COMET Task Force

16/Oct/2008

J-PARC PAC meeting

Satoshi MIHARA

Task Force

If possible a task force should be set up to consider the special demands of the required beam structure, energy, and intensity. Reports from these committees should be made to the PAC in upcoming meetings….

Minutes of the 4th PAC meeting

- Members
  - S.Mihara, N.Saito, K.Yoshimura (KEK)
  - M.Ieiri, K.Tanaka (KEK, Beam line experts)
  - T.Ogitsu (KEK, SC magnet expert)
  - A.Ando, K.Oide, M.Tomizawa (KEK, Acc experts)
  - M.Aoki, A.Sato (Osaka Uni.)

- Goal (defined by ourselves)
  - In order to realize an experiment that can provide significant physics result, the task force aims at showing a realistic solution(s) for the experiment under discussions among experts from accelerator, beam channel, and physics groups.

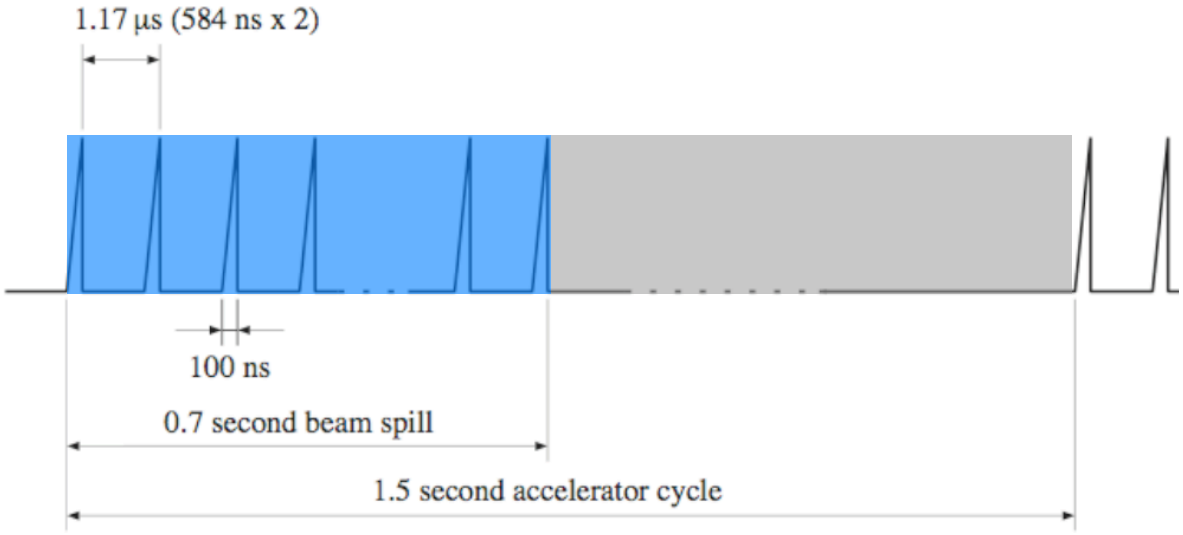
Tasks

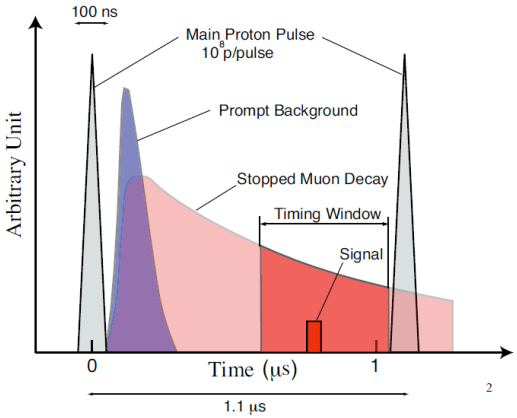
- Proton beam acceleration
  - Investigation of the method described in the proposal
  - Other possibilities to produce required proton beam structure
- Extinction
  - 10^{-9} level necessary to reach 10^{-16} sensitivity
  - Development of measurement technique
- Proton beam extraction/transport
  - Proton beam transport to the target
  - Radiation shield around the target
  - Beam dump
- Experimental area
  - Possible location(s)
    - In the current experimental hall
    - Extension of the current hall

Proton Acceleration

Requirements on the Proton Beam

- Beam Energy and power: 8GeV, 56kW(7μA)
- Bunch width and bunch-bunch spacing:~100nsec, ~1μsec
- Extinction: $<10^{-9}$
- Bunched slow extraction (slow extraction w/o switching off acceleration RF cavity)

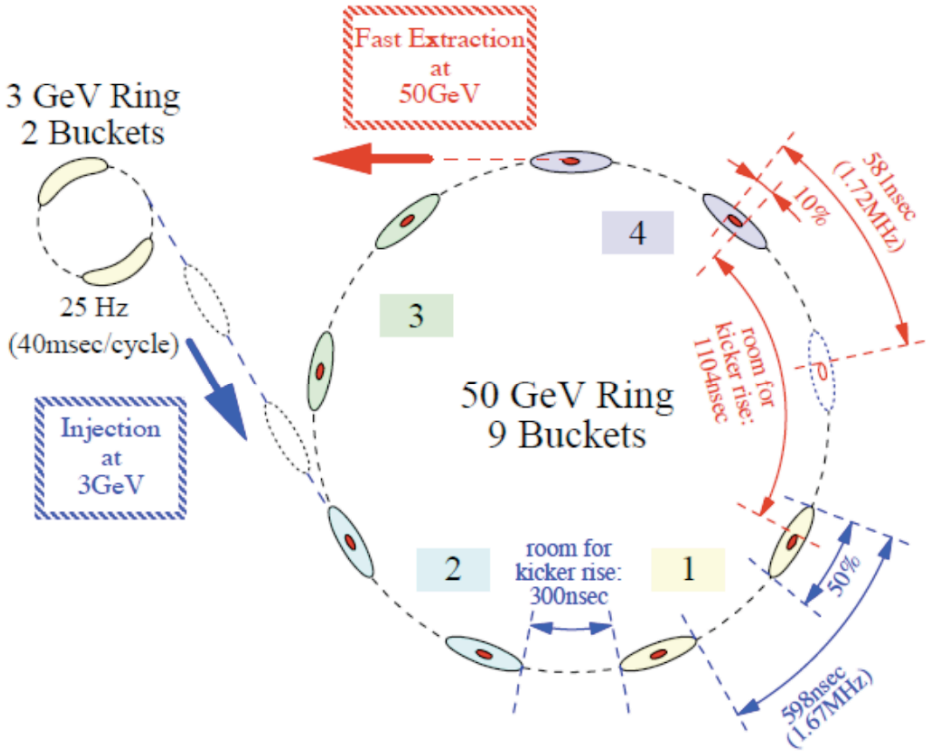




Proton Acceleration

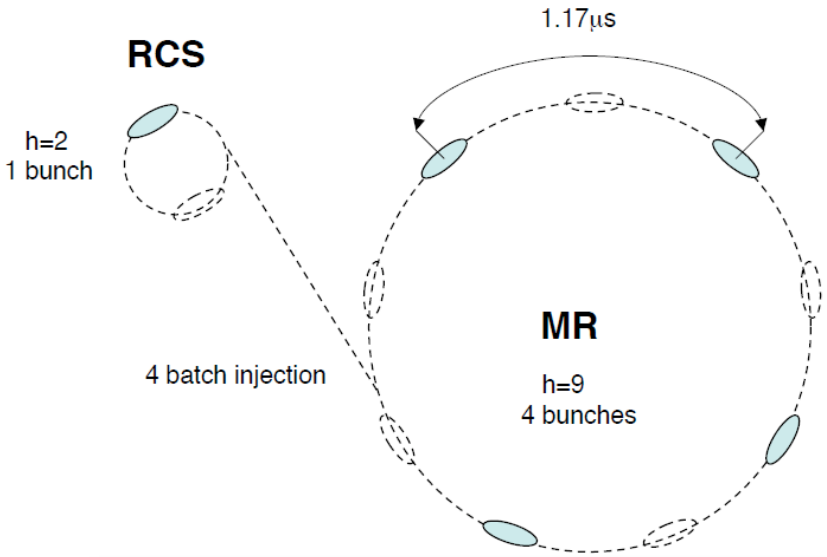
- Nominal scheme
  - RCS: h=2
  - MR:h=9
    - 8 buckets filled
    - 1 empty bucket, used for kicker excitation
- MR RF cavities are designed for this scheme
  - h=18 optional by removing capacitors on cavities
  - Need long shutdown to change the configuration

8 filled buckets out of 9 buckets

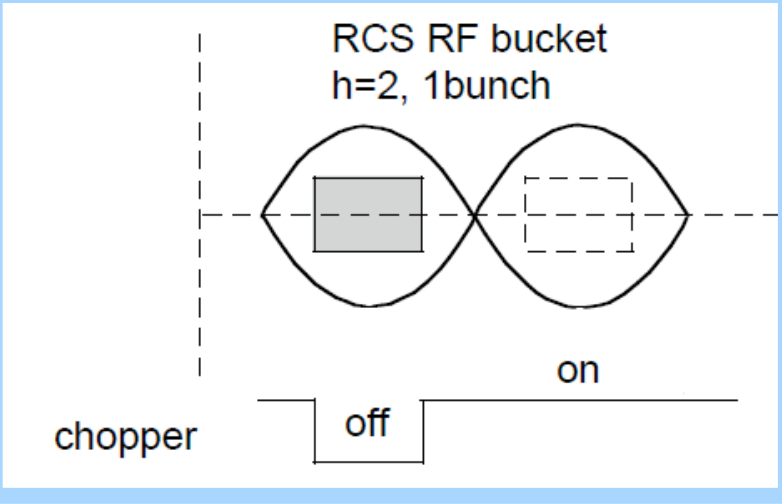


Proposed Scheme (I)

