High Momentum Beamline at J-PARC

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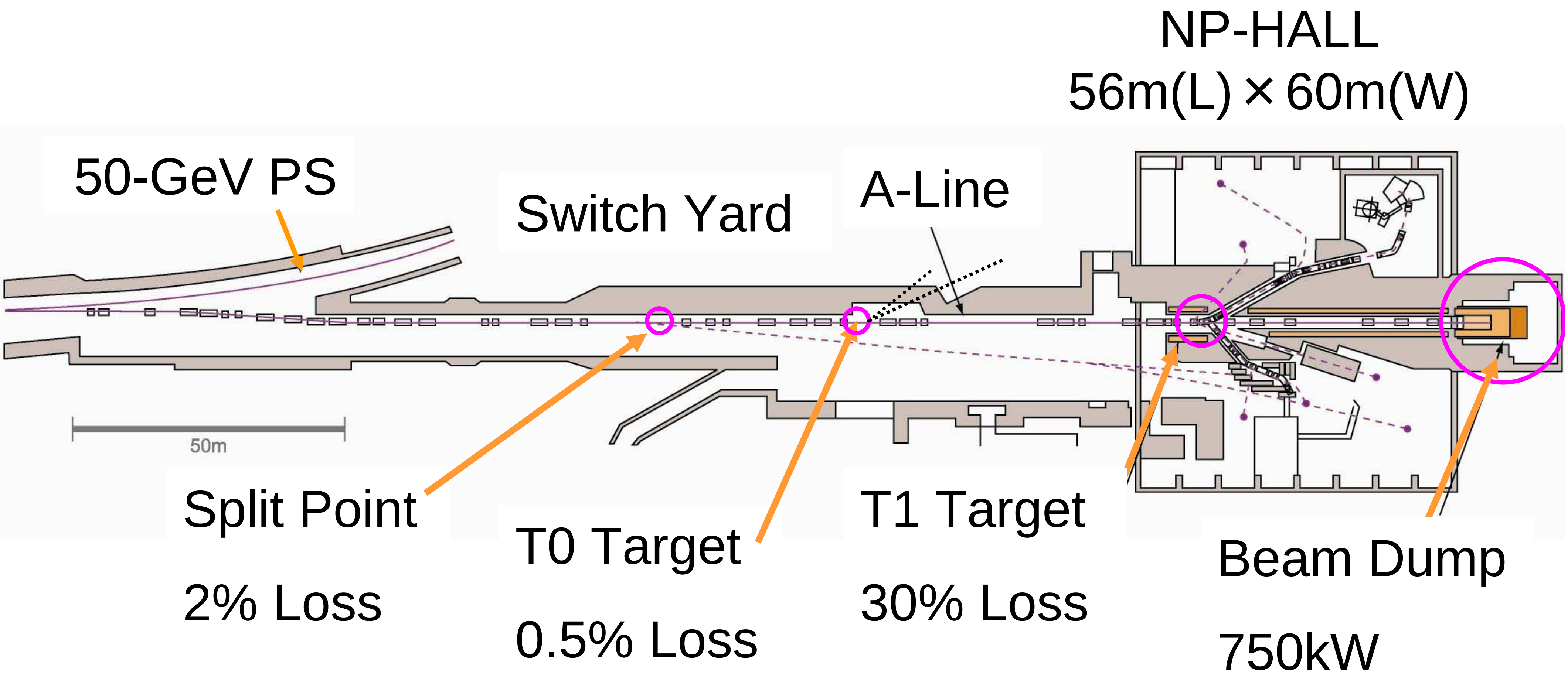
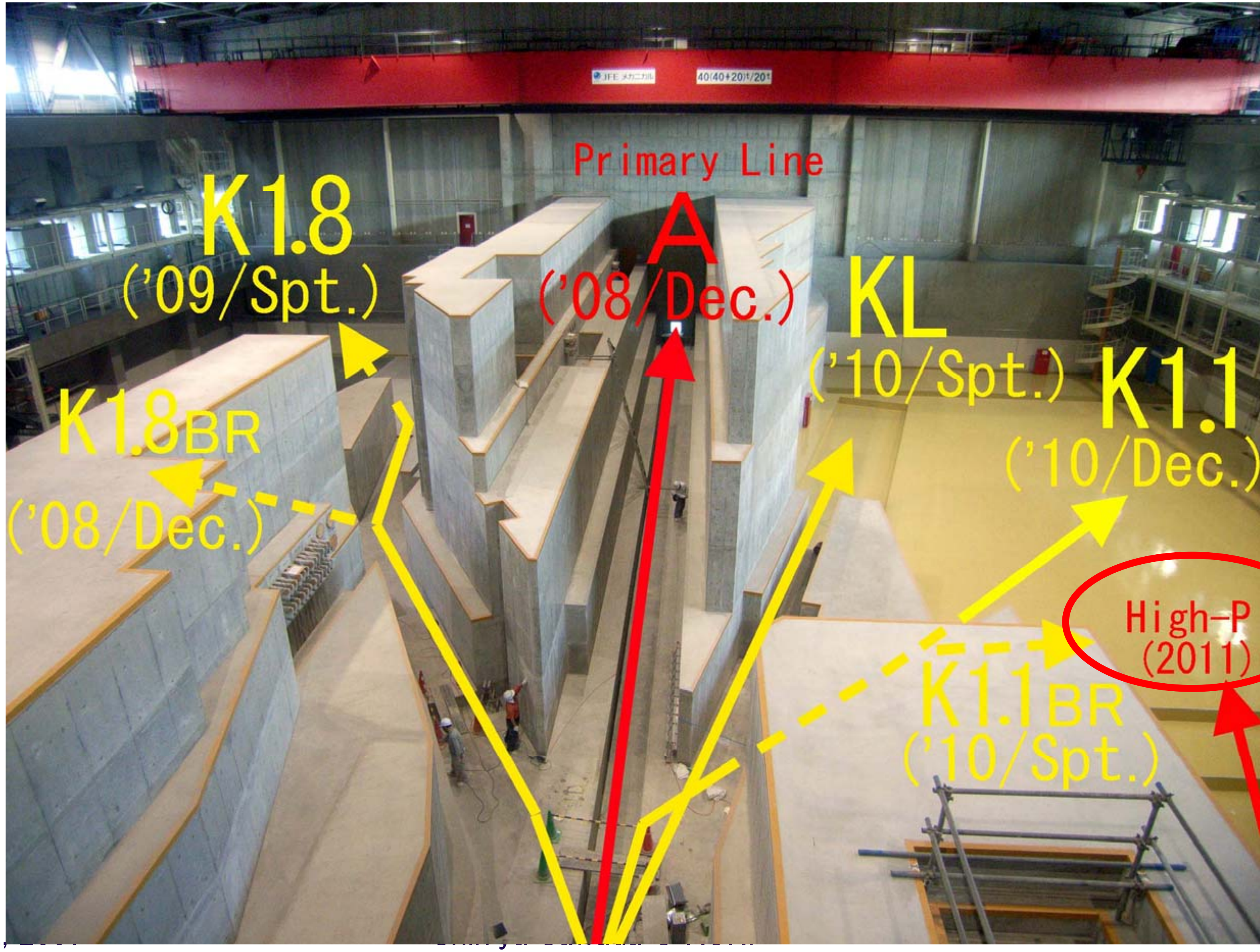
- Introduction
- Examples of Experiments
  - High Mass Dimuon (unpol)
  - High Mass Dimuon (pol): Goto-san
  - Phi: Yokkaichisan
  - ...
- Beamline Overview and R&D

