Event generator comparison

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2013/12/03 original
2014/02/12 update
2014/11/04 update

Intro

- We are trying to compare particle rate between event generators and data

- All code mentioned can be obtained from
  https://hallaweb.jlab.org/wiki/index.php/Solid_eventgenerator

Wiser fit

- Wiser fit is based on photon on proton target from SLAC data
- It can output pip,pim,kp,km,p,anti-p result
- no result on neutron

- For electron on nuclei target, one can approximate electron with virtual photon flux
- This way we can represent different targets solely in rad_len and the output is linearly proportional to rad_len
- Here is one example of estimating rad_len

“RAD_LEN (%)is the radiation length of target, including internal (typically 5%)

= .5 *(target radiation length in %) +5.

= 100. IF BREMSTRULUNG PHOTON BEAM OF 1 EQUIVIVENT QUANTA”

- Also one need to estimate rate on neutron somehow

Whitlow and qfs fit

- Whitlow fit gives only DIS electron rate on proton and deuteron
- qfs fit gives general electron rate on proton and deuteron
- both have nothing to do with target rad_len

Generator "eicRate"

- e rate (including eDIS and others) based on CTEQ6 PDF on proton or neutron
  - (others including inelastic and resonance region, the estimation could be off)
- eES rate based on formula on proton or neutron
- hadron rate based on Wiser fit
  - pip,pim,Kp,Km,p and p-bar on proton from Wiser fit directly
  - pi0 rate = (pip+pim)/2 , Ks,Kl rate = (Kp+Km)/2
  - pip or pim rate on proton = pim or pip rate on neutron
  - Kp or Km rate on proton = Km or Kp rate on neutron
  - p rate on proton = p rate on neutron
  - Randomly choose proton or neutron as target for each event or take average
  - It can take general target with these consideration

radlen= 0.5*rad*100.*(4.0/3.0) + intrad*100.0
= 8.22 (40cm LD2 with rad=40/745.4=0.0537 and 11GeV beam)
= 6.14 (20cm LD2 with rad=20/745.4=0.0268 and 6GeV beam)
= 4.69 (40cm 10amg He3 with rad=40/(67.42/1.345e-3)=0.8e-3 and 11GeV beam)
= 4.40 (40cm 10amg He3 with rad=40/(67.42/1.345e-3)=0.8e-3 and 6GeV beam)

Intrad = 2.0*ln(e_lab/0.000511)/(137.0*3.14159)
= 0.0464 (11 GeV beam)
= 0.0435 (6 GeV beam)

See rad_len formula in backup slides from Seamus

All Use "nucleon luminosity =A*nuclei luminosity" for normalization

Generator “single_rate” by Xin Qian

- eDIS 1 based on whitlow fit on proton or deuteron
  - Rate of He3 = rate of proton + rate of deuteron
- eDIS 1 based on qfs fit on proton or deuteron
  - Rate of He3 = rate of proton + rate of deuteron
- Hadron based on wiser fit
  - has no treatment for rate on neutron, only can do fixed target
  - rad_len used

    Hydrogen target

    rad_len=2.7 + 0.5*(15.*0.0708)/61.28*100.=3.57

    Deuterium target

    rad_len=(2.7 + 0.5*(12.*0.169)/122.4*100.)*2=7.06

    He3

    rad_len= 3.57+ 7.06 = 10.63
- It use nuclei luminosity for normalization
- Beyond “single_rate”, Xin has additional correction from comparison between the calculation and 6GeV Transversity exp data on He3

Rate on He3

He3 hadron rate difference between "eicRate" and "single_rate" with 6GeV beam

- Both are based on wiser fit, but use it differently, so they have different distribution and normalization factor

- "eicRate" has He3 rad_len=4.40
- "eicRate" uses "nucleon luminosity =A*nuclei luminosity" for normalization where A=3
- "eicRate" assumes "pip or pim rate on proton = pim or pip rate on neutron", so its distribution is NOT exactly like wiser fit
  - its pip rate ~ (2/3 pip_wiser+1/3pim_wiser)
  - its pim rate ~ (2/3 pim_wiser+1/3pip_wiser)