- RCS: h=2 with one empty bucket
- MR:h=9 with 5 empty buckets
- Bunched slow extraction
  - Slow extraction with RF cavity ON, 210kV



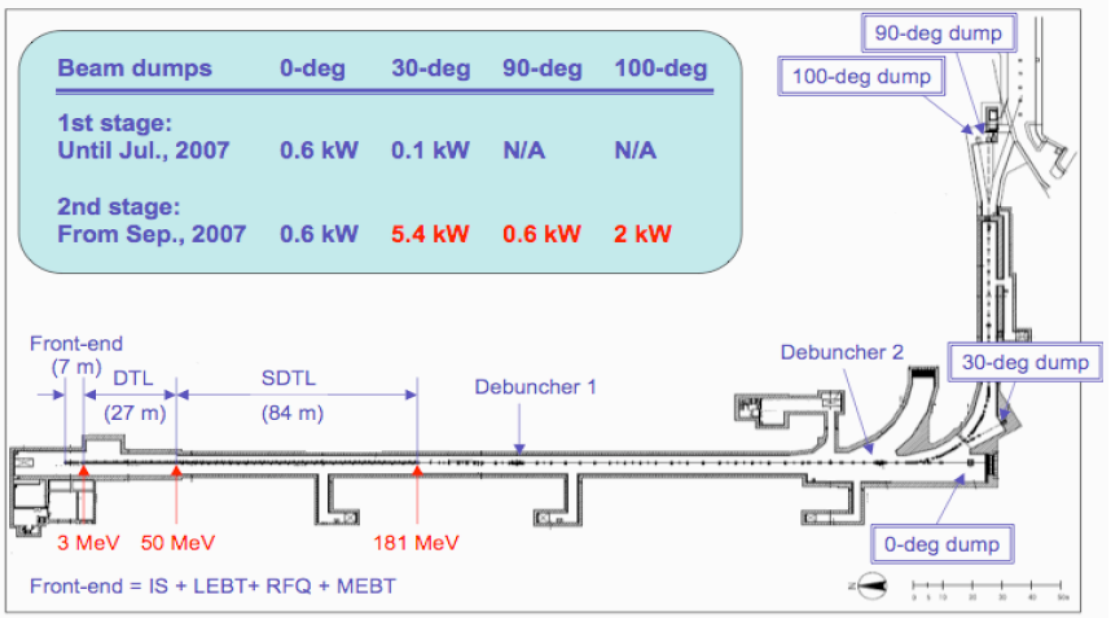
Realization of an empty bucket in RCS by using the chopper in Linac

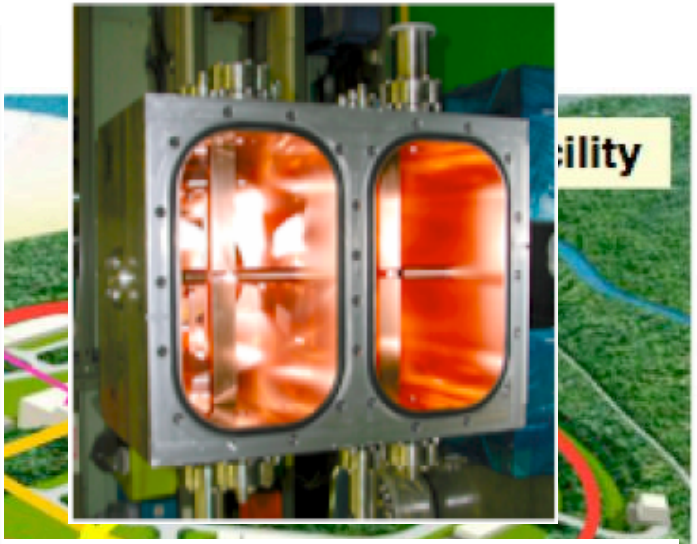


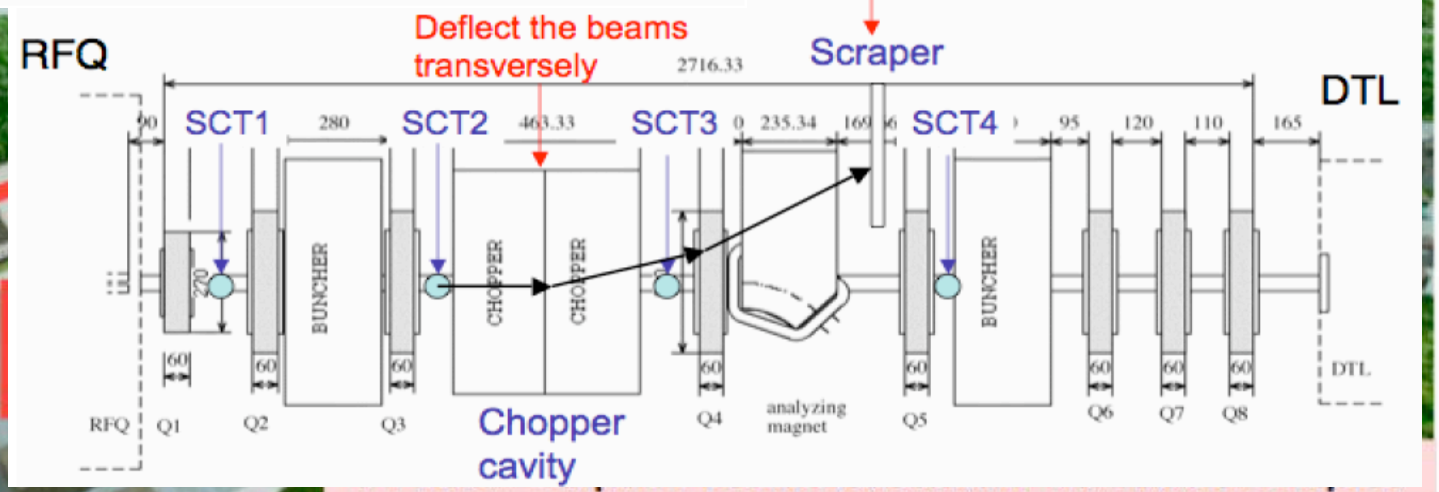
- Simple solution
  - No need of hardware modification
- Heavier heat load in the scraper
- Possible leakage of chopped beam in empty buckets

High-frequency Chopper

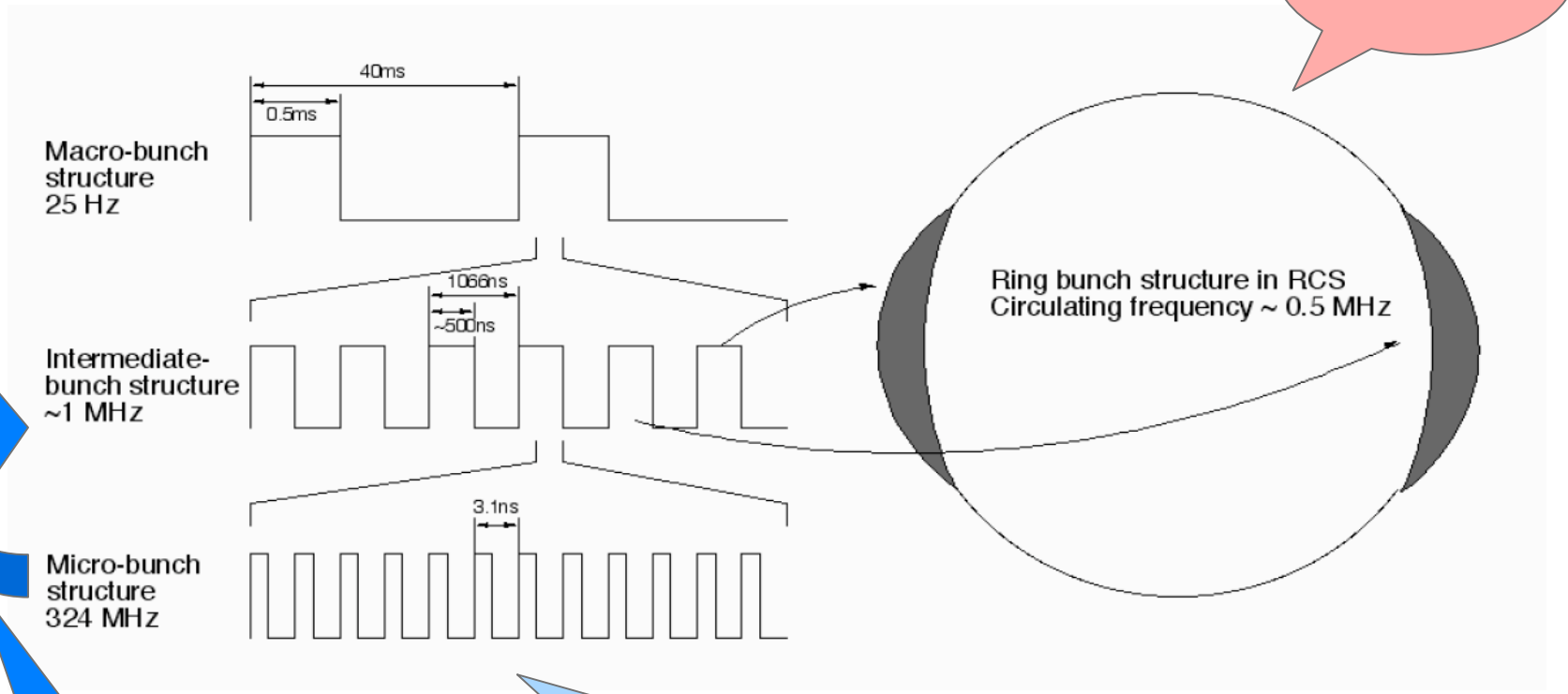
Beam dumps	0-deg	30-deg	90-deg	100-deg
1st stage: Until Jul., 2007	0.6 kW	0.1 kW	N/A	N/A
2nd stage: From Sep., 2007	0.6 kW	5.4 kW	0.6 kW	2 kW