Slow Extraction Beamline (Phase 1)



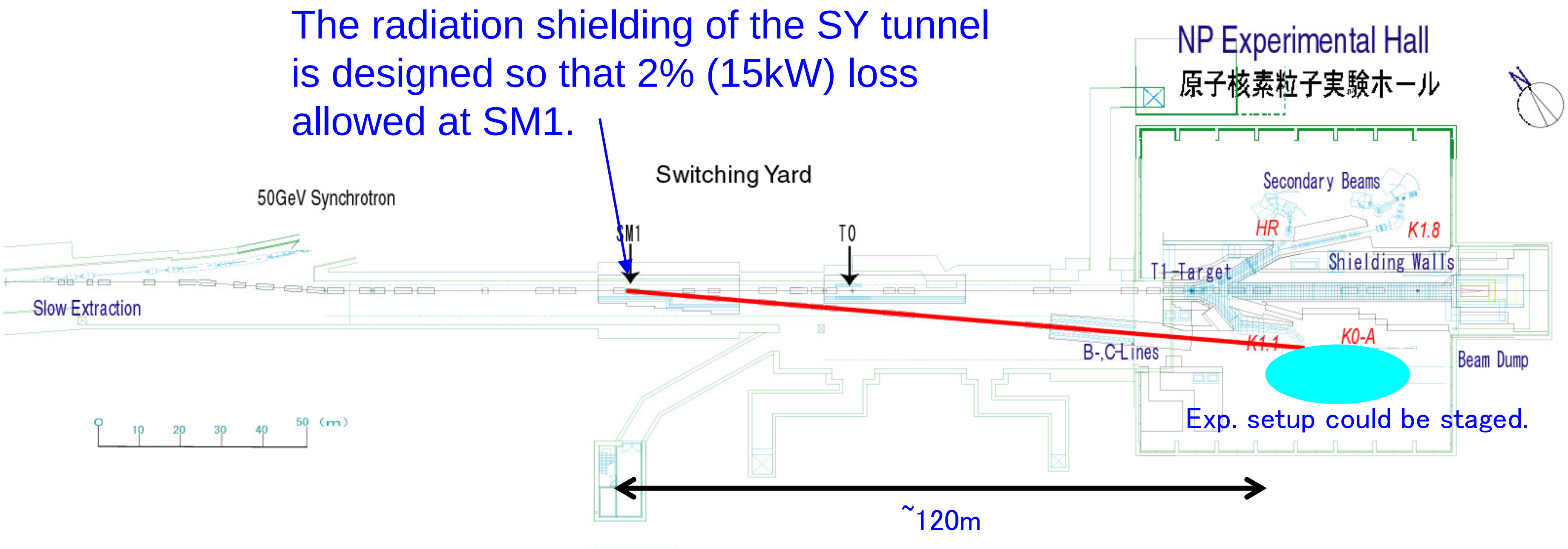
Plan to extend the hall downstream (~50m)
in the Phase 2.

Beamlines at the Hadron Hall

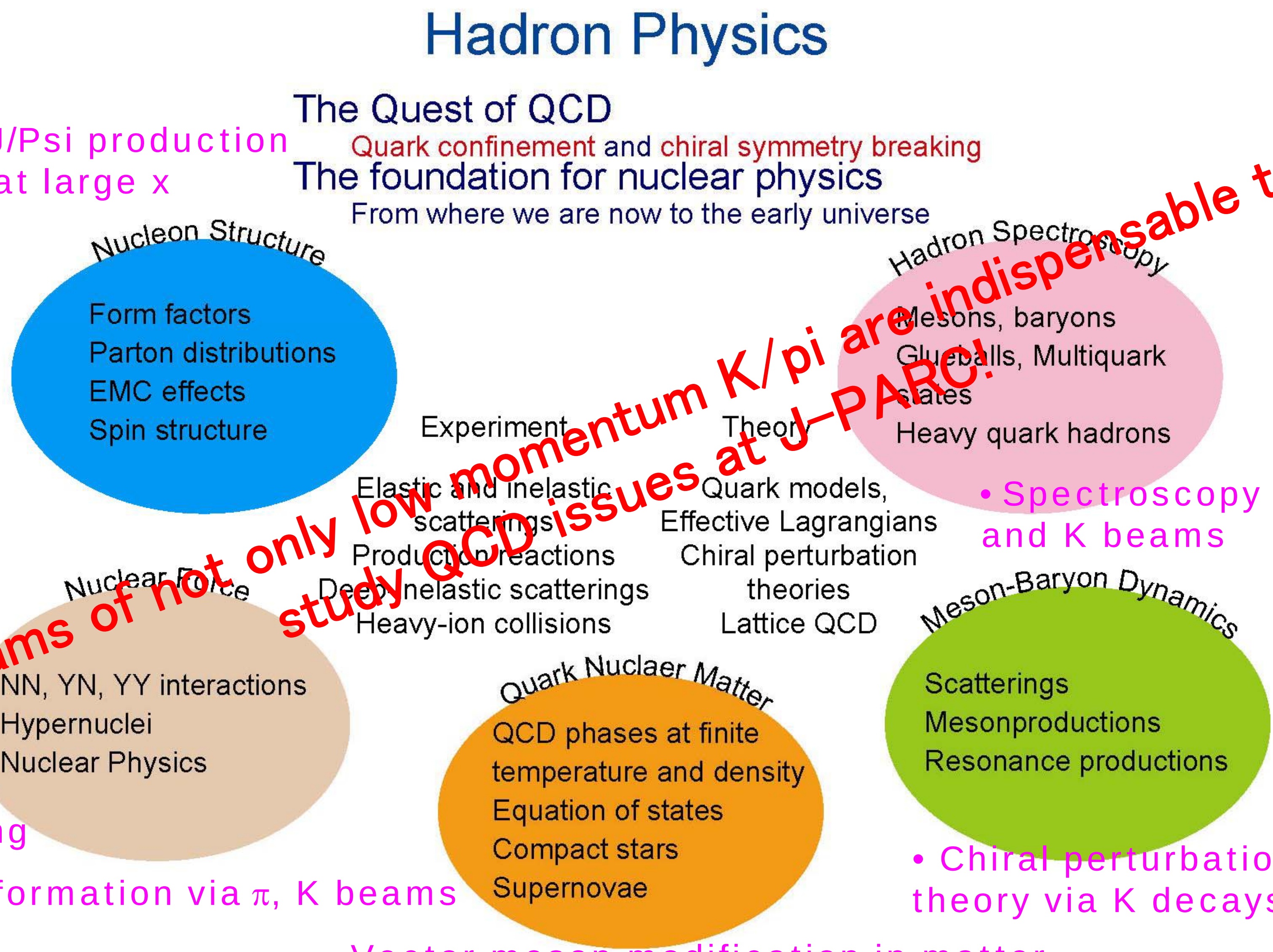


What is the High Momentum Beamline?

