K1.8 and K1.8BR beam lines

K1.8 configuration - outline -
K1.8BR option
FIFC06
Homework
Beam Line Element - status -

+ S. Sawada + T. Miura + M. Numajiri
+ T. Takahashi + N. Saito + M. Iio (RIKEN)
+ M. Naruki + R. Muto + A. Kiyomichi
K1.8 configuration
- outline -

- Design
  Design goal/Layout and Concept

- Optics
  Beam envelope/Beam analyzer/Profile@FF
K1.8 design

Design Goal

✓ Optimized for $\Xi$ hypernuclear spectroscopy
✓ Max. Central Momentum of K1.8: $\sim 2 \text{ GeV/c}$
  since the $\Xi$ production is a max. at 1.8 GeV/c
✓ Intense K- at 1.8 GeV/c: $\sim 10^7$ ppp for 50 GeV-15 $\mu$A
  30 GeV-9 $\mu$A is a target specification in Phase I
✓ Pure K- at 1.8 GeV/c: $K/\pi >> 1$ at FF
  Better $K/\pi$ even at MS2 for beam line counters
✓ Required a High Res. Beam Analyzer
  for Precision Spectroscopy of $\Xi$ hypernuclei
K1.8 design

Layout and Concept

✓ Front End Section
  2ndary Beam Extraction at 6 deg.
  Thermal protections/ Rad-Hard Equipments
    Cu collimator before D1
    Magnet Operation in a Vacuum Chamber

✓ 1\textsuperscript{st} and 2\textsuperscript{nd} Separation Sections
  Double Stage Separation:
    3 vertical Slits for Kaon purification
    Higher order corrections to the 3\textsuperscript{rd} order
      4 6-poles & 3 8-poles for vertical focus at MS1 & MS2

✓ Beam Analyzing Section
  Point-to-point Optics btwn entrance & exit of a QQDQQQ
    eliminate the multiple scattering effect to the 1\textsuperscript{st} order
  Focus on FF: R12~R34~R16~0
Configuration layout of K1.8 (Max. 2 GeV/c)

- 4 Sextupoles
- 3 Octupoles
- IF-slit
- T1 Target
- SPES-II
- FF
- SKS+
- Double Separators
- Front End
- MS1
- MS2
- ES1
- ES2
- Beam Analyzer
K1.8 Beam Line Optics

Beam envelope to the 1st Order

IF

ES1

ES2

QQDQQ

3 Vertical Slits: IF and 2 Mass Slits (MS1, MS2)
to purify kaon beam with 2 Electrostatic Separators

Total Length: 45.853 m
Beam Analyzer

For $\Xi$ hypernuclear Spectroscopy by $(K^-,K^+)$ [E05]
$\Delta E \sim 3$ MeV (FWHM) together w/ SKS+

$\text{VO} \rightarrow \text{VI}$ (Point to Point Optics)
1$\text{st}$ Order Resolution:
$R_{11} = -0.44, \ R_{12}=0, \ R_{16}=1.57$ cm/%
$dp/p \sim 1.4 \times 10^{-4}$ (in Sigma)
assuming $\sigma_x \sim 200 \mu$m
(c.f. in case of K6: $1.3 \times 10^{-4}$)
→ h.o. correction:
orbit analysis w/ Tracking Dev.

Dipole:
A12 from Saclay
Q’s from KEK-K6
Kaon Beam Profile at FF of K1.8

- **x (cm)**
  - Mean = 0.134
  - RMS = 1.984
  - Sum = 1239

- **y (cm)**
  - Mean = 0.021
  - RMS = 0.321
  - Sum = 1240

- **x' (mrad)**
  - Mean = -1.132
  - RMS = 16.646
  - Sum = 1385

- **y' (mrad)**
  - Mean = -0.595
  - RMS = 2.197
  - Sum = 1409
Contour Plot No 47 (lin) at z= 34.185 m (FGY7)

- $X_{\text{mean}} = -0.047$
- $X_{\text{rms}} = 3.310$
- $Y_{\text{mean}} = 0.403$
- $Y_{\text{rms}} = 2.339$
- $\text{Corr} = 0.022$
- $\text{Area}/\pi = 7.743$
- $\text{Sum} = 830$

Contour Plot No 70 (lin) at z= 45.853 m (FGY8)

- $X_{\text{mean}} = -6.456$
- $X_{\text{rms}} = 5.888$
- $Y_{\text{mean}} = 0.755$
- $Y_{\text{rms}} = 2.128$
- $\text{Corr} = -0.314$
- $\text{Area}/\pi = 11.894$
- $\text{Sum} = 70$

Histogram No 46 (lin) at z= 34.185 m (FGY7)

- Mean = -0.029
- RMS = 0.385
- Sum = 102

Histogram No 53 (lin) at z= 45.853 m (FGX8)