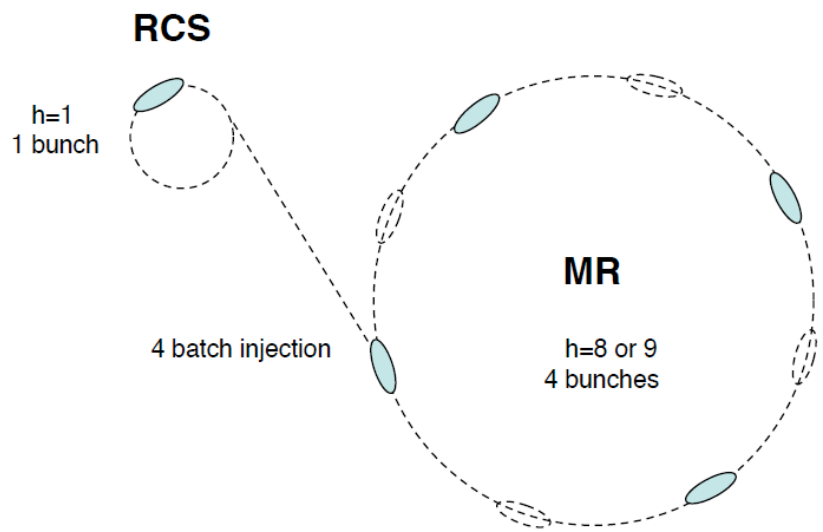


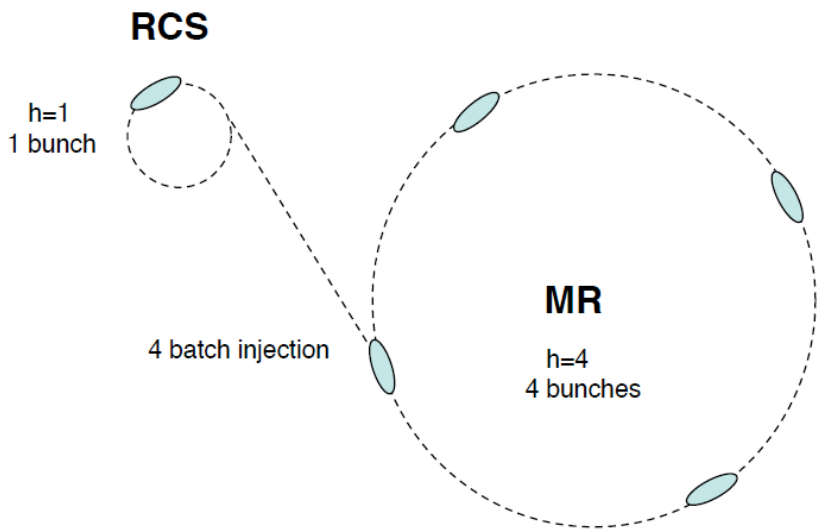


RCS Bunch Structure



Proposed Scheme (II) & (III)





- Space charge tune shift is half of (1)
- Longitudinal emittance is twice of (1)
- NO EMPTY BUCKET IN RCS
- RCS RF system needs minor modification (low level RF)

- NO EMPTY BUCKET BOTH IN RCS AND MR
- Space charge tune shift is half of (1)
- **LARGE MODIFICATION OF MR RF SYSTEM IS NECESSARY**
- Long bunch

Proton Acceleration Prospect

- Try scheme (I) first for an extinction study
  - No hardware modification is necessary
  - Investigate
    - Time structure of the proton beam
    - Heat load at chopper
    - RF voltage while extraction
- Scheme (II) may be able to be tested if h=1 operation of RCS is realized for MR intensity upgrade
  - Check how extinction can be improved

Extinction

Extinction

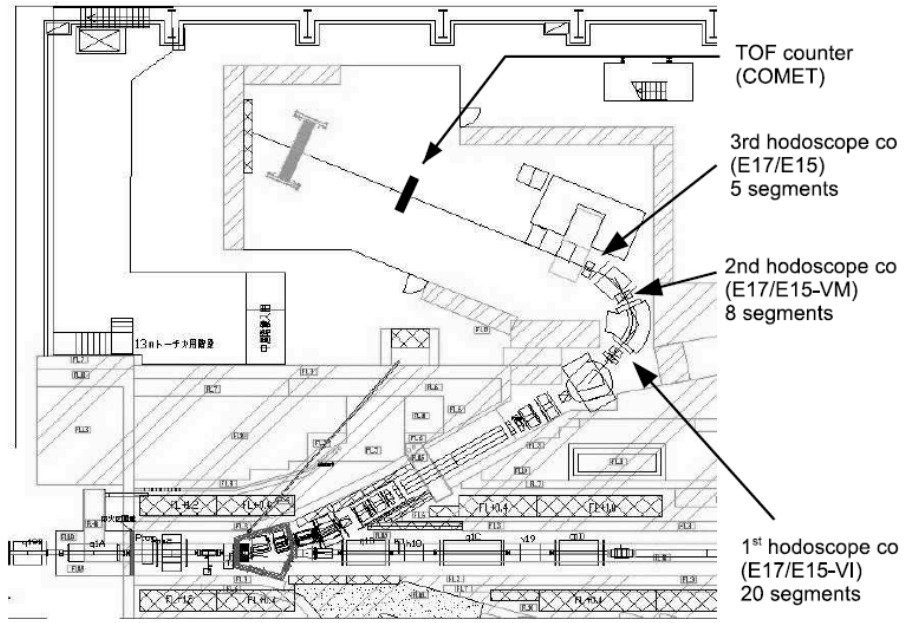
- Simulation Plan
  - Need help of Acc group
  - Particle tracing in the MR
  - Scheme (I)-(III)
  - Input
    - Particle leakage in empty buckets
      - May need measurement at LINAC (beam dump) and/or RCS (MLF)

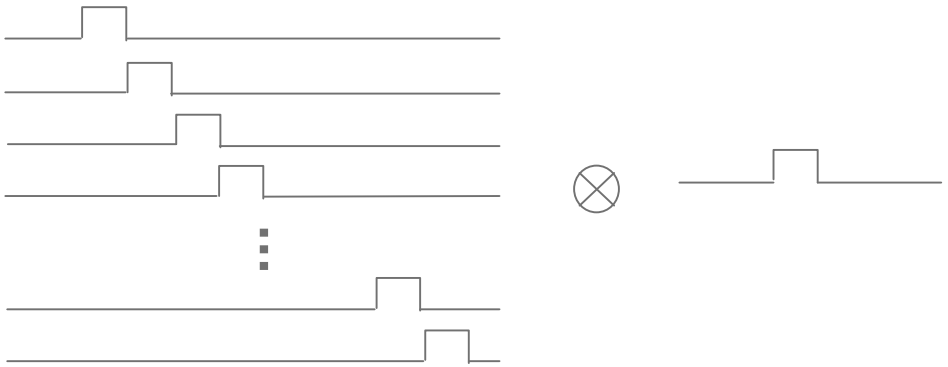
	RCS	MR
Scheme (I)	h=2, 1 empty bucket	h=9, 5 empty buckets
Scheme (II)	h=1, no empty bucket	h=9, 5 empty buckets
Scheme (III)	h=1, no empty bucket	h=4, No empty bucket

- Measurement
  - COMET group plans to perform a measurement at K1.8BR in 2009 (Autumn)
  - "Beam monitoring" at beam dump is also planned (in 2008 if possible)

Measurement at K1.8BR

- Measure secondary particle time structure relative to a reference signal from the MR
  - We need
    - MR RF signal in the experimental area
    - Beam line hodoscope counters at the K1.8BR line
      - Support by E15/E17 group
    - MR operation with empty buckets
    - Bunched slow extraction
  - Count the number of secondary particles as a function of time
    - Particle identification
      - TOF
    - Integration for ~10^3 seconds supposing 1MHz counting rate