– Primary beams: proton (Phase 1), polarized proton and heavy ions (future) up to 51 GeV/c.
– Secondary beams: proton, pion, kaon, etc.



- Drell-Yan, J/Psi production → structure at large x



Beams of not only low momentum K/pi are indispensable to study QCD issues at J-PARC!

- Spectroscopy with π and K beams
- π, K scattering
- Hypernuclei formation via π, K beams
- Chiral perturbation theory via K decays
- Vector meson modification in matter

Physics Possibilities of the High Momentum Beamline

- Hadron Physics ~ Physics of QCD
- Two Major Quests of QCD
  - quark confinement and chiral symmetry breaking
- Subjects of Hadron Physics: attacking these quests from various aspects of view, at J-PARC.
  - Hadron spectroscopy: spectroscopy with pi/K
  - Meson-baryon dynamics: chiral perturbation via K decays,…
  - Quark nuclear matter
  - Nuclear force: pi/K scattering, hypernuclear formation via pi/K
  - Nucleon structure
- Experiments to explore major hadron physics quests are possible at the high momentum beamline!
  - vector meson modification in matter → chiral symmetry restoration
  - Drell-Yan and J/Psi production → nucleon structure at large x

Examples of Experiments

- High Mass Dimuon Measurement
  - ~10^{12}/s protons
  - talk by Goto-san for the pol. part
- Vector Meson Modification in Nuclei
  - ~10^{9}-10^{10}/s protons
  - talk by Yokkaichi-san
- Other Possibilities
  - GPD with pp → p pi Delta ?
    - talk by Sudoh-san at the Autumn JPS meeting
    - "J-PARCにおける一般化パートン分布研究（の可能性）とクォーク軌道角運動量"
  - Vector meson inside nucleus
    - talk by Ozawa-san
  - High momentum kaon/pion??

P04: Measurement of High-Mass Dimuon Production at the 50-GeV Proton Synchrotron

needs 30 and 50 GeV, 10^{12} protons per sec.

Physics with High-Mass Dimuons at J-PARC

Drell-Yan (at 50 GeV):

- $\bar{d}/\bar{u}$ flavor asymmetry at large x
- Antiquark distributions in nuclei
- Quark energy loss in nuclei

J/Ψ Production (at 30 or 50 GeV):

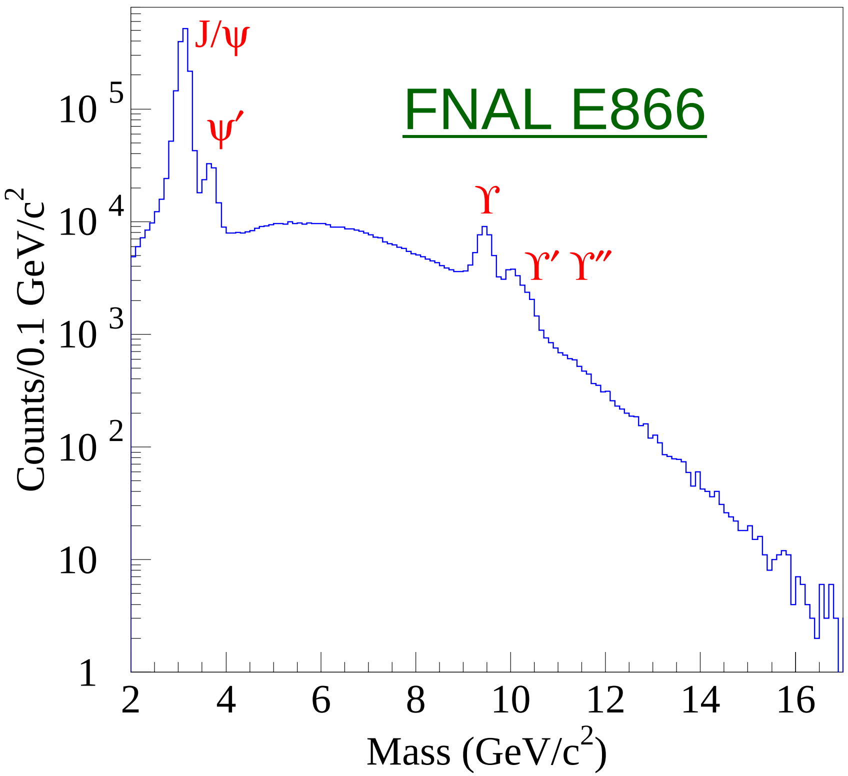
- J/Ψ nuclear dependence
- $\bar{d}/\bar{u}$ via J/Ψ production

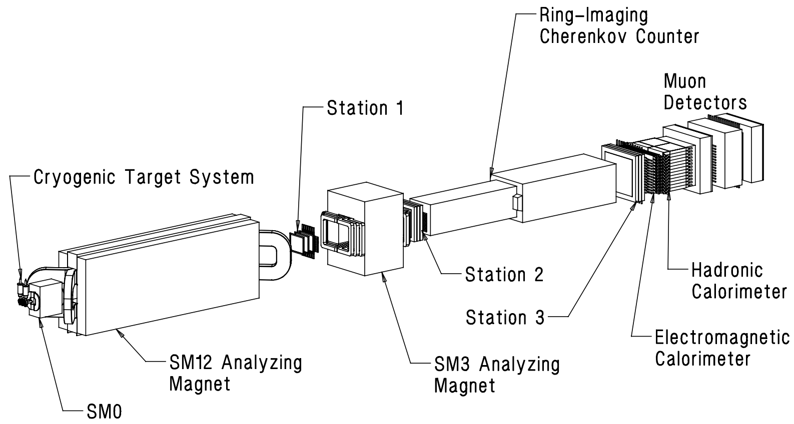
Spin physics with dimuons (mostly with polarized beam/target):

- Drell-Yan with polarized beam/target
  (Sea-quark polarizations, transversity, Sivers function)
- J/Ψ with polarized beam/target
  (Quark polarization, transversity, Sivers function)
- Unpolarized Drell-Yan decay angular distributions
  (Boer-Mulder's distribution function)