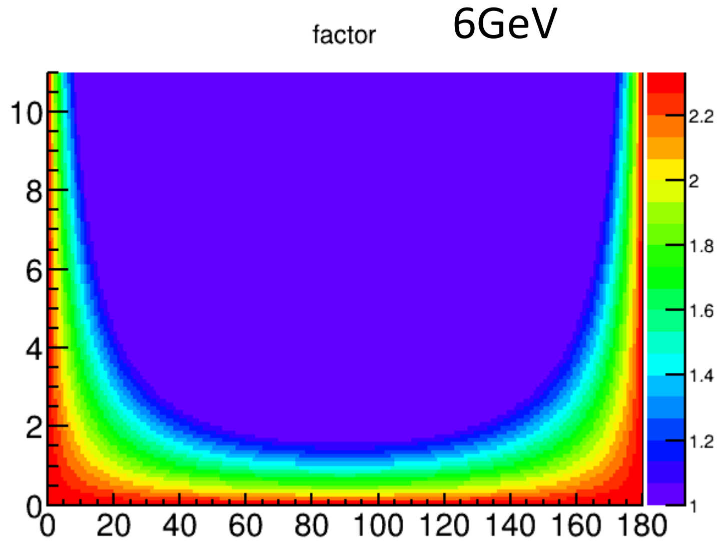
- "single_rate" uses rad_len=10.63
- "single_rate" uses "nuclei luminosity" for normalization
- "single_rate" treats rate on neutron the same as proton, so its distribution is exactly like wiser fit

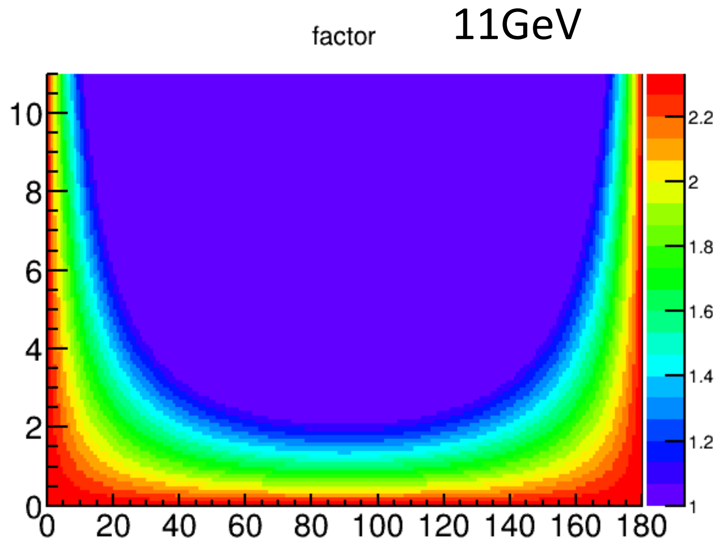
- At least, "eicRate" over "single_rate w/o correction" has a factor 1.24=4.40*3/10.63

Xin's He3 wiser pion correction factor (Mom VS theta) for 11GeV and 6GeV

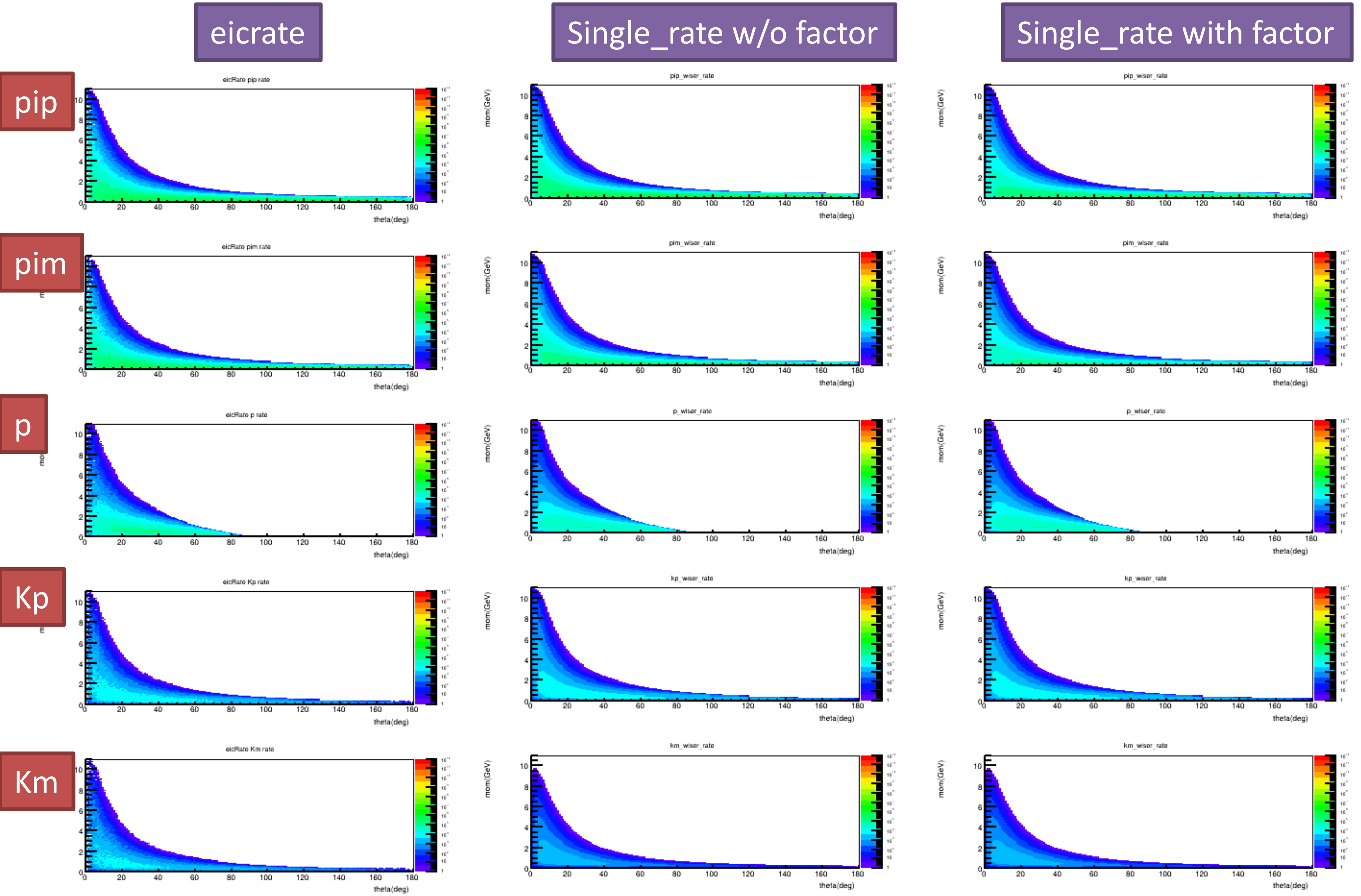
- factor = 2.33369*exp(-0.508963*mom*sin(theta/180.*3.1415926)*
  sqrt(0.938*0.938+2.*0.938*5.892)/sqrt(0.938*0.938+2.*0.938*ebeam));
- if (factor<=1) factor=1