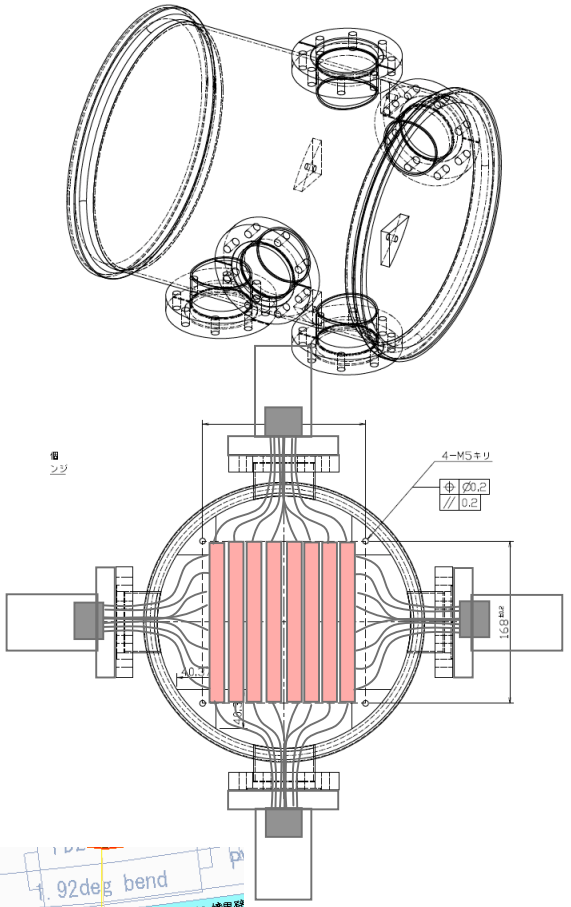


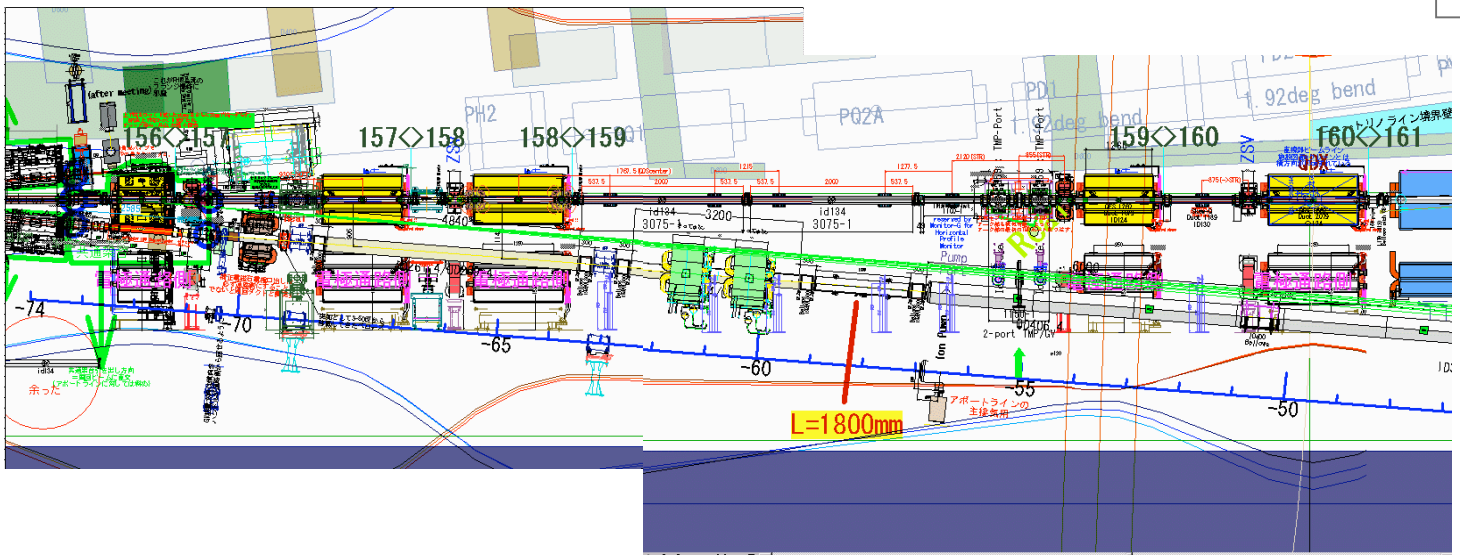


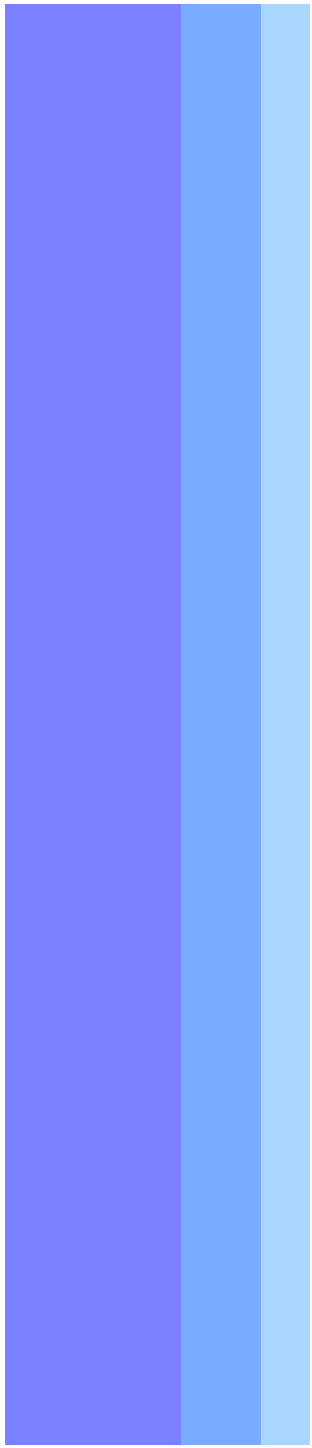
Delayed reference signals Counter signal

Monitor in the Abort Line

- Utilize beam monitor in the abort line
- Single bunch operation of the MR
  - Look at the empty bucket before the filled one
  - Detector that can count the number of protons
- Two layers of 2mmt scintillator hodoscopes
  - Support by thin carbon fiber plates
  - Read by Multi-anode PMT through optical fibers
  - Operated in the beam line vacuum







Extraction/Transport

Extracted Beam Size

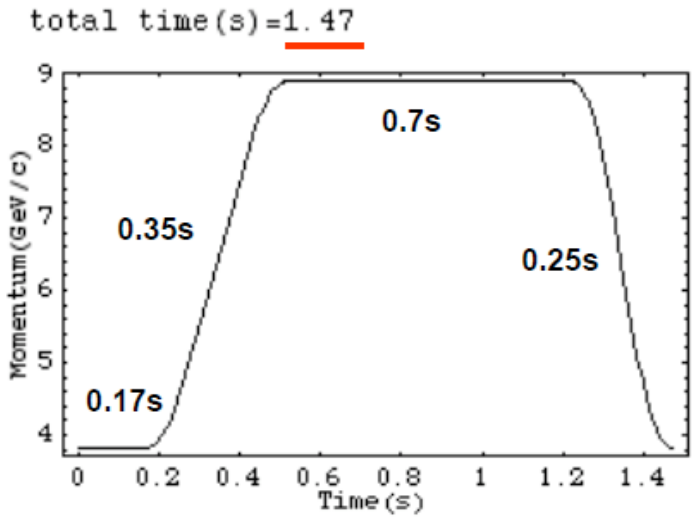
- Acceptance at MR slow extraction line and transport line is **25πmmmad**
- Beam size shrink by adiabatic damping is **SMALL** in 3→8GeV acceleration

- Nominal scenario
  - space charge tune shift: -0.24 (RCS), -0.2 (MR)
  - 144π (0.4GeV) → 54π (3GeV) → **35π (8GeV)**
    1.5 times 1.5times
- Strategy
  - Keep MR rep. rate as high as possible
    - reduce particle number in the bunch to suppress space charge effect
  - Accelerate beam with smaller emittance than nominal
  - This can be achieved by
    - reducing painting area in RCS
    - narrowing transport line and MR collimator apertures

Possible RCS Painting and MR Operation Pattern

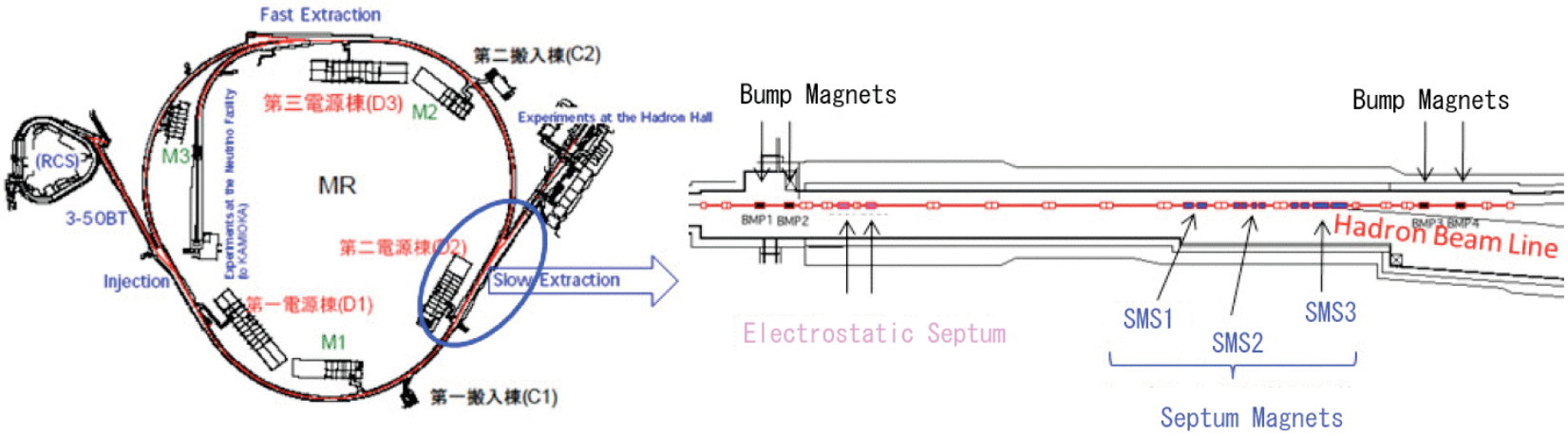
- 0.16×10^{14} ppb (1/2.6 of designed value)
  - 144π(0.4GeV) → 36π (3GeV) →15π(8GeV)
    - RCS tune shift -0.046
  - 93π(0.4GeV) → 23π (3GeV) →10π(8GeV)
    - RCS tune shift -0.072
  - Need measurement

- MR operation pattern
  - 8GeV extraction
  - 7μA, 56kW
  - RCS: h=1 (1 bunch)
  - MR: h=9 (4 bunch), 4 batch injection



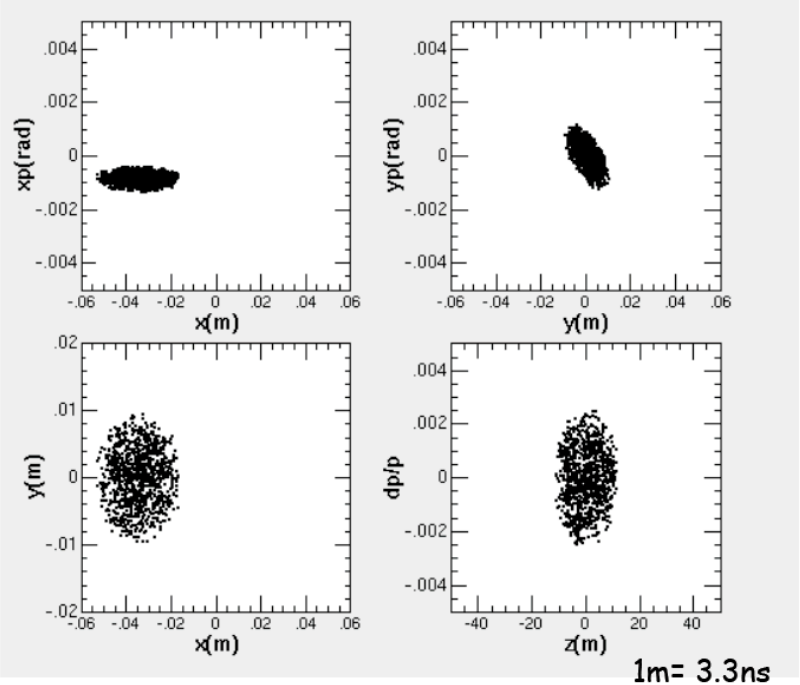
Extraction

- Same with normal slow extraction
- Can we keep bunch structure during slow extraction process?