Dimuon Spectrometer for FNAL E605/772/789/866

$p + p(d) \rightarrow \mu^+ \mu^- x$ at 800 GeV/c





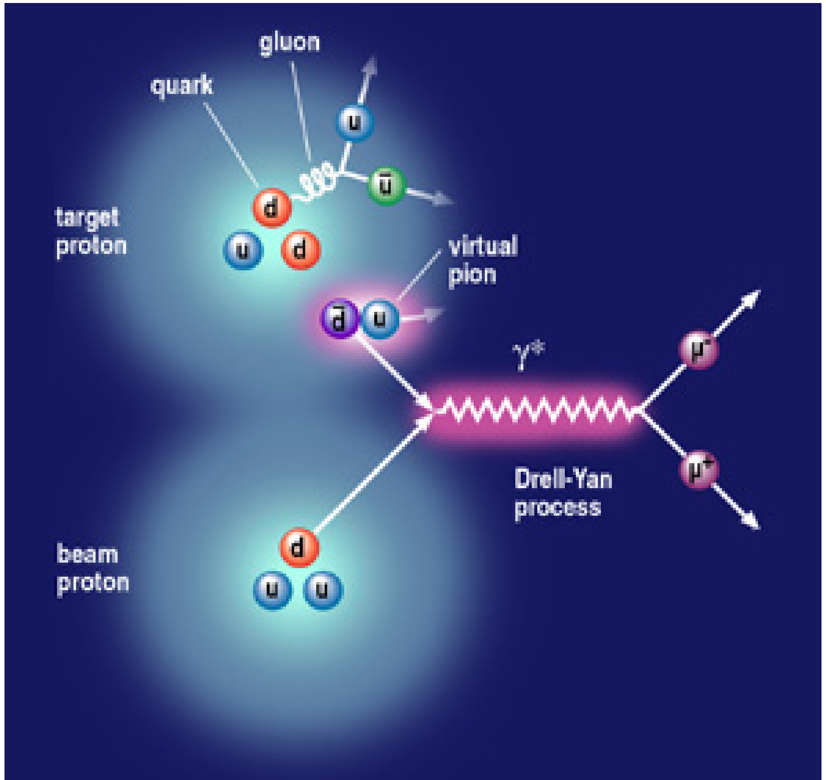
Two components in the $\mu + \mu -$ spectrum:

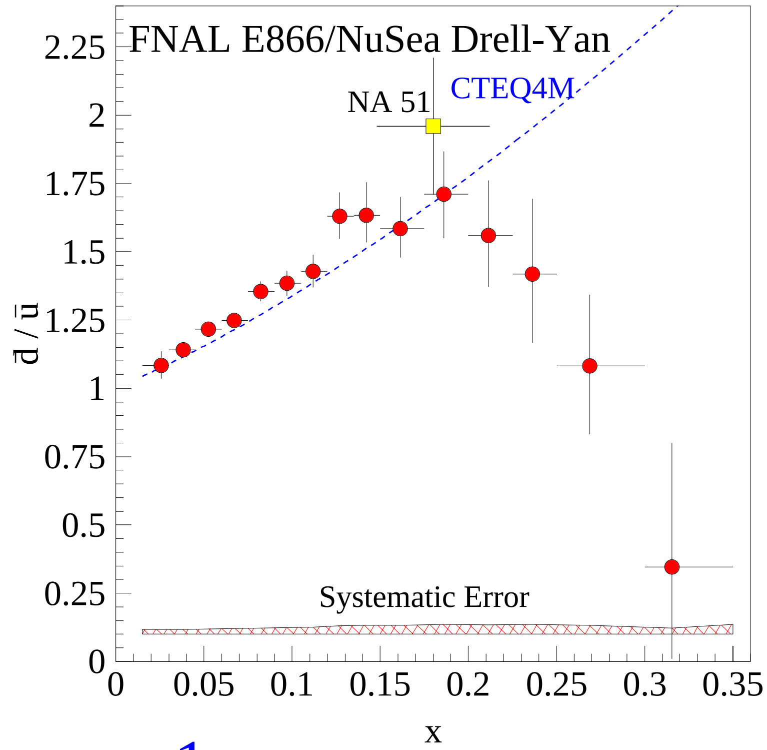
(a) Continuum: Drell-Yan process

(b) Vector mesons: J/ψ , Y

$\bar{d}/\bar{u}$ flavor asymmetry from Drell-Yan

$$\left(\frac{d^2\sigma}{dx_1 dx_2}\right)_{D.Y.} = \frac{4\pi\alpha^2}{9sx_1x_2}\sum_a e_a^2\left[q_a(x_1)\bar{q}_a(x_2)+\bar{q}_a(x_1)q_a(x_2)\right]$$





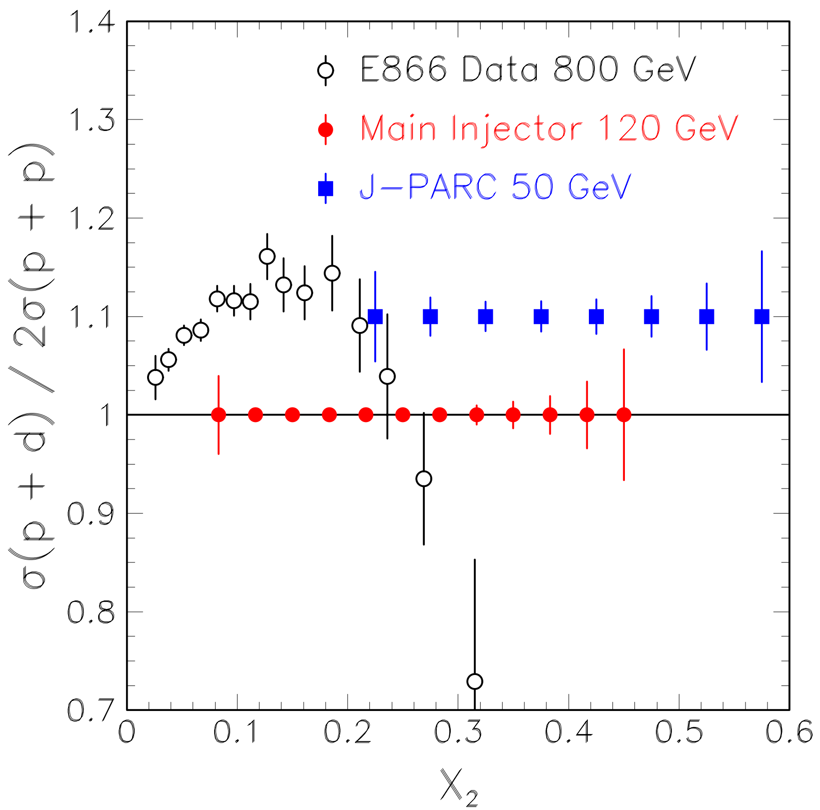
at $x_1 > x_2$: Drell-Yan: $\sigma^{pd}/2\sigma^{pp} \approx \frac{1}{2}(1+\bar{d}(x_2)/\bar{u}(x_2))$

pertubative $g \to u\bar{u},\ g \to d\bar{d}$ should give symmetric $\bar{u},\bar{d}$

$\bar{d}/\bar{u}$ and $\bar{u}$ at large x using 50-GeV proton beam

$$\frac{d\sigma_{DY}}{dx_1 dx_2} \propto \frac{1}{s} \text{ at fixed } x_1,\ x_2$$