- At 10 deg and 1GeV, it is 2.14 for 6GeV beam, 2.19 for 11GeV beam
- At 10 deg and 2GeV, it is 1.96 for 6GeV beam, 2.04 for 11GeV beam
- At 16 deg and 2.35GeV, it's 1.68 for 6GeV beam (6GeV Transversity condition)





He3 Hadron rate



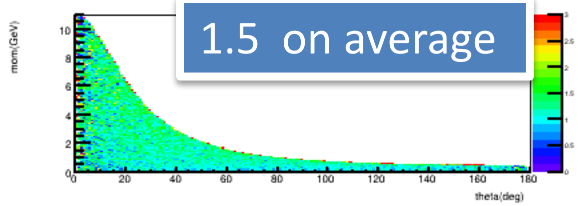
He3 Hadron rate ratio

eicrate /(Single_rate w/o factor)

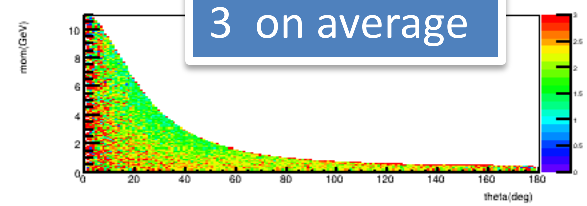
eicrate/(single_rate with factor)