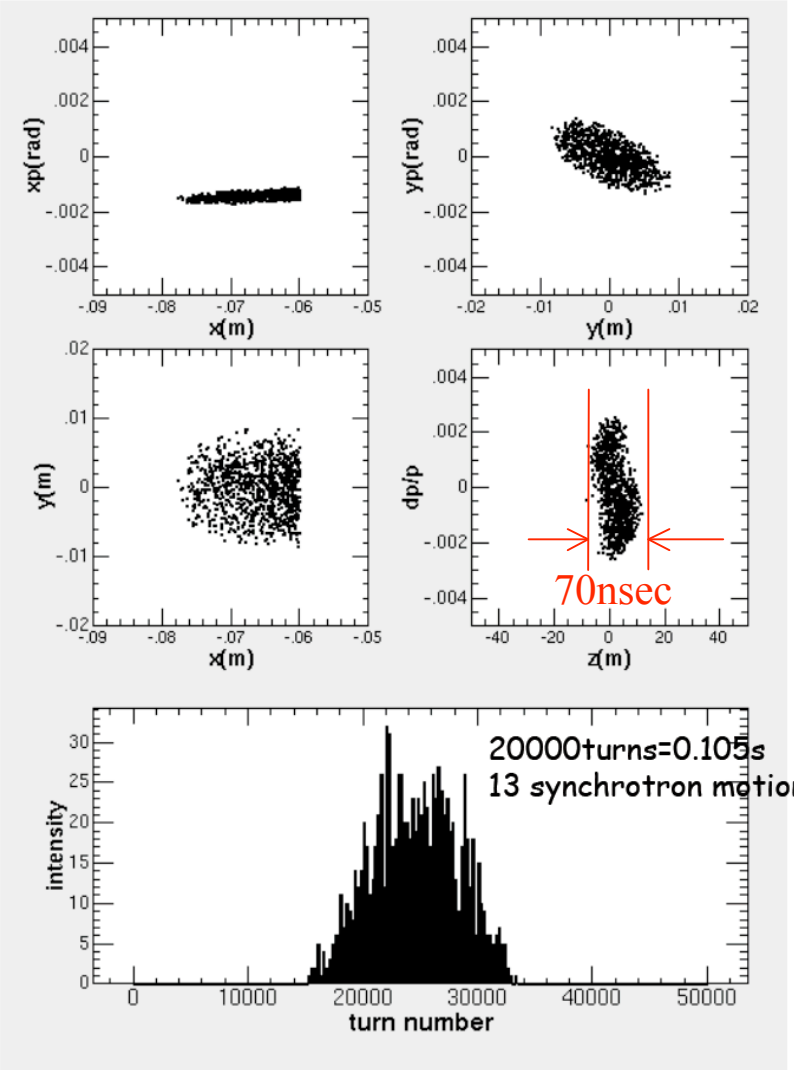
Bunched Slow Extraction

Before extraction at ESS



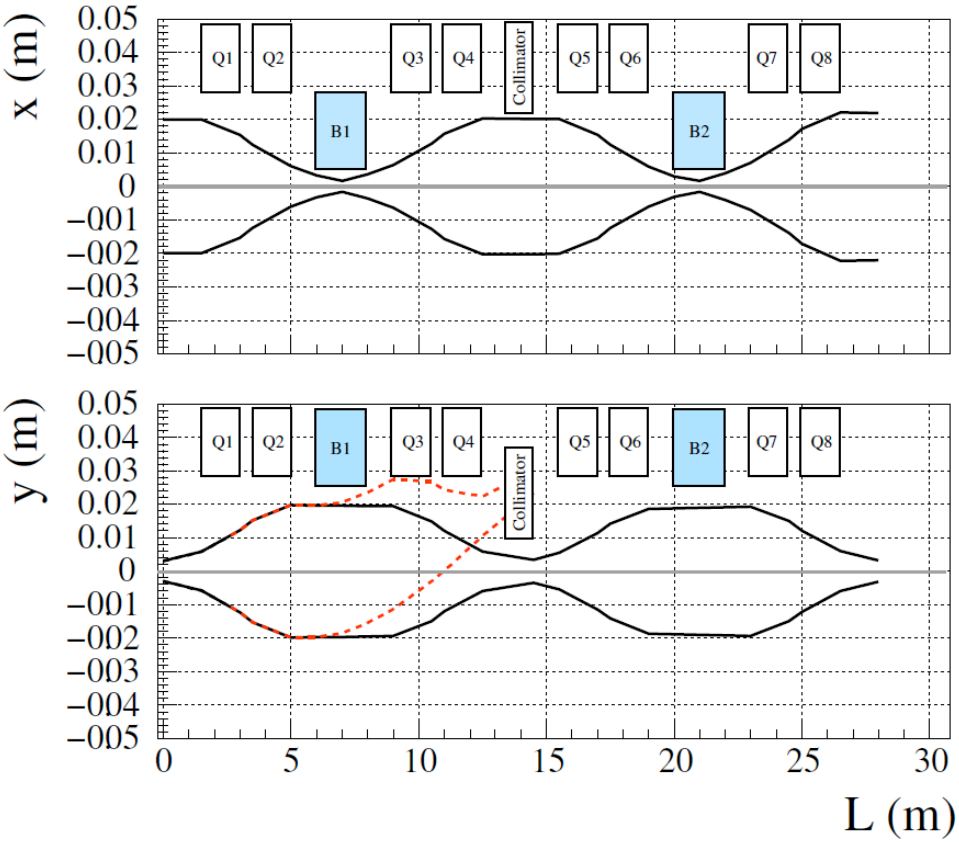
- 8GeV energy
- h=9, RF cavity ON, 210kV
- EL=3eVs, matched ellipse

Extracted beam at ESS



Transport to the Target

- Detailed study is not started yet in the task force
- Probably COMET needs external-extinction device, like AC dipole, to improve the extinction after extraction
- The transport line must be long enough (50-100m) to include necessary equipments.
  - R&D work is in progress by the COMET group in collaboration with the Mu2e group