- Mean = -6.267
- RMS = 3.629
- Sum = 7

---

muons at MS2out

\[ \frac{K}{\pi + \mu} \approx 0.7 \]

muons at FF

\[ \frac{K}{\pi + \mu} \approx 3.5 \]

---

pions at MS2out

\[ \frac{K}{\pi} \approx 1.1 \]

pions at FF

\[ \frac{K}{\pi} \approx 6 \]
## K1.8 Performance Summary

<table>
<thead>
<tr>
<th></th>
<th>K1.8 (50 GeV-15μA)</th>
<th>K1.8 (30 GeV-9μA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Mom. (GeV/c)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Length (m)</td>
<td>45.853</td>
<td></td>
</tr>
<tr>
<td>Acceptance (msr.%)</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>K⁻/π⁻ Intensity (ppp)#</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.8 GeV/c</td>
<td>6.6E+06</td>
<td>1.4E+06</td>
</tr>
<tr>
<td>1.5 GeV/c</td>
<td>2.7E+06</td>
<td>0.54E+06</td>
</tr>
<tr>
<td>1.1 GeV/c</td>
<td>0.38E+06</td>
<td>0.08E+06</td>
</tr>
<tr>
<td>Electro-static</td>
<td>750kV/10cm</td>
<td></td>
</tr>
<tr>
<td>Separator</td>
<td>6m x 2</td>
<td></td>
</tr>
<tr>
<td>Single Rate @ MS2 @ 1.8 GeV/c $</td>
<td>&gt;33E+06</td>
<td>&gt;8E+06</td>
</tr>
<tr>
<td>K⁻/π⁻ @ FF @ 1.8 GeV/c</td>
<td>8</td>
<td>6.9</td>
</tr>
<tr>
<td>X/Y(rms) size @ FF (mm)</td>
<td>19.8/3.2</td>
<td></td>
</tr>
</tbody>
</table>

# using Sanford-Wang formula, assuming 1pulse=3.53s (0.7s flat top)

$ Single Rate Estimation for Trigger/Tracking Devices to be placed just after MS2
K1.8BR option

- Concept
- Optics
  Beam envelope/Profile@FF
- K1.8BR performance summary
K1.8BR Beam Line

- Branch at D3 of K1.8
  Beam bent opposite side at D3, +SQDQ to focus at FF
  Time sharing with K1.8
  helpful for efficient experimental execution/coordination
- Single ES Stage, Shorter BL (27.6m)
  Intensity of K- at 1.1 GeV/c:~15 times > K1.8
  Intense Low Momentum Kaon (<1.2 GeV/c)
K1.8BR Beam Line Optics (Beam envelope to the 2\textsuperscript{nd} Order)

Total Length: 27.573 m
Beam Profile at FF of K1.8BR (S3 on)

- **Counts**
  - **Mean** = 0.024
  - **RMS** = 0.292
  - **Sum** = 2405

- **Counts**
  - **Mean** = -0.009
  - **RMS** = 0.588
  - **Sum** = 2405

- **Counts**
  - **Mean** = 0.514
  - **RMS** = 2.565
  - **Sum** = 2399

- **Counts**
  - **Mean** = -0.687
  - **RMS** = 22.717
  - **Sum** = 2051

- **Counts**
  - **Mean** = 0.024
  - **RMS** = 0.292
  - **Sum** = 2405

- **Counts**
  - **Mean** = -0.009
  - **RMS** = 0.588
  - **Sum** = 2405

- **Counts**
  - **Mean** = 0.514
  - **RMS** = 2.565
  - **Sum** = 2399

- **Counts**
  - **Mean** = -0.687
  - **RMS** = 22.717
  - **Sum** = 2051
<table>
<thead>
<tr>
<th></th>
<th>K1.8BR (50 GeV-15μA)</th>
<th>(30 GeV-9μA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (m)</td>
<td>27.573</td>
<td></td>
</tr>
<tr>
<td>Acceptance (msr.% )</td>
<td>2.5¥</td>
<td></td>
</tr>
<tr>
<td>K⁻ Intensity (ppp)#</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1 GeV/c</td>
<td>5.5E+06</td>
<td>1.2E+06</td>
</tr>
<tr>
<td>0.8 GeV/c</td>
<td>1.0E+06</td>
<td>0.2E+06</td>
</tr>
<tr>
<td>0.6 GeV/c</td>
<td>0.1E+06</td>
<td>0.02E+06</td>
</tr>
<tr>
<td>Electro-static Separator</td>
<td>500kV/10cm</td>
<td>6m</td>
</tr>
<tr>
<td>Single Rate@D3out @1.1 GeV/c $</td>
<td>&gt;30E+06</td>
<td>&gt;7E+06</td>
</tr>
<tr>
<td>K⁻/π⁻ @ FF@1.1 GeV/c &amp;</td>
<td>7.5</td>
<td>6.8</td>
</tr>
<tr>
<td>X/Y(FWHM) size @ FF (mm)</td>
<td>5.9/2.9</td>
<td></td>
</tr>
</tbody>
</table>