pip

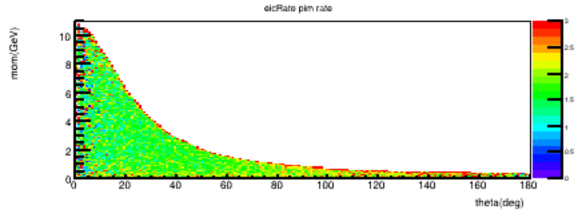
1.5 on average

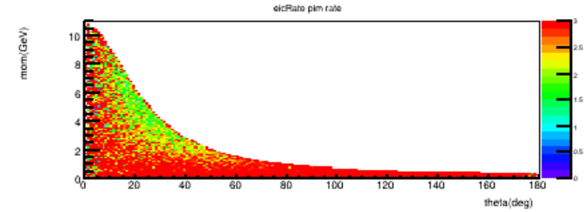


3 on average

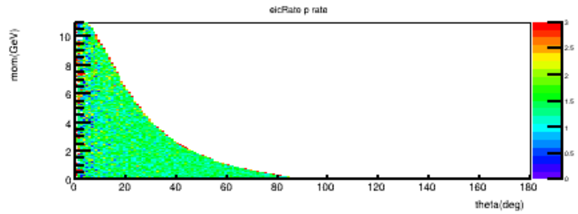


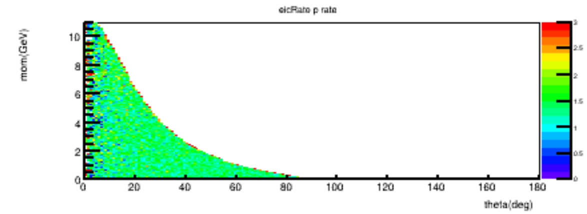
pim



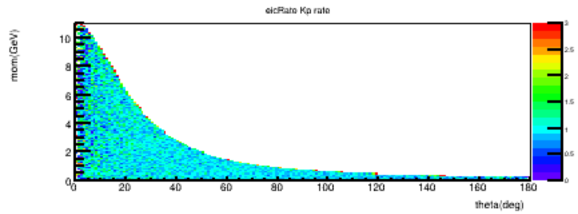


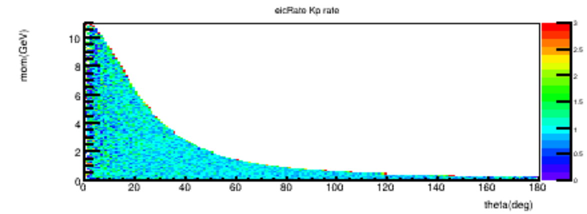
p



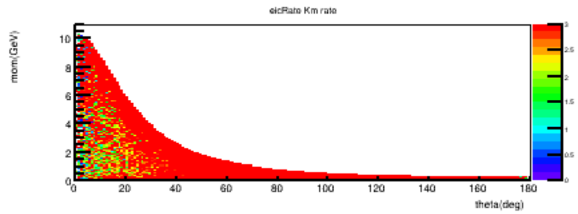


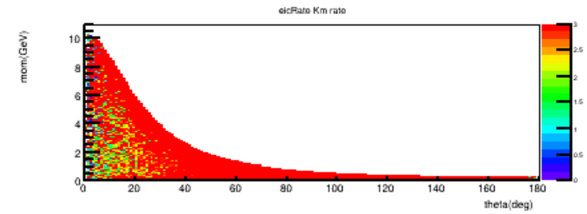
Kp





Km





My calculation using "single_rate" for 6GeV Transversity Condition

- method
  - Calculate Xsec at one fixed kinematic point, then multiply by luminosity and phase space
  - No radiative correction
  - same method used by Xin
- Assume
  - 6 GeV beam, theta 16 deg, Mom 2.35GeV
  - Current 10uA, target 33cm 10amg He3 target
  - nuclei Lumi 0.557e36/cm2/s
    = 10e-6/1.6e-19*33*1.345e-3*6.02e23/3
  - Phase space 0.0013 according to Zhihong's simulation
    (comparing to Xin's estimation 0.0016 = 6.7msr*2.35GeV*10%)

HRS rates comparison

Xin's summary

Calculations

For hadron rate, wiser code is used.
For electronr rate, whitlow code is used.
Condition: 16 degrees, 2.35 GeV/c, Q2 is about 1
Target density: 10 atm @ 27 degrees.
Pion decay: 2.6*2.35/0.14*3 = 131 m, exp(-23.5/131) = 0.8357
Kaon decay: 2.35*1.24/0.49*3 = 17.8 m, exp(-23.5/17.8) = 0.267
Acceptance: 6.7 msr for solid angle , +-5% momentum acceptance
Target length: 33 cm

Data

For negative mode, we used run 4015.
For position mode, we used run 4223.
Cuts: Trigger 3, edtpl, trip, acceptance, ntrack == 1, vertex:33 cm, momentum +-5%,
PID cuts (electron): A1>150 && Cer > 300 && E/p > 0.6
PID cuts (Pion): A1>150 && Cer < 300 && E/p < 0.6
PID cuts (Proton/Kaon): A1<150 && Cer < 300 && E/p < 0.6
Correction: livetime

Results: Unit: events/uC

	Pi+	Pi-	e-	K-	Proton
Calulation	105	62.4	11.6	0.88	71
Data	54.8	34	12.4	1.34	49.6

Conclusion

electron rate, calculation is reasonable.
pion rate, calcultion overestimates by a factor of 2.
proton rate, calculation overestimates by 45%
kaon, hard due to dirty PID

- Result

	e-	Pi+	Pi-	K+	K-	p
Xsec (nb/GeV-sr)	134	1540	916	309	4.2	889
Rate(uC)	9.73	93.19	55.4	5.95	0.81	64.36
Data	12.4	54.8	34		1.34	49.6

  - e- rate by whitlow fit, hadron rate by wiser fit with radlen=10.63
  - Get rate by "./main 0 557 6 1 1 1.85 2.85 15.5 16.5" on proton and "./main 1 557 6 1 1 1.85 2.85 15.5 16.5" on deuteron, add both to get rate on He3.
  - (sin(16/180*3.1416)*1/180*3.1416*2*3.1416)*1 =0.0302 is phase space used in the code
  - 10uA current is 10uC/s
  - Pion decay 0.8357, kaon decay 0.267
  - For example (1.46e-3+8.08e-4)*1e6/0.0302*0.0013/10=9.73 /uC for e-