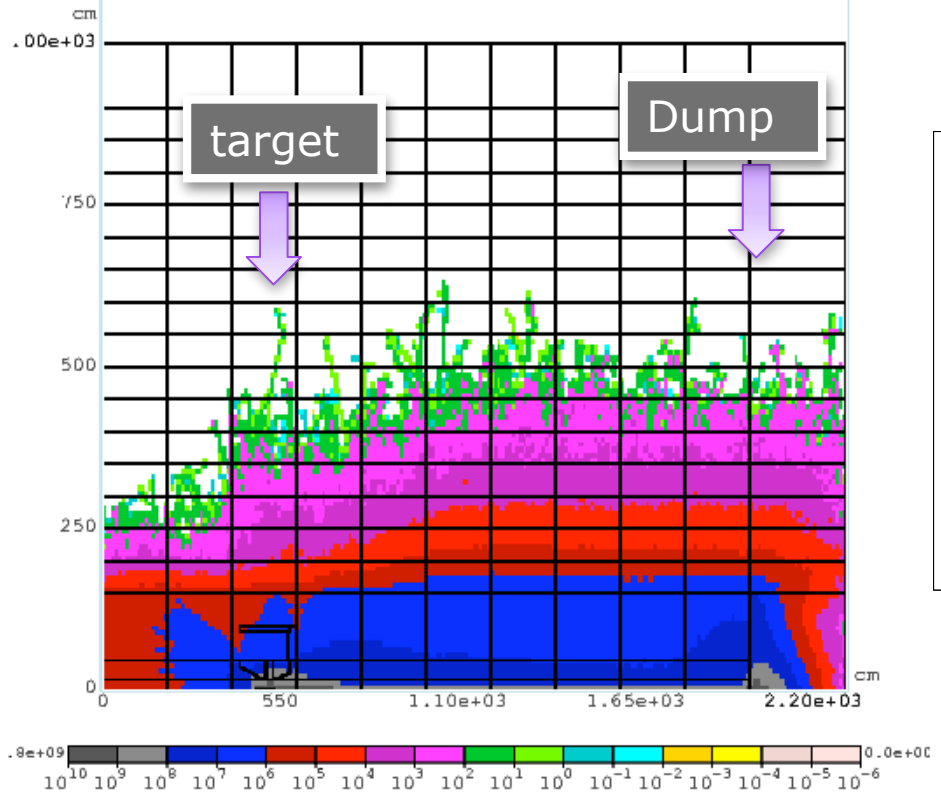


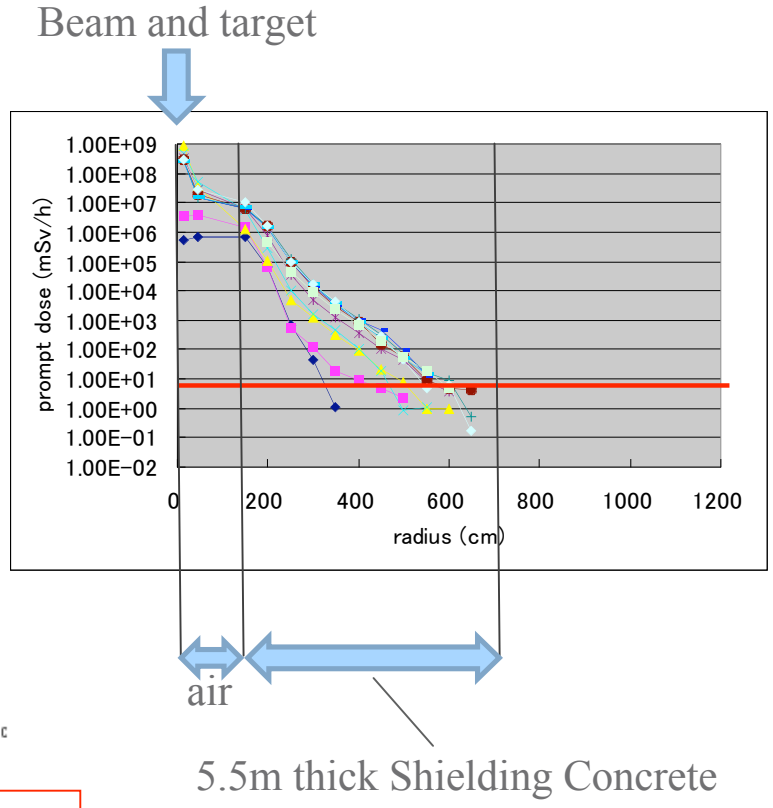
Radiation Shield and Beam Dump

- Proton beam power for COMET:~50kW
  - Detector is operational up to 100kW
- ~80% loss at the pion/muon production target
- Radiation shield
  - Floor
  - Dump
    - Target maintenance must be taken into account in shield designing
    - Radiation shield of the muon transport line must be considered
    - Neutrons produced at the dump can be the background source?

MARS Simulation

- 1st look on underground prompt Dose (8GeV x 7μA)
- Necessary to be less than 5mSv/h (?)



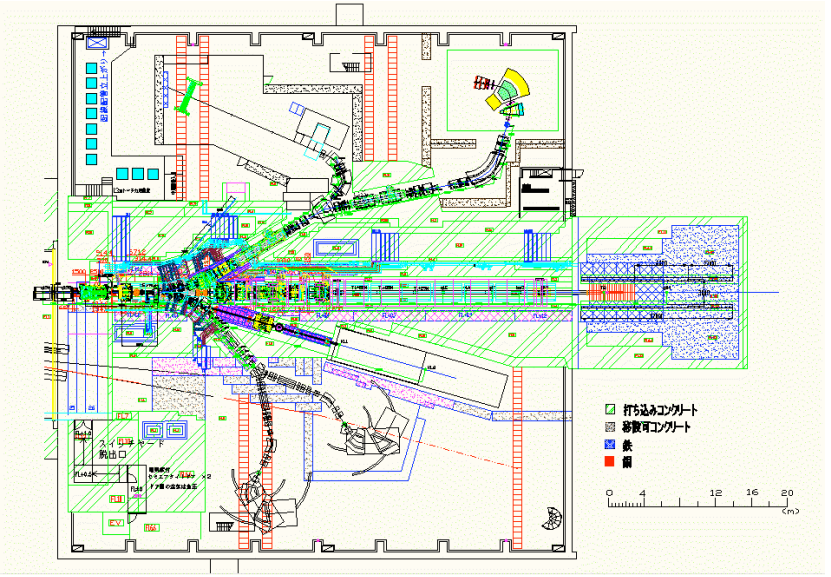


Graphite target (L=60cm = 1.5 int. length, R=2cm)

Experimental Area

Experimental Area

- Requirements
  - Muon production target and beam dump
  - Long enough proton transport line (50-100m)
    - Better to separate the COMET proton line (and target) from the 30GeV line
  - Detector at a distance of ~20m from the target

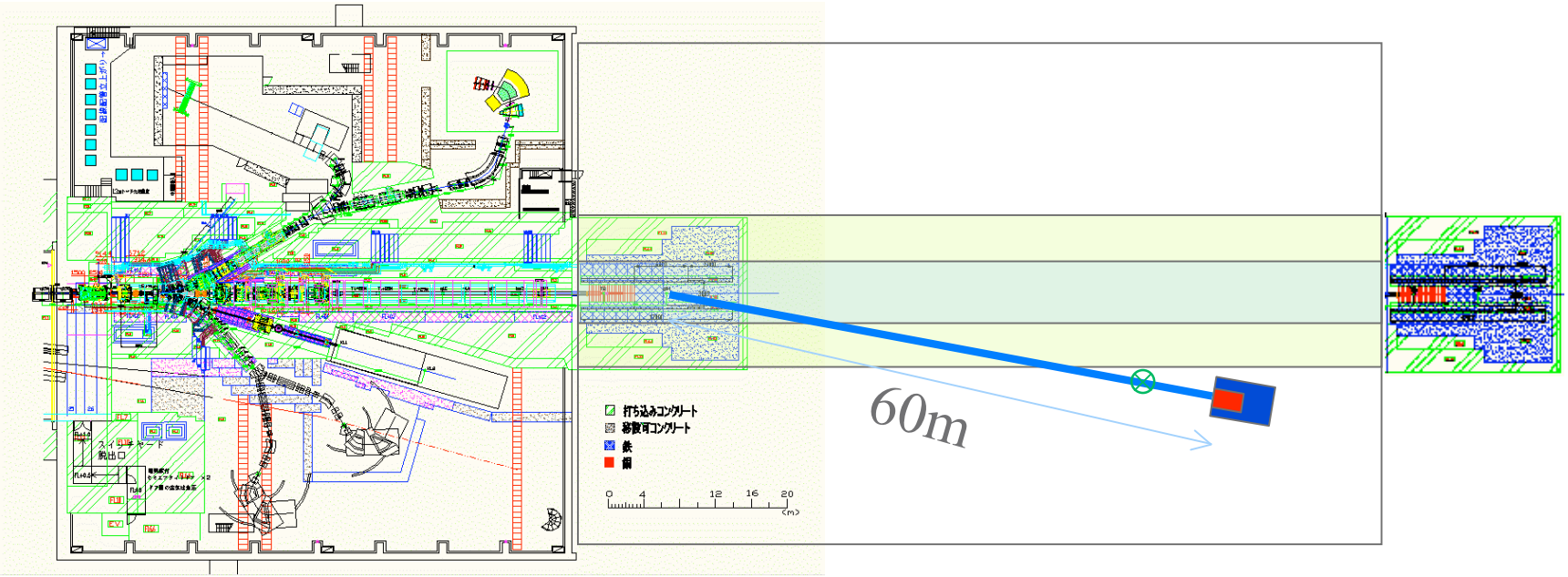


Where can we locate the target?

- Not easy to locate the target in the current A line
  - No space for external-extinction devices
  - No space to prepare a separate 8GeV proton line
- Possible solutions
  - A line in the extended hadron hall
  - B line in the current hadron hall

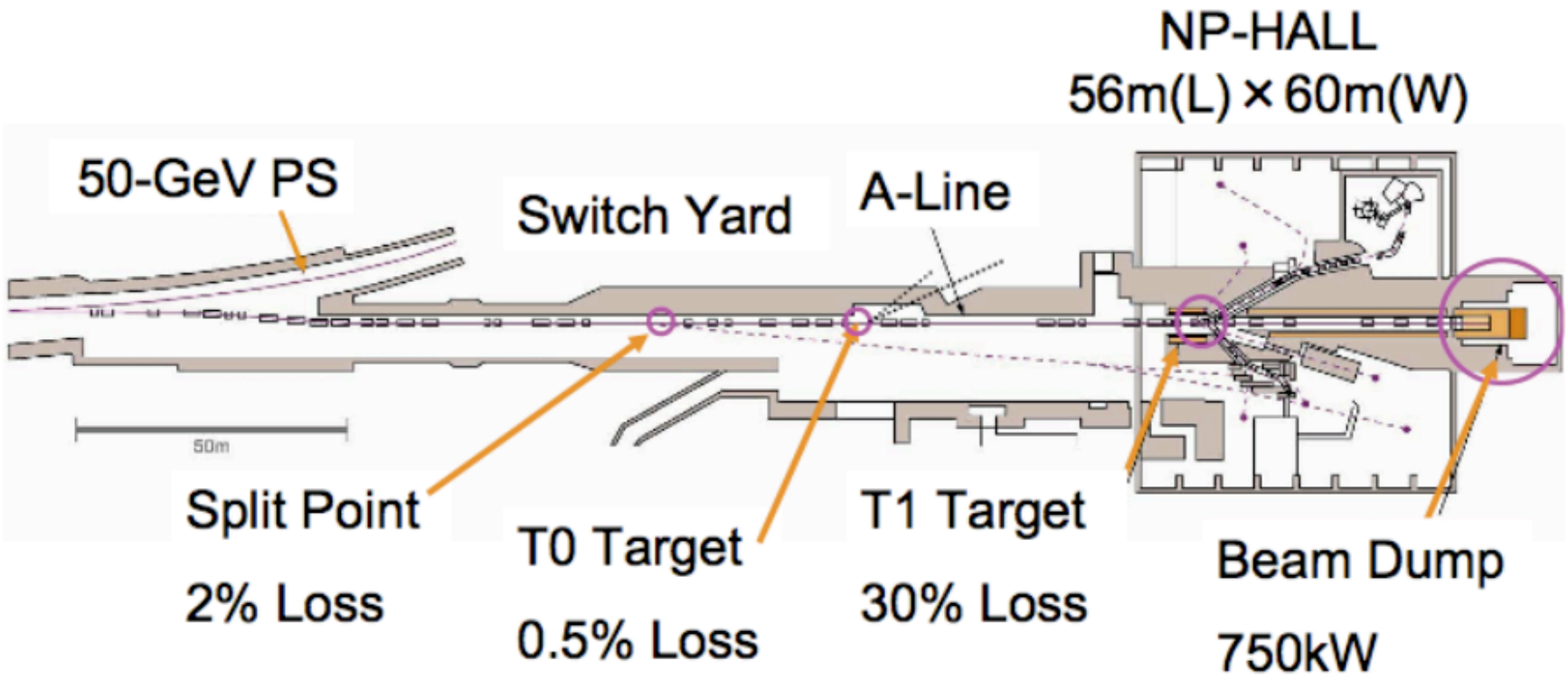
Extension of the Hall

- Possible A-line solution
- Enough space to newly design an 8 GeV primary beam line if the hall is extended sufficiently



