---|---|
| FY10 | **Design & layout** | | | |
| | Architectural | Engineer | 1056 | 1 person/50% of time/1year |
| | | Designer | 528 | |
| | Electrical | Engineer | 176x3 | 3p/10%/1y |
| | | Designer | 132 | |
| | Mechanical | Engineer | 176x3 | 3p/10%/1y |
| | | Designer | 528 | |
| | Instrumentation | | 176 | to evaluate what is available, needed |
| | Controls | | 176 | to evaluate what is needed |
| | Additional magnets | Engineer | 200 | |
| | | Designer | 300 | |
| | | Physicist | 4100 | about 2 FTE + other support |

| | | | | |
|---|---|---|---|---|
| FY11 | **Design & layout** | | | |
| | Electrical | Engineer | 176x3 | 3p/10%/1y |
| | | Designer | 132 | |
| | Mechanical | Engineer | 176x3 | 3p/10%/1y |
| | | Designer | 528 | |
| | Instrumentation | | 704x2 | Estimates for diagnostics can be done during FY10. As such, FY11-FY13 numbers in this table are arbitrary until more firm estimates. |
| | Cooling section | Engineer | 200 | |
| | | Designer | 200 | |
| | **Site preparation** | Engineer | 520 | |
| | | Designer | 70 | |
| | | Assigned | 640 | |
| | | DTS | 160 | |
| | | Physicist | 4100 | about 2 FTE + other support |

| | | | | |
|---|---|---|---|---|
| FY12 | **Disassembly &** | Engineer | 528 | The rest is assigned/to be paid to |
| | **Transport** | Technician | 240 | FNAL (additional 8000hours), which |
| | **Installation** | DTS | 336 | is included in cost estimate |
| | Vacuum system | Engineer | 120 | |
| | | Designer | 180 | |
| | Instrumentation | | 1056x2 | |
| | Controls | | 2800 | Presently, numbers for controls are based on hardware complexity (no |
| | | | | bottoms up estimate done yet). |
| | | | | Accurate estimate will be done later. |
| | Assembly | Technician | 2760 | Some of needed labor is already |
| | | Assigned | 200 | included in cost estimate, including |
| | | DTS | 380 | up to 5520 hours paid to FNAL+NEC |
| | | Physicist | 4100 | |

| | | | | |
|---|---|---|---|---|
| FY13 | **Installation &Commissioning** | Engineer | 320 | Project engineer |
| | Vacuum svstem | Technician | 178 | |
| | | Engineer | 120 | |
| | Instrumentation | | 2000 | |
| | Controls | | 2800 | Assumes that most of present software |
| | | | | will need to be rewritten |
| | | Technician | 2760 | +FNAL+NEC help, which is included |
| | | Assigned | 200 | in cost estimate |
| | | DTS | 380 | |
| | Several people | Engineer | 1760 | help from Tandem? |
| | Working in shifts | Physicist | 3520 | +possible FNAL experts |

# Other topics

## Needed Recycler cooler modifications for RHIC



- As a result of the discussions, it became clear that significant modifications of