¥ IF/MS1 Heavy Alloy: IF opening 4 mm, MS1 opening 4.66 mm
# using Sanford-Wang formula, assuming 1 pulse = 3.53s (0.7s flat top)
$ Single Rate Estimation for Trigger/Tracking Devices to be placed just after D3 & cloud π not included
FIFC in October, 2006

- FIFC report
- report to FIFC by J. Doornbos
1. Front end part
   ...does not find any essential problems
2. ES and MS
   ...no significant concern about its performance. It is remarked that the experience at KEK-PS is very useful and important in the operation for these separators.
3. BA and Final Focusing system
   ...convinced with this performance of momentum resolution from the beam optical point of view. ...essential for the chamber to work properly in high hit-rate...
4. Optics design and K-pi separation
   ...agrees with the presented performance as a whole, although it wants to reserve some uncertainty in the estimate of the K/pi ratio.
5. K1.8BR
   ...accepts the proposed performance... the K/pi which had better to be regarded with some ambiguity. ...was concerned about the muon contamination in the beam, since it could influence on the exp condition...
   ... recommends ... to evaluate it seriously soon.
6. Conclusion
   ...found no problem in the prospect that K1.8 and K1.8BR will be operational with sufficient performance for the experiments, in general. It is remarkable that the high K/pi presented ...has been supported by an independent check by an external reviewer (J.D.). However, the ambiguity of the estimate has to be taken to be large.
Individual check by using ZGOUBI and REVMOC

**K1.8**: 1.8 GeV/c, 750 kV/10cm double stage ES, $\sigma \sim 1.3$mm at T1
- $\sim 45$ m, 1.4 msr%, pion/kaon at FF$\sim 570$ if ES1=ES2=0
  
1. **Direct pions**
   - pion/kaon $\sim 0.1$ at FF, even no octupoles
2. **Cloud pions**
   - no problem, MS1 & 2 reduce by a factor 5, IF further reduce by a factor 3
3. **Muons**
   - muon/kaon $\sim 0.1$
4. **Slit scattering of pions (at IF)**
   - pion/kaon $\sim 0.2$ at most
5. **In total**, Kaon/(pi+mu) $\sim 3$ at FF

**K1.8BR**: 1.1 GeV/c, 500 kV/10cm single stage ES
- $\sim 27$ m, 2 msr%, pion/kaon at FF$\sim 1200$ if ES1=ES2=0

1. **Direct pions will be negligible**
2. **Cloud pions can be reduced by an order of magnitude by IF and MS1**
3. **Slit scattering at IF**: pion/kaon $\sim 0.3$
4. **Muons**: muon/kaon $\sim 1.75$ at FF
Homework given on 22/Dec/2006
Beam Envelope (30 GeV SEB: $\varepsilon_H=4.4\pi$ / $\varepsilon_V=10.4\pi$ mm·mr)

Matching S.  Switch Yard  HD-Hall

Beam Dump
Tracking Simulation for Slow Extraction Beam
by M. Tomizawa

メイン取り出しビーム 50GeV (エミッタンス6.1pi, dp/p 0.25%)
Q、D磁石共multipole 成分 ON ステップサイズ約20mm@ESS

プロット:ビーム分布@QFP入口

Fixed Bump

Dynamic Bump
Beam Emittance (color) and Acceptance (black)

Beam Profile @ T1(30 GeV)

Histogram No 39 (lin) at z=202.796 m (T1X)

Histogram No 41 (lin) at z=202.796 m (T1Y)
30 GeV scattered at ESS(1.39kW)  
Loss:18W@q17,18/ 229W@q1D

seb8f1tu.dat
30 GeV scattered, recirculated (1.12kW) No Loss

seb8f1tu.dat
Slow Extraction Beam:
- 30 GeV, 9μA (270 kW) in Phase 1
- Tracking Simulation for Extraction Beam by M. Tomizawa
  Extracted Beam Power normalized to be 270 kW
  Scattered by ESS
    Kicked & Extracted ........... 1.39 kW (0.5%)
      Horizontally shifted
      Vertically broadened
    Recirculated & Extracted ....... 1.29 kW (0.5%)
      Vertically broadened

Beam Loss along the Beam Line
- Kicked & Extracted ........... 18W Loss at q17,18 (<200W)
- Recirc. & Extracted ......... no loss till T1

Beam Profile at T1
- Kicked & Extracted ........... Vertically broad tail (small fraction)
- Recirc. & Extracted ......... Vertically broad tail (small fraction)
Kaon intensity and K/pi as a function of the beam spot size at T1
Beam Line Element
- status -