He3 hadron rate

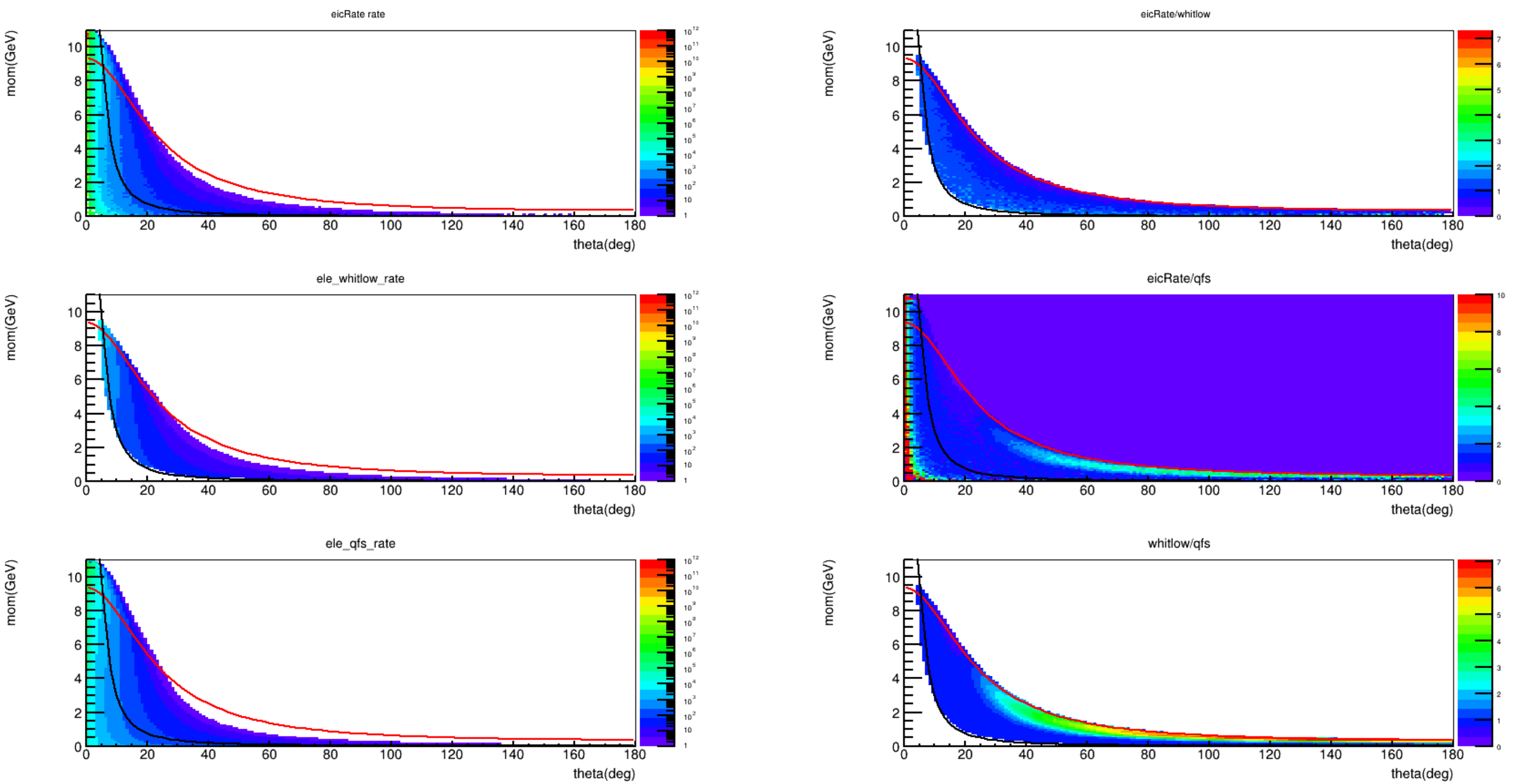
- “eicRate” over “single_rate w/o correction” has a factor 1.24
- single_rate correction factor is 2 on average
- “eicRate” over “6GeV Transversity data” is a factor 2.48=1.24*2

- So we may use 40% (~ 1/2.5) hadron rate from “eicRate” for 6GeV beam
- but it’s not clear how it would be for 11GeV

- It would be good to do a direct comparison between “eicrate” and data

He3 e rate
W=2 red line, Q2=1 black line

- “single_rate” whitlow covers DIS only, no output for Q2<1 or W<2
- In DIS, “eicrate” and “single_rate” whitlow ratio is around 1
- Compare sum of rate between of 7-24 degree and W>2, Q2>1. The result of “eicRate” is 1.2 times of “single_rate” whitlow



He3 e rate

- “eicRate” and “single_rate” use different fit to estimate, “eicRate” over “single_rate” is 1.2 for SoLID kinematics
- “single_rate” whitlow comparing to 6GeV Transversity data needs a correction factor 1.25