DY cross section is ~ 16 times larger at 50 GeV than at 800 GeV



10^{12} protons per spill (3 s)

50-cm long LH_2 / LD_2 targets

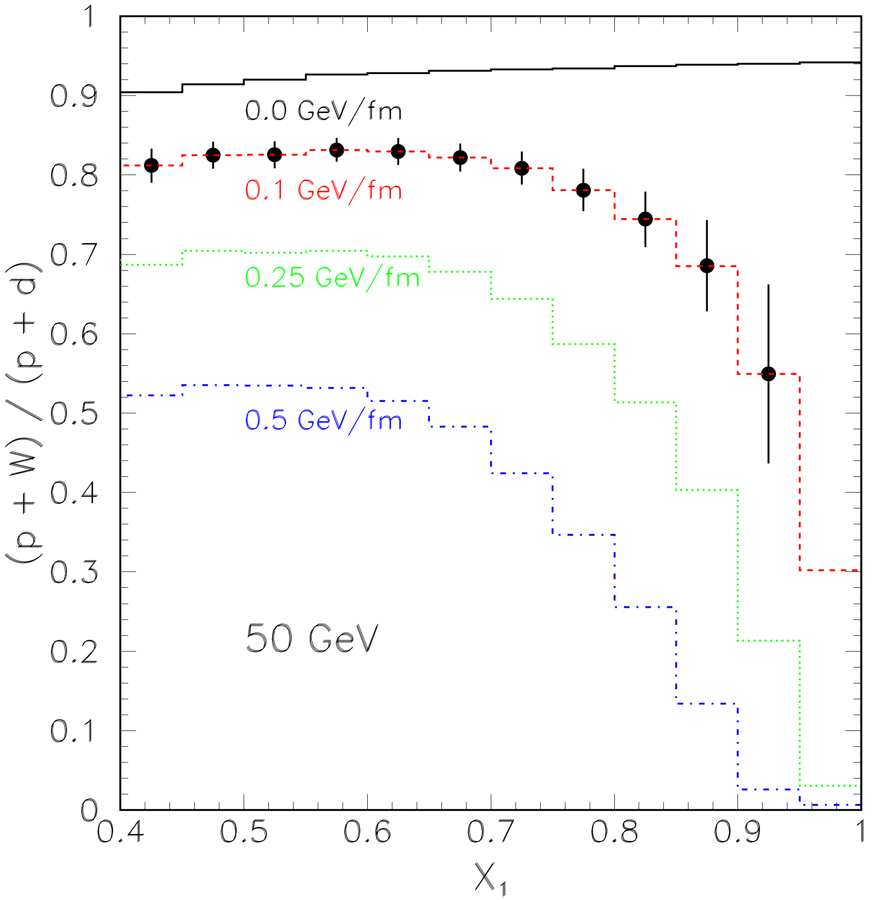
60-day runs for each targets

assuming 50% efficiency

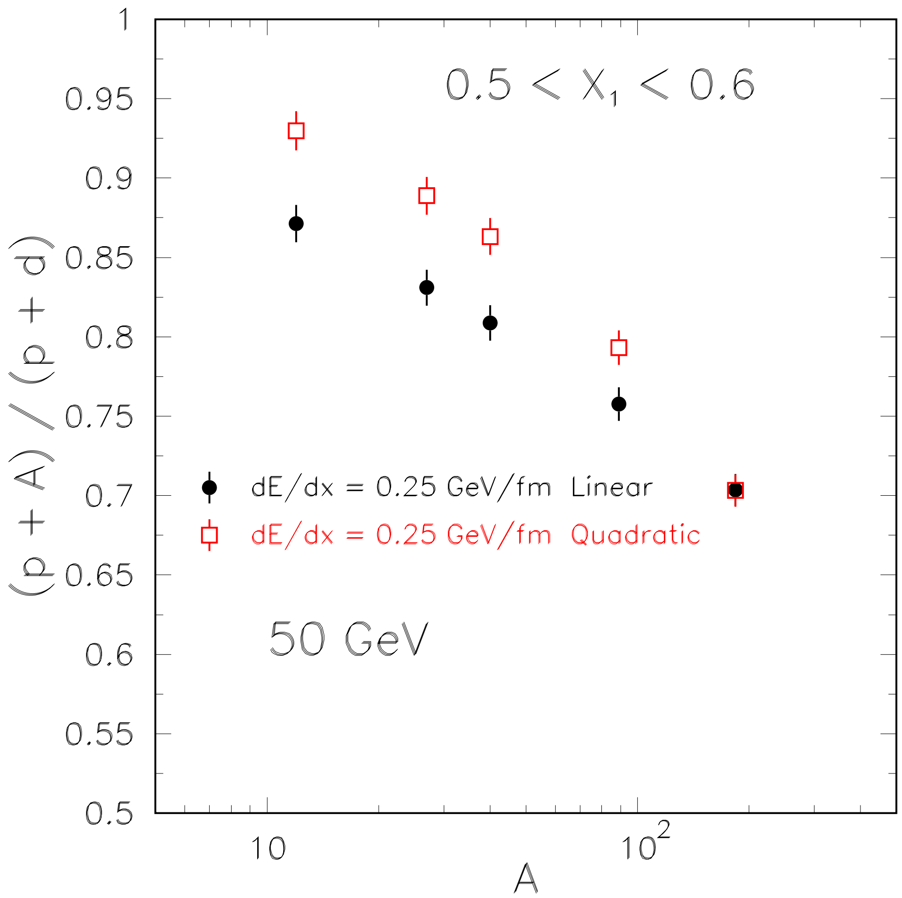
$p+p$ D-Y at 50 GeV also directly measure $\bar{u}$ at large x

Quark Energy Loss with D-Y at 50 GeV

Fractional energy loss is larger at 50 GeV



Possible to test the predicted L^2-dependence from the A-dependence measurement



Garvey and Peng, PRL 90 (2003) 092302

Issues raised by PAC

- Relation with Fermilab E906?
- 50GeV proton beam is not available.
  - Shoji Nagamiya says that a 50-GeV proton may be available with slow ramping even without a flying-wheel generator, according to Prof. Yamazaki, the leader of the J-PARC accelerator group.

- What is a stage-1 approval?

Status of Fermilab E906

- Approved by Fermilab PAC in 2001
- Reviewed by Fermilab PAC again in October 2006, and the PAC again endorsed E906
- A technical review of E906 was held at Argonne National Lab in December 2006
- In June 2007, US DOE/Office of Nuclear Physics decided to fund E906
  - Construction of the coils for a new magnet
  - Construction/refurbishing the hodoscopes and tracking chambers
  - Construction and installation will be completed by Fall of 2009
- E906 is scheduled to run for two years in 2009-2011
- Equipments would become available in late 2011

Theoretical Consideration by Yokoya-san

- "QCD correction to the Drell-Yan process at J-PARC energy"
  - H. Yokoya (Niigata)
  - 第１回「J-PARCにおける高エネルギーハドロン物理」セミナー
  - ８月29日＠KEK
- 50GeVのような「低エネルギー」においてDrell-Yan過程をQCDできちんと表せるのか？
  - pQCDからの「ずれ」をきちんと予測・コントロールできるか？
- Summary by Yokoya-san: Drell-Yan process at the J-PARC energy,
  - QCD correction is very important, and higher-order corrections beyond NLO may be required.
  - Resummation studies tell us, however, pQCD correction can be controlled by summing the large log terms.
  - Power-corrections must become relevant, and needs more studies.
  - Unpolarized PDFs (sea-quark, gluon) is still unknown, and have to be measured at the J-PARC experiments.