- Schedule
- IF Slit
- Magnet Layout
  Q3~CM1
- Mass Slit
## Construction Schedule of K1.8 and K1.8BR

<table>
<thead>
<tr>
<th>Magnet (Front End)</th>
<th>Status</th>
<th>FY2006</th>
<th>FY2007</th>
<th>FY2008</th>
<th>FY2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>*D1</td>
<td>Op. in Vac. done Fabricating</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Q1</td>
<td>Drawing for fabrication to be fabricated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Q2, Q3, Q4, Q5, Q6</td>
<td>Existing to be fabricated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q3, Q4</td>
<td>Existing to be fabricated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q5, Q6</td>
<td>Existing to be fabricated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q1</td>
<td>Existing to be reformatted</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q2</td>
<td>Existing to be reformatted</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q3</td>
<td>Existing to be reformatted</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q4, Q5</td>
<td>Existing to be reformatted</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q6</td>
<td>Existing to be reformatted</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>K1.8BR magnet</th>
<th>Status</th>
<th>FY2006</th>
<th>FY2007</th>
<th>FY2008</th>
<th>FY2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>*S3</td>
<td>to be fabricated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q7, Q8</td>
<td>Existing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Separator</th>
<th>Status</th>
<th>FY2006</th>
<th>FY2007</th>
<th>FY2008</th>
<th>FY2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>ES1</td>
<td>Fabricating to be reformatted</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ES2</td>
<td>to be reformatted</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Slit</th>
<th>Status</th>
<th>FY2006</th>
<th>FY2007</th>
<th>FY2008</th>
<th>FY2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACC1, IF</td>
<td>to be fabricated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MS1, MOM, MS2</td>
<td>to be fabricated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Target</th>
<th>Status</th>
<th>FY2006</th>
<th>FY2007</th>
<th>FY2008</th>
<th>FY2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proof Model</td>
<td>Long run test Reforming the Proof Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real Model</td>
<td>Peripheral Shield Cooling System</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shielding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Color coding: Drawing, Fabrication/Reform, Installation, Test Operation

* Dates: Beam Commissioning for K1.8BR (Dec-08) and Beam Commissioning for K1.8 (Oct-09)
K1.8 upstream configuration
IF slit (brass)

水平方向可動スリット

鉛直方向可動スリット

φ300 pillow seal
Design of the mass slit

Choice of Materials for Three Vertical Slits

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>IF</td>
<td>4</td>
<td>300</td>
<td>100</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MS1</td>
<td>4.5</td>
<td>300</td>
<td>100</td>
<td>10.9</td>
<td>200</td>
</tr>
<tr>
<td>MS2</td>
<td>4.8</td>
<td>400</td>
<td>100</td>
<td>9.2</td>
<td>100</td>
</tr>
</tbody>
</table>

Unit:mm
D6 at BNL-AGS

(1997-99)

Muon Channel (inactive)

1st Mass Slit

2nd Mass Slit

2nd Separator

Momentum Collimator

4-Jaw (θϕ) Collimator

24 GeV/c protons

E906 Experimental Area

48D48 K+ Spectrometer

CDS
Beam Line Magnet Installation

2007. 6  HD-Hall Civil Construction Complete
  →  Survey,  Beam Line Marking will start
平成19年7月～平成20年3月

主な作業:
- 一次ビームライン設置、同ライン電源設置配線
- 再利用鉄購入、はめ込みシールド購入
- ビームライン用再利用シールド撤去
- T1標的、中央真空槽設付

再利用鉄等仮置場所
(300m³)

再利用鉄・再利用電磁石等
設置場所

シールド
設置場所

再利用鉄等仮置場所
(300m³)

ビームライン
機器等
仮置場所
(150m³)

第2種管理区域
(H19.3～)

第2種管理区域
(H19.7～)

第2種管理区域
(H20.1～)
平成20年4月〜平成20年11月

主な作業
- K1.8BRライン設置、同ライン電源設置配線
- ビームダンプ本体および遮蔽体設付
- 実験機器設付（K1.8BR）、SKS+移設
- シールド購入、ビームラインシールド設置

再利用鉄等仮置場所（300㎡）

シールド等仮置場所（300㎡）

ピームライン機器等仮置場所（150㎡）

第1種管理区域（H20.5〜)

* その他のH2Dホール周辺フェンス内全域は第2種管理区域に設定（H20.5〜)
平成20年12月～平成21年10月

主な作業

- K1.8ライン下流部設置、同部電源設置配線
- 実験機器設付（SKS+、BAほか）
- K1.8ラインソイルド設置

第1種管理区域 (H20.5〜)
第1種管理区域 (H20.12〜)

＊その他のHDホール周辺フェンス内全域は第2種管理区域に設定 (H20.5〜)