- If we can combine these two, “eicRate” is close to data now

- It would be good to do a direct comparison between “eicrate” and data

Rate on LD2

LD2 hadron rate difference between “eicRate” and “single_rate” with 6GeV beam

- Both are based on wiser fit, but use it differently, so they have different distribution and normalization factor

- “eicRate” has rad_len=6.14 for 20cm LD2
- “eicRate” uses “nucleon luminosity =A*nuclei luminosity” for normalization where A=2
- “eicRate” assumes “pip or pim rate on proton = pim or pip rate on neutron“, so its distribution is NOT exactly like wiser fit
  - its pip rate ~ (1/2 pip_wiser+1/2pim_wiser)
  - its pim rate ~ (1/2 pim_wiser+1/2pip_wiser)

- “single_rate” uses rad_len=7.06
- “single_rate” uses “nuclei luminosity” for normlization
- “single_rate” treats rate on neutron the same as proton, so its distribution is exactly like wiser fit

- At least, “eicRate” over “single_rate” has a factor 1.74=6.14*2/7.06

My calculation using "single_rate" for 6GeV PVDIS Condition "DIS#1"

- method
  - Calculate Xsec at one fixed kinematic point, then multiply by luminosity and phase space
  - No radiative correction
  - same method used by Xin
- Assume
  - 6.067 GeV beam
  - Current 100uA, target 20cm LD2
  - nuclei Lumi 0.635e39/cm2/s
    =100e-6/1.6e-19*20*0.169*6.02e23/2
  - Phase space by Zhihong's simulation: 0.0022 for DIS#1, 0.0015 for DIS#2

Kine#	HRS	E_b (GeV)	θ_0	E'_0 (GeV)	R_e(kHz)	R_{π^-}/R_e
DIS#1	Left	6.067	12.9°	3.66	≈ 210	≈ 0.5
DIS#2	Left & Right	6.067	20.0°	2.63	≈ 18	≈ 3.3
RES I	Left	4.867	12.9°	4.0	≈ 300	<≈ 0.25
RES II	Left	4.867	12.9°	3.55	≈ 600	<≈ 0.25
RES III	Right	4.867	12.9°	3.1	≈ 400	<≈ 0.4
RES IV	Left	6.067	15°	3.66	≈ 80	<≈ 0.6
RES V	Left	6.067	14°	3.66	≈ 130	<≈ 0.7

Table 1
Overview of kinematics settings during the experiment, including: the beam energy E_b, the spectrometer central angle setting θ_0 and central momentum setting E'_0, the observed electron rate R_e and the π^-/e ratio R_{π^-}/R_e.

Xiaochao's summary of data

DIS#1	e-	Pi+	Pi-	K+	K-	p
Xsec (nb/GeV -sr)	225.25	135.75	80.25	43.75	2.875	80.25
Rate (kHz)	315.25	158.75	93.5	16.675	1.065	112.25
Data	210		105			

DIS#2	e-	Pi+	Pi-	K+	K-	p
Xsec (nb/GeV -sr)	30.2	124.4	75.6	33.1	3.1	121
Rate (kHz)	28.8	99.5	60.5	8.38	0.802	116
Data	18		59.4			

- e- rate by whitlow fit, hadron rate by wiser fit with radlen=7.06
- Get rate by "./ main 1 0.635e6 6.067 1 1 3.16 4.16 12.4 13.4" for DIS#1, "./main 1 0.635e6 6.067 1 1 2.13 3.13 19.5 20.5" for DIS#2
- (sin(12.9/180*3.1416)*1/180*3.1416*2*3.1416)*1=0.0245 for DIS#1 and (sin(20.0/180*3.1416)*1/180*3.1416*2*3.1416)*1=0.0375 for DIS#2, phase space used in the code
- Pion decay 0.8357, kaon decay 0.267
- For example, 3.51*1e6/0.0245*0.0022/1e3=315kHz for e-

LD2 hadron rate

- “eicRate” over “single_rat” has a factor 1.74
- single_rate seems reproduce 6GeV PVDIS data at DIS region well
- “eicRate” over “6GeV PVDIS data” is a factor 1.74

- So we may 60% (~ 1/1.74) hadron rate from “eicRate” for 6GeV beam
- but it’s not clear how it would be for 11GeV

- It would be good to do a direct comparison between “eicrate” and data

LD2 e rate (unfinished)

- “eicRate” and “single_rate” use different fit to estimate
- “single_rate” whitlow comparing to 6GeV PVDIS data needs a correction factor 0.65