E16: Electron pair spectrometer to explore the chiral symmetry in QCD

stage-1 approved

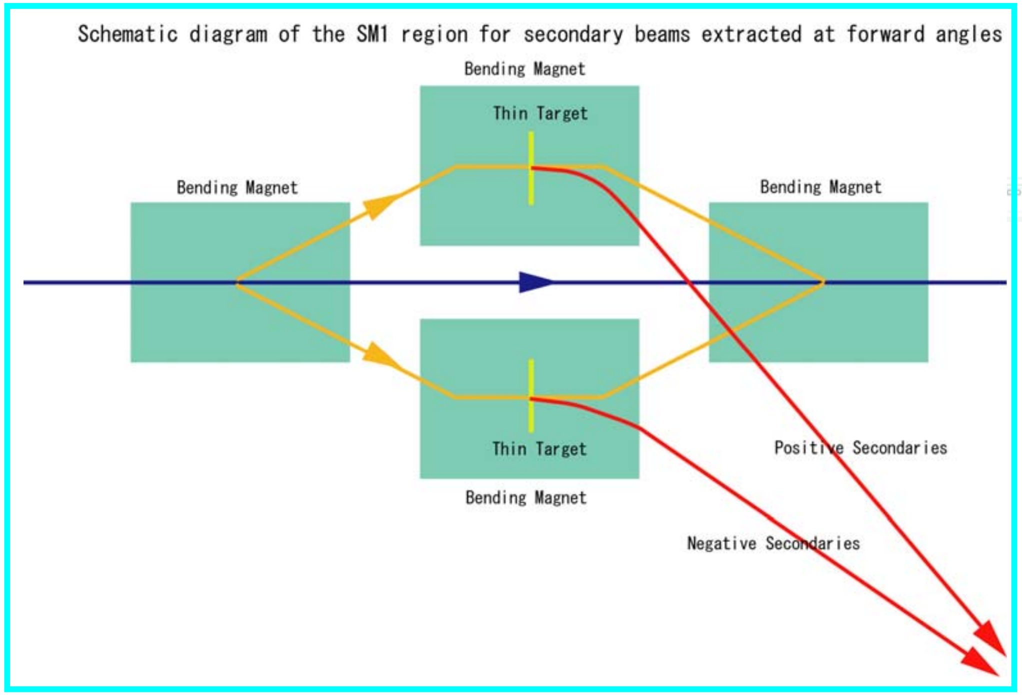
need 30 GeV, 10^9 – 10^{10} protons per sec.

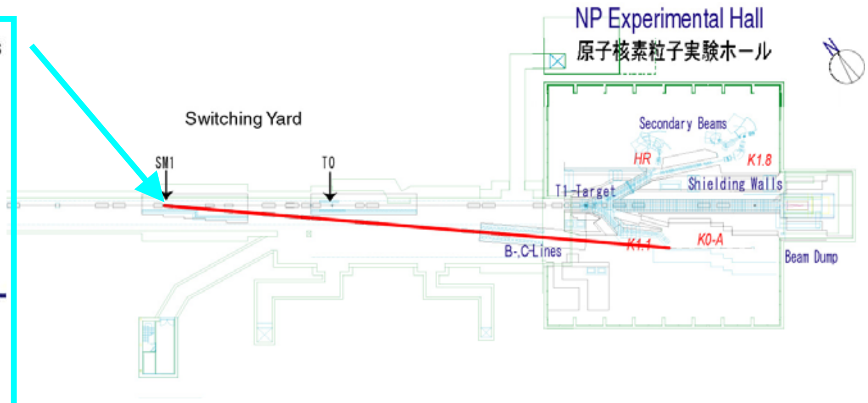
See Yokkaichi's talk.

- Introduction
- Examples of Experiments
  - High Mass Dimuon (unpol)
- Beamline Overview and R&D

Beam Line Configuration & Optics I

- Secondary Beams:
  - Use a thin (2% = 15kW loss) target at SM1
  - Collect them at forward angles
  - Transfer them for ~120m
- Schematic Layout around SM1:

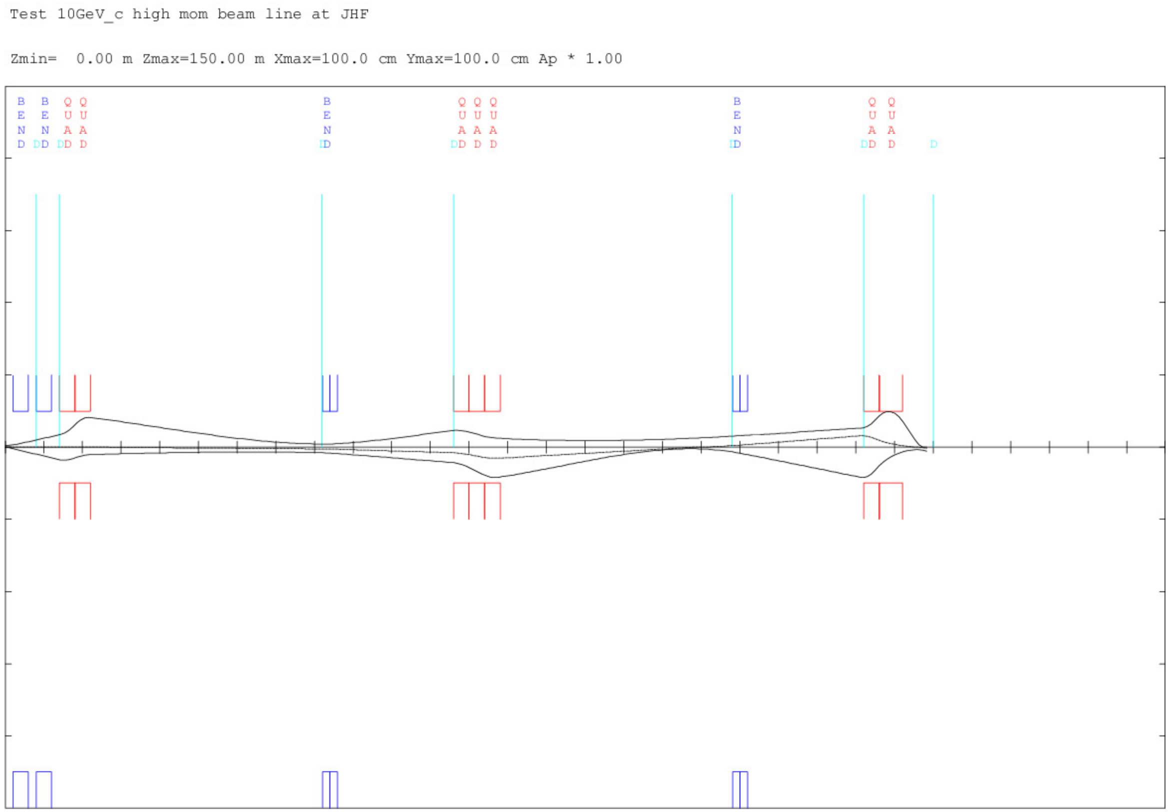




Shielding of the switching yard has been designed to accommodate the loss at SM1

Beam Line Configuration & Optics II

- Beam Optics: a preliminary design has been studied.
  - Example: 10 GeV/c particles
    - Bore radius of the quadrupole magnets is 10 cm or less.
  - 0.2 msr% can be achieved.



Yield Estimation (30GeV)

- 30GeV protons + 2% loss copper target. Production angle of 4 degree and $(\Delta p/p)\Delta\Omega$ = 0.2msr%.

	Momentum (GeV/c)	$d\sigma/dpd\Omega$ (mb/sr/GeV/c)	Yield at SM1 (per 10^{14} protons)	Yield at 120m (per 10^{14} protons)
π^+	5	1400	3.7E7	2.4E7
π^+	10	210	1.1E7	8.9E6
π^-	5	1000	2.6E7	1.7E7
π^-	10	130	6.7E6	5.4E6
K^+	5	130	3.3E6	1.3E5
K^+	10	28	1.4E6	2.8E5
K^-	5	61	1.6E6	6.4E4
K^-	10	7.0	3.6E5	7.2E4
pbar	5	11	2.8E5	2.8E5
pbar	10	1.1	5.7E4	5.7E4

- Even with 30 GeV protons, enough intensity can be obtained especially for pions!

Yield Estimation (50GeV)

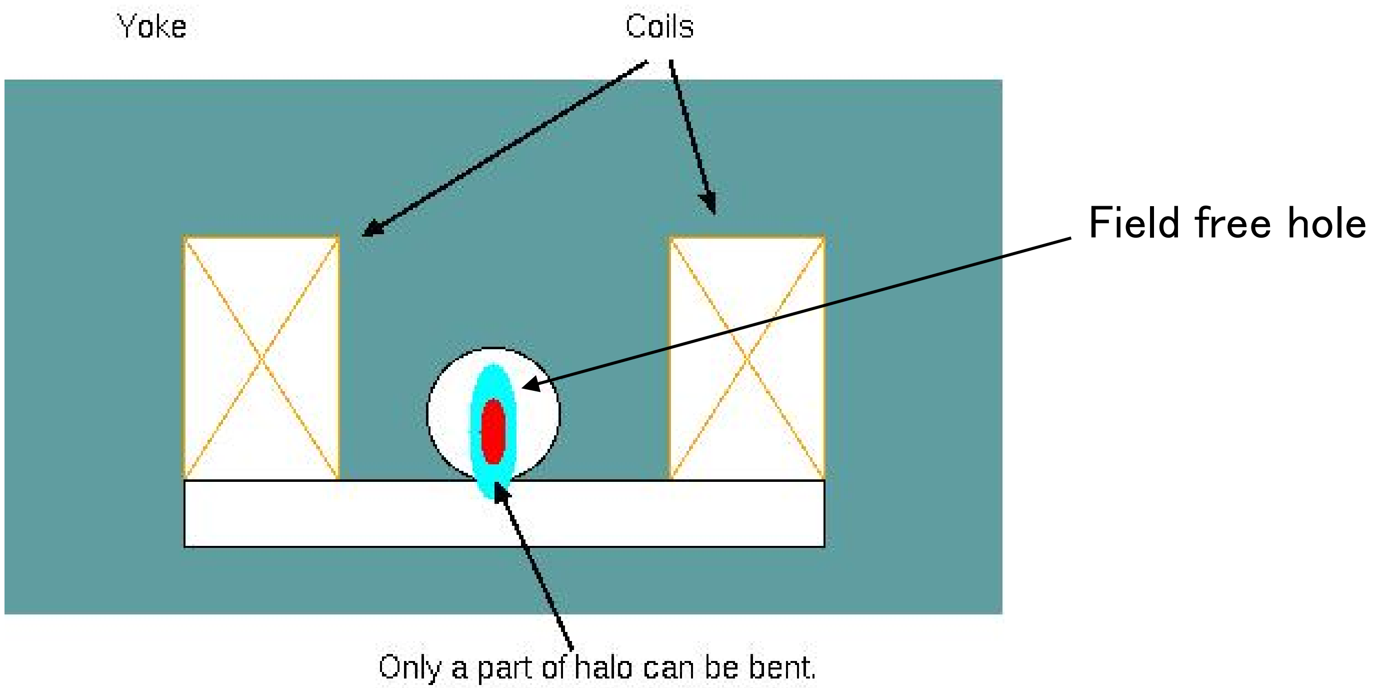
- 50GeV protons + 2% loss copper target. Production angle of 4 degree and $(\Delta p/p)\Delta\Omega$ = 0.2msr%.

	Momentum (GeV/c)	$d\sigma/dpd\Omega$ (mb/sr/GeV/c)	Yield at SM1 (per 10^{14} protons)	Yield at 120m (per 10^{14} protons)
π^+	5	3700	9.5E7	6.2E7
π^+	10	930	4.7E7	3.8E7
π^-	5	3700	9.5E7	6.2E7
π^-	10	700	3.6E7	2.9E7
K^+	5	440	1.1E7	4.4E5
K^+	10	120	6.2E6	1.2E6
K^-	5	220	5.7E6	2.3E5
K^-	10	56	2.9E6	5.8E5
pbar	5	53	1.4E6	1.4E6
pbar	10	16	8.4E5	8.4E5

- To get more intensity for higher momentum beams, extraction at more forward angles can be considered.