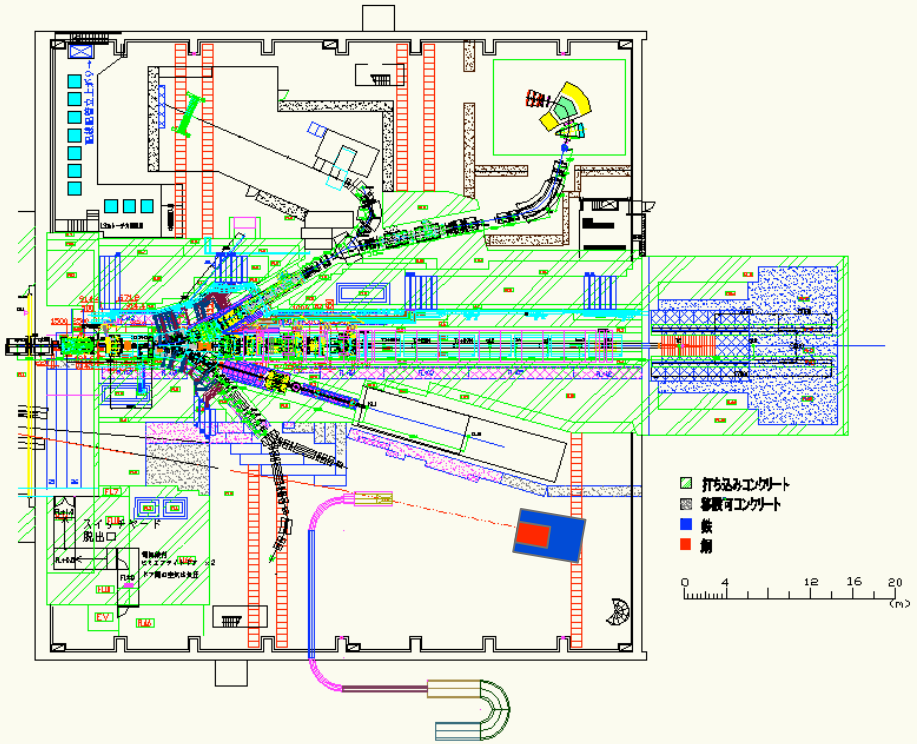
B line ?

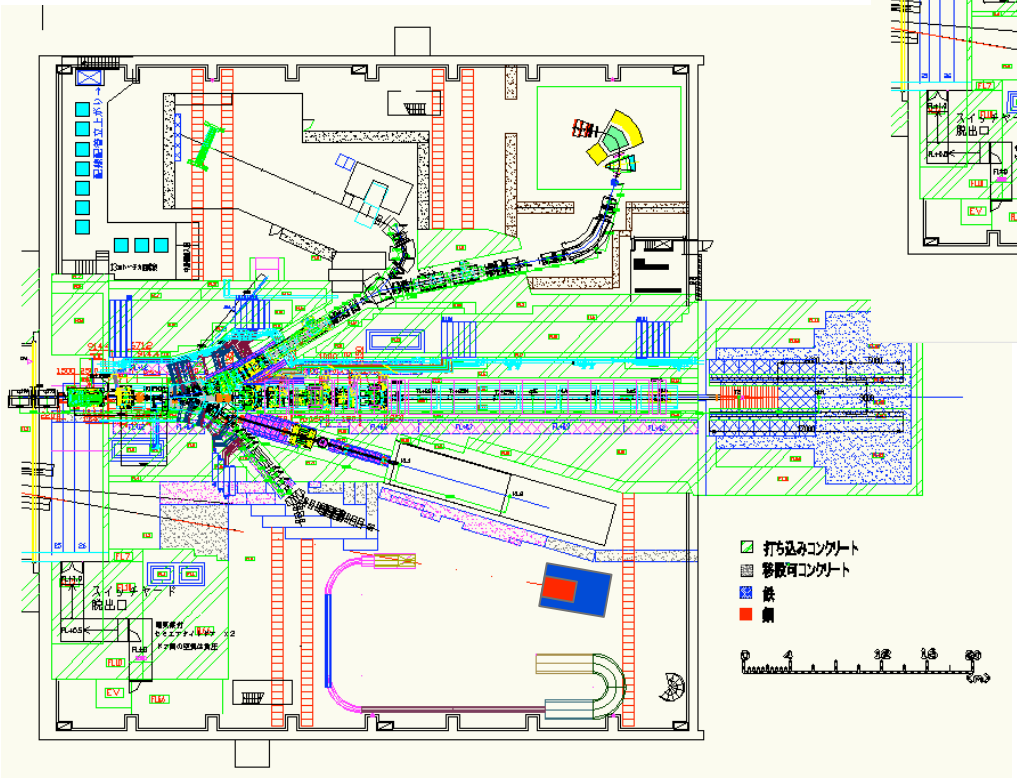
- Long enough to locate external-extinction devices
- Where to locate the target and COMET detector?

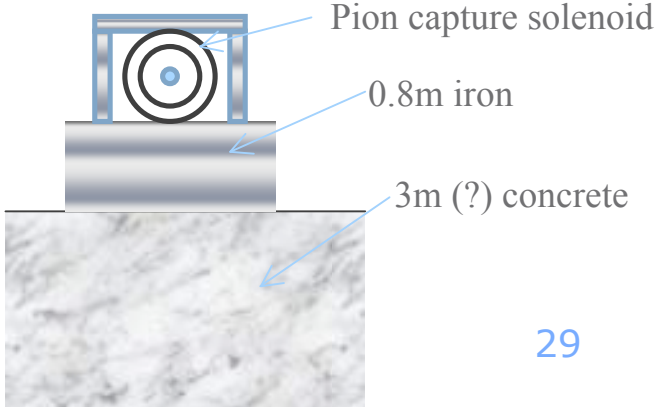


Possible B-line Solutions

- The collaboration needs to optimize the length of the straight section of transport solenoids