- It would be good to do a direct comparison between “eicrate” and data

backup

Code “single_rate” result

- [zwzhao@lily single_rate]$ ./main 0 557 6 1 1 1.85 2.85 15.5 16.5
- use mom and theta as variables
- mom_min 1.85000002 mom_max 2.84999990 theta_min_deg 15.5000000 theta_max_deg 16.5000000
- Electron from whitlow : 8.07928212E-04 MHz
- Electron from qfs : 7.99543574E-04 MHz
- Positive Pion from wiser: 8.67747795E-03 MHz
- Negative Pion from wiser: 5.17326035E-03 MHz
- Proton from wiser : 5.01987291E-03 MHz
- Positive Kaon from wiser: 1.74075132E-03 MHz
- Negative Kaon from wiser: 2.36223714E-04 MHz

- zwzhao@lily single_rate]$ ./main 1 557 6 1 1 1.85 2.85 15.5 16.5
- use mom and theta as variables
- mom_min 1.85000002 mom_max 2.84999990 theta_min_deg 15.5000000 theta_max_deg 16.5000000
- Electron from whitlow : 1.46477344E-03 MHz
- Electron from qfs : 1.72863191E-03 MHz
- Positive Pion from wiser: 1.71696413E-02 MHz
- Negative Pion from wiser: 1.02360398E-02 MHz
- Proton from wiser : 9.93254315E-03 MHz
- Positive Kaon from wiser: 3.44432797E-03 MHz
- Negative Kaon from wiser: 4.67402628E-04 MHz

- [zwzhao@lily single_rate]$ ./main 1 0.635e6 6.067 1 1 3.16 4.16 12.4 13.4
- use mom and theta as variables
- mom_min 3.16000009 mom_max 4.15999985 theta_min_deg 12.3999996 theta_max_deg 13.3999996
- Electron from whitlow : 3.50617242 MHz
- Electron from qfs : 4.11271048 MHz
- Positive Pion from wiser: 2.11581039 MHz
- Negative Pion from wiser: 1.24890971 MHz
- Proton from wiser : 1.24679077 MHz
- Positive Kaon from wiser: 0.682648838 MHz
- Negative Kaon from wiser: 4.33244333E-02 MHz

- [zwzhao@lily single_rate]$ ./main 1 0.635e6 6.067 1 1 2.13 3.13 19.5 20.5
- use mom and theta as variables
- mom_min 2.13000011 mom_max 3.13000011 theta_min_deg 19.5000000 theta_max_deg 20.5000000
- Electron from whitlow : 0.719959378 MHz
- Electron from qfs : 0.921629548 MHz
- Positive Pion from wiser: 2.96858835 MHz
- Negative Pion from wiser: 1.81487012 MHz
- Proton from wiser : 2.89821553 MHz
- Positive Kaon from wiser: 0.783541083 MHz
- Negative Kaon from wiser: 7.48522878E-02 MHz

Zhihong Ye' simulation of HRS acceptance

- 6GeV Transversity (16deg, 2.35GeV)
  Deltap = ± 6%
  Theta = ± 90mrad
  Phi = ± 45mrad
  VZ = ± 16.5 cm
  acceptance of this phase space 0.276781
  effective phase space 0.00126
  =180e-3*90e-3*0.276781*2.35*0.12
- 6GeV PVDIS
  Phase Space is: Dp = ± 6%, Theta = ± 90mrad, Phi = ± 45mrad, VZ = 20cm
  - DIS #1, P0 = 3.66, Theta = 12.9, the acceptance is 0.304386
    effective phase space 0.0022=180e-3*90e-3*0.304386*3.66*0.12
  - DIS #2, P0 = 2.63, Theta = 20.0, the acceptance is 0.292408
    effective phase space 0.0015=180e-3*90e-3*0.292408*2.63*0.12

- NOTE that I use a much larger phase space that the HRS can accepted so we can cover any possible way the events going through the HRS, like using very long target. If we use a smaller phase space, the acceptance value could be smaller, but the effective phase space (= full phase space*acceptance) should be a constant.

Seamus’s slides about “eicRate”

Generators

- Need Λ decay generator
- Pion asymmetry generator
- Add in radiative effects into DIS?

Issues with pion rates

- Used "Wiser code", based on $\gamma N \to \pi^{\pm}$ cross sectino fits from SLAC
- Brehmstralung from target for photoproduction, Weizsacker-Williams for electroproduction
- Found inconsistencies in calculations

π cross section calculations

Photoproduction:

$$\sigma_\pi^{\mathrm{photo}} = \int dk \rho_\gamma(k) \frac{d\sigma_\pi(\gamma(k)N \to \pi)}{dk}$$

$$\rho_\gamma(k) = \frac{t}{X_0} \frac{\frac{4}{3} - \frac{4}{3}x + x^2}{E_{\mathrm{beam}} x}, x = k/E_{\mathrm{beam}}$$

Electroproduction:

$$\sigma_\pi^{\mathrm{electro}} = \int dx N_{\mathrm{eff}}(E_{\mathrm{beam}}, x) \frac{d\sigma_\pi(\gamma(xE_{\mathrm{beam}})N \to \pi)}{dx}$$

$$N_{\mathrm{eff}}(E_{\mathrm{beam}}, x) = \frac{\alpha}{\pi} \ln\left(\frac{E_{\mathrm{beam}}}{m_e}\right) \frac{1 + (1-x)^2}{x}$$