Beam Line Configuration & Optics III

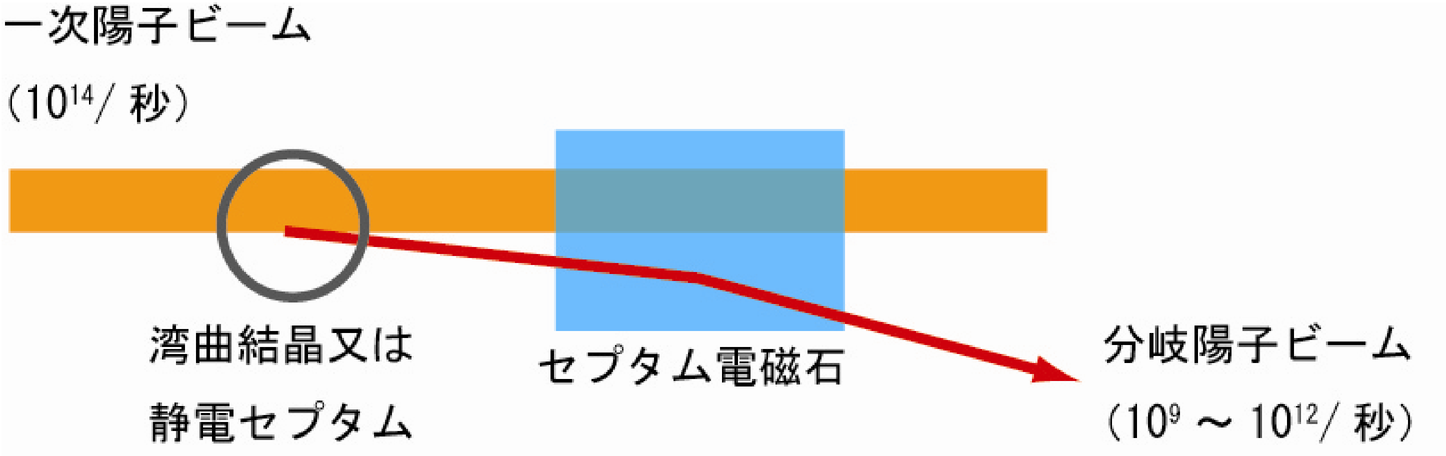
- Primary Beams:
  - Beam line configuration is almost the same as the case for the secondary beams except for equipments at SM1.
  - In order to cut a fraction (10 to 100 ppm) of the primary beam, a beam stealer can be used.
    - 10^{14} primary protons ➔ 10^{9}-10^{10} protons



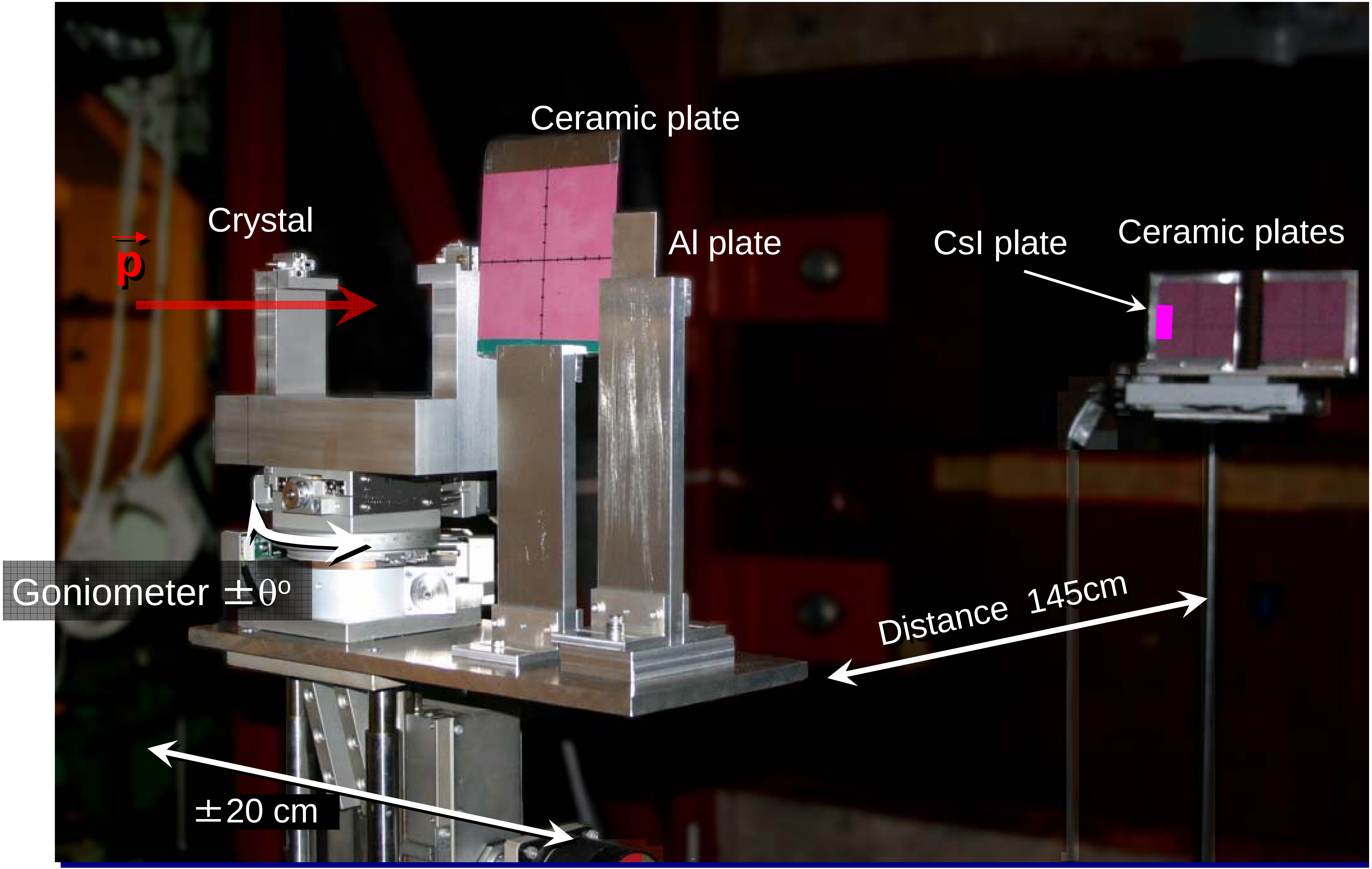
Beam Line Configuration & Optics IV

– In order to get a few % of the primary beam, an electrostatic septum will be used.
  - 10^{14} primary protons ➔ ~10^{12} protons
  - High heat and radiation deposit have to be taken into account.
  - More R&D works should be necessary to estimate the beam loss and to finalize the design.

– In order to get a fraction of the primary beam, a system with a bent crystal would be a good candidate.



R&D for a bent crystal system



Cost & Schedule: Magnets from the World

- Total cost if constructed from scratch: $5-8M??
- We have no budget so far to construct a high momentum beam line. But we are doing every effort to construct it with as small cost as possible, e.g. reuse of second-hand magnets…
- Already from SLAC, Saclay, CERN, …
- Large dipole magnets from ANL (previously used for the polarized beam line at FNAL) are under process!
- The high momentum beam line can be constructed by using some of these second-hand magnets.

- The high momentum beam line can be constructed even at the beginning of the hadron hall operation from the viewpoint of the facility design.

Large dipole magnets at the Meson Pol beam line (FNAL)

Summary

- High momentum beam line.
  - Branch line from SM1.
  - p < 51 GeV/c, ~120 m, primary and secondary beams.
- Rich physics possibility and many requirements.
  - Needs for test experiments with high momentum beams can also be fulfilled.
- Come and join for the physics at the high momentum beamline!
  - “Coherent” efforts toward realization should be important!