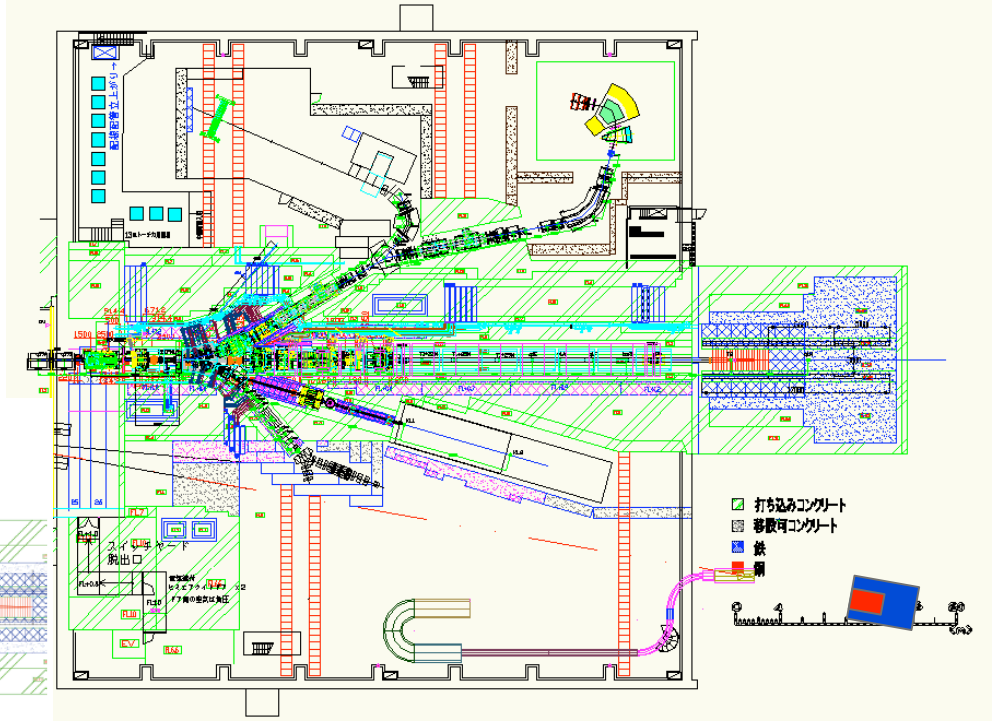


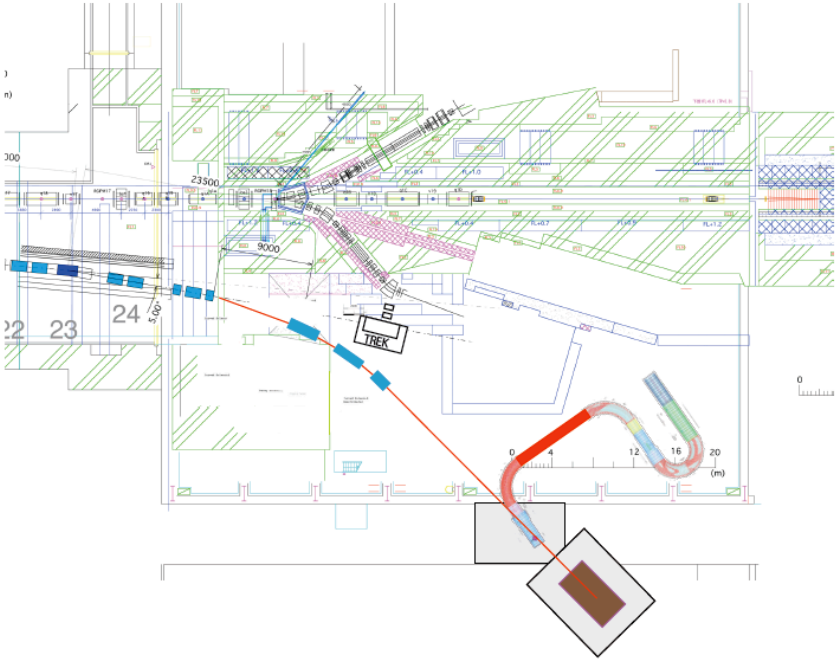


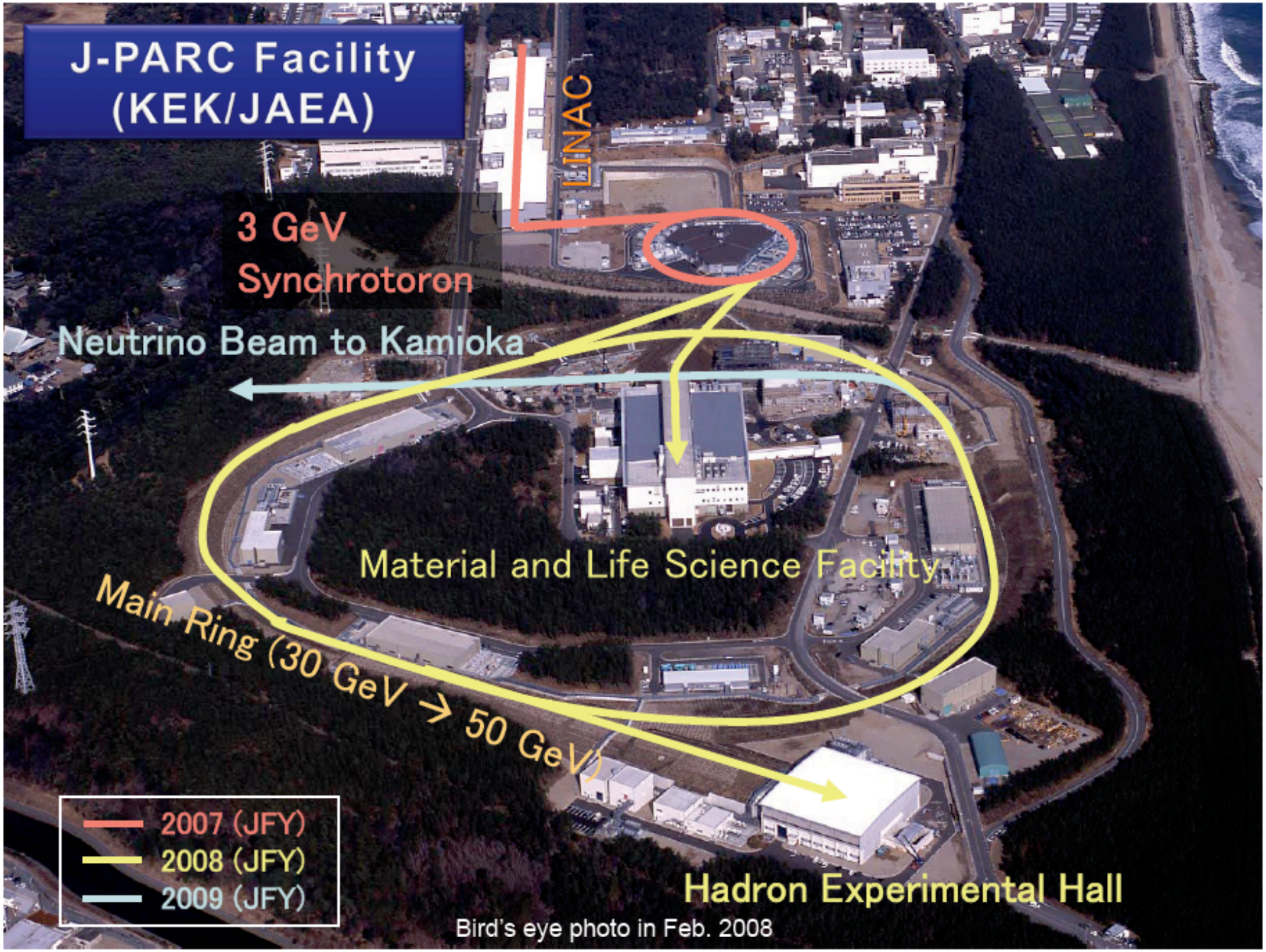


Other Possible B-line Solutions

- In case floor curing is not enough and/or available space is limited in the hall
  - easier to dig in the ground for curing (ground shielding)
  - Need a hütte outside the hall





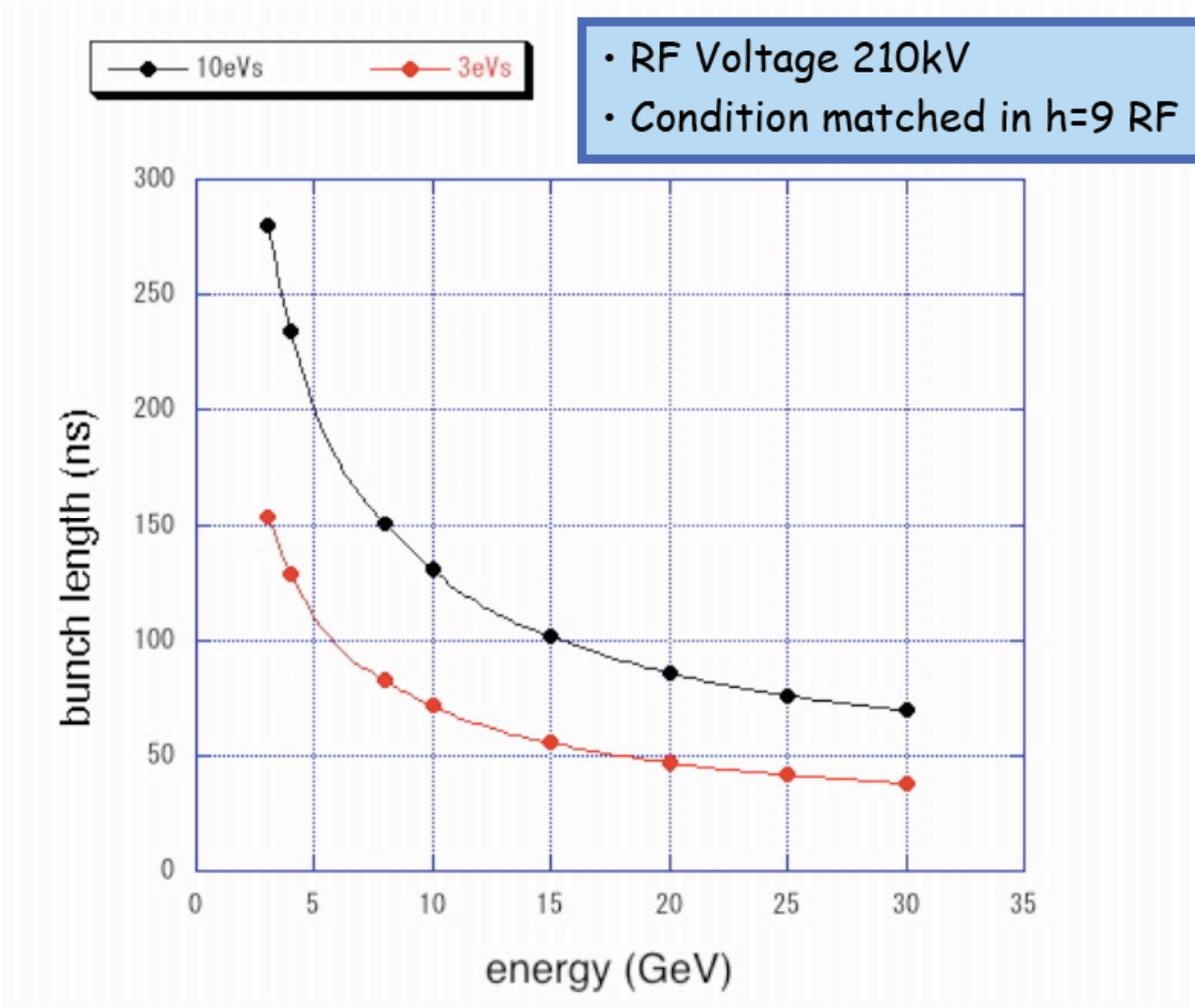

J-PARC Facility
(KEK/JAEA)
LINAC
3 GeV
Synchrotoron
Neutrino Beam to Kamioka
Material and Life Science Facility
Main Ring (30 GeV → 50 GeV)
2007 (JFY)
2008 (JFY)
2009 (JFY)
Hadron Experimental Hall
Bird's eye photo in Feb. 2008

Hadron Hall in August 2007

Summary

- COMET task force is set up
  - Working with the collaboration
  - No conclusion yet
- Tasks
  - Proton beam acceleration
  - Extinction
  - Proton beam extraction/transport
  - Experimental area
- Need support from the lab for further study
  - Acceleration
  - Bunched slow extraction
  - Extinction (support by E15/E17 group)

Bunch length



- RF Voltage 210kV
- Condition matched in h=9 RF Bucket

Internal Extinction Device

AGS internal extinction test
(from BNL K. Brown slide)

- Stripline AC dipole at 80 kHz excites coherent vertical betatron resonance
- Fast (100 ns) kickers cancel AC dipole at the bunches
- Kicker duty factor is low 100 ns / 2.7μs = 4%
- Concept tested in FY98 using existing AC dipole and kickers