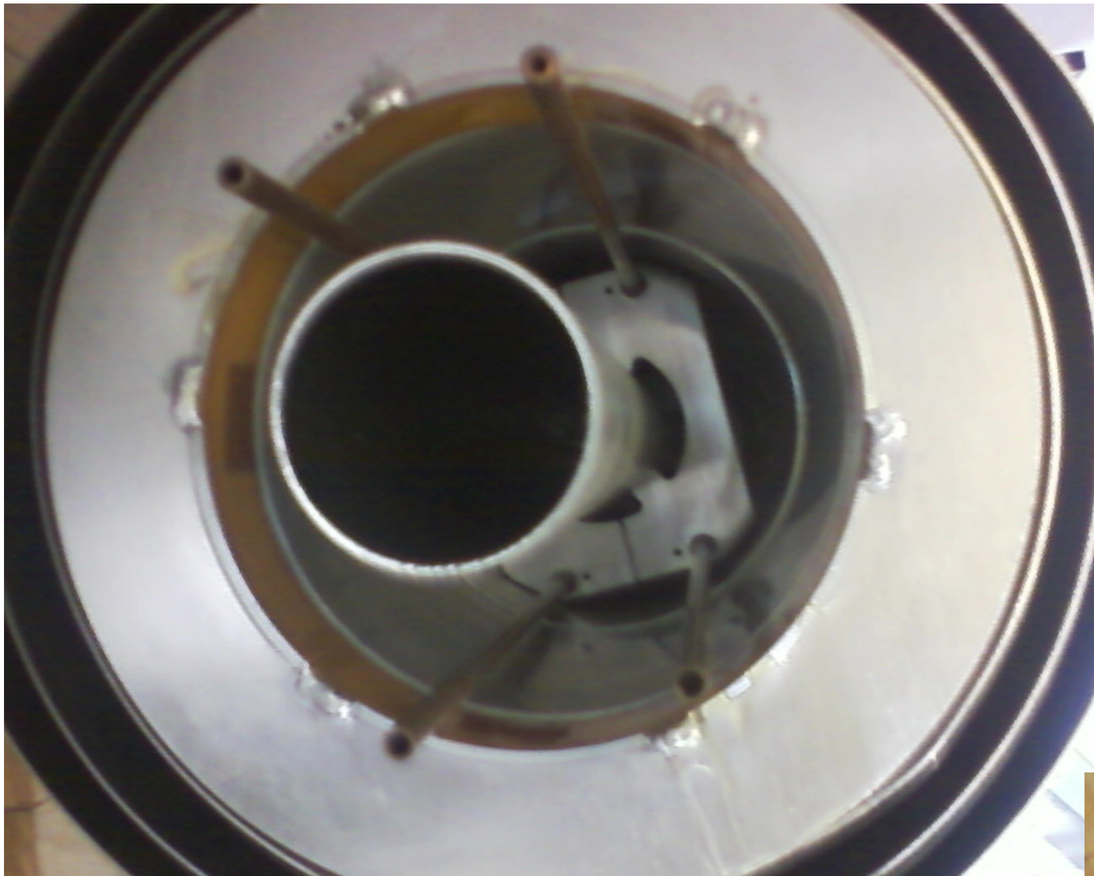
  - electron cooling section

  and

  -beam transport will be needed to adopt Recycler cooler for RHIC.

  Several engineering approaches were identified.

- However, in order to proceed with detailed engineering and site preparation at BNL, decision about which approach to adopt (zero or non-zero magnetic field in cooling section) should be made soon, with physics design finalized by the end of 2010.



If we go with zero magnetic field approach, then we do not change present 5” beam pipe in RHIC.
But this approach requires several other questions to be addressed.

If approach with magnetic field:
What is maximum allowable pipe diameter for baking to fit into solenoids?
R_solenoid=6.9cm?
Can we do R=3.75cm (3” pipe)?
R=5cm (4” pipe)?

# Mike Mapes (Oct. 26, 2009)



**Option with keeping solenoids:**

**There are a few options for the beampipe**

- **Maximize the pipe diameter. We could use 4.5″ OD pipe with an 0.065″ wall thickness which gives a clear aperture of 4.37″, but it would require standard flanges to be bored for this diameter and also very thin heating jackets. This would also leave only about 0.2″ air gap between the heating jacket and solenoid magnet. The flanges would have to be welded on after the pipe is inserted into the magnet and would become trapped.**
- **Maximize the pipe diameter with standard vacuum flanges. We could use 4″ OD pipe with 0.065″ wall which will give a clear aperture of 3.87″. This would also give a .46″ air space between the blanket and the solenoid magnet which is more reasonable. The flanges would have to be welded on after the pipe is inserted into the magnet and would become trapped.**
- **Make the chamber in the solenoid removable so the flanges slip through the magnet with standard flanges. This would require using 4-5/8″ flanges and 3″ OD tube with 0.065″ wall which gives a clear aperture of 2.87″ This also give plenty of room for the heating blankets and allows easy removal from the magnet.**

# Sasha Shemyakin (FNAL):



Please remember when you discuss the increased pipe diameter that in our attempt to make a design with 3" pipe the limitations were the BPM connectors and a place for their wiring, safe for the time of the bake.

Also, let me remind you that you can't increase any noticeably the gap between the solenoids without either significant modifications of them or adding some winding in between.

Because of the need to keep BPMs, having solution with larger than 3" diameter is difficult.

**Summary, the question whether one can use >3" diameter depends on BPM's design and evaluation of "gap length" issue.**

# Baseline for cooling section:



**No long solenoids. Keeping present 5″ RHIC beam pipe.**

**Requires addressing an issue of ion clearing.**