- Add together to get pion rates - need radiation length of target traversed and internal radiation factor

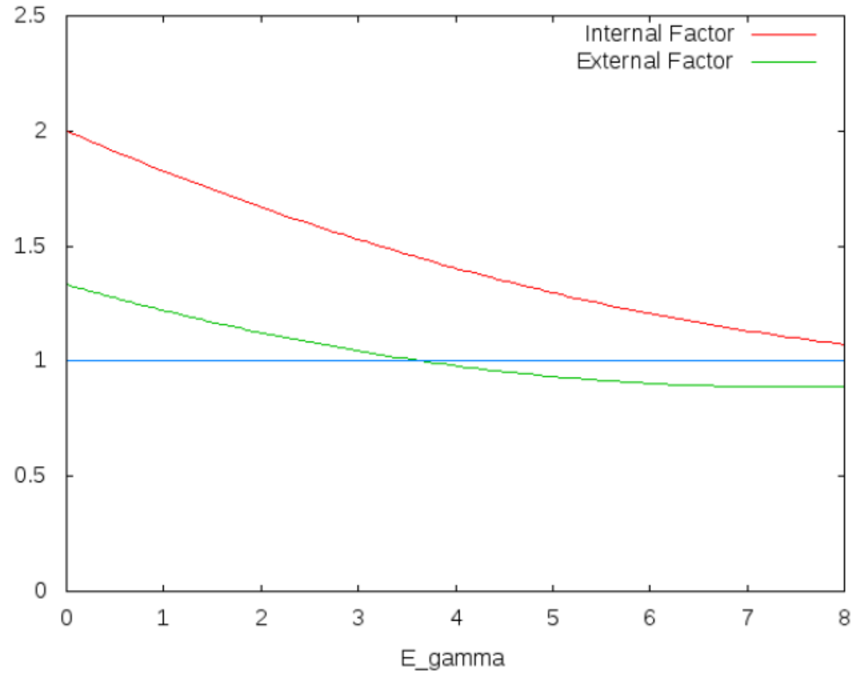
Wiser Issues

Issues:

- Wiser just weights by just $1/k$, not complete photon spectrum - makes difference when k not small, we're interested in higher energy pions
- Target radiation length needs relative $4/3$ not accounted for in any calculations
- Internal radiation goes to $2\alpha/\pi \ln(E/m_e)$, $k \to 0$, calculations used $\alpha/\pi \ln(E/m_e)$, $k \to 0$

Wiser Issues II

Overall effect:



- π rates low, especially for lower p
- PVDIS $RL_{\rm int}/2 \sim \bar{R}L_{\rm ext}$, shouldn't change too much for pions making it through the baffles

Should fix photon spectrum in code

other

(outdated)
My calculation using "eicrate" for 6GeV Transversity Condition

- Method
  - eicrate generate a distribution, find the event within HRS acceptance, then count the rate
  - Should be more accurate comparing to calculation at a fixed point
- Assume
  - HRS P range (2.2325,2.4675)
  - HRS solid angle is a cone with half angle 2.65 deg

    6.7e-3=2*3.1416*(1-cos(2.65/180*3.1416))
- Result
  - 2857/10*0.8357= 238 uC for pip
  - 2753/10*0.8357= 230 uC for pim

HRS rates comparison

Calculations

For hadron rate, wiser code is used.
For electronr rate, whitlow code is used.
Condition: 16 degrees, 2.35 GeV/c, Q2 is about 1
Target density: 10 atm @ 27 degrees.
Pion decay: 2.6*2.35/0.14*3 = 131 m, exp(-23.5/131) = 0.8357
Kaon decay: 2.35*1.24/0.49*3 = 17.8 m, exp(-23.5/17.8) = 0.267
Acceptance: 6.7 msr for solid angle , +-5% momentum acceptance
Target length: 33 cm

Data

For negative mode, we used run 4015.
For position mode, we used run 4223.
Cuts: Trigger 3, edtpl, trip, acceptance, ntrack == 1, vertex:33 cm, momentum +-5%,
PID cuts (electron): A1>150 && Cer > 300 && E/p > 0.6
PID cuts (Pion): A1>150 && Cer < 300 && E/p < 0.6
PID cuts (Proton/Kaon): A1<150 && Cer < 300 && E/p < 0.6
Correction: livetime

Results: Unit: events/uC

	Pi+	Pi-	e-	K-	Proton
Calulation	105	62.4	11.6	0.88	71
Data	54.8	34	12.4	1.34	49.6

Conclusion

electron rate, calculation is reasonable.
pion rate, calcultion overestimates by a factor of 2.
proton rate, calculation overestimates by 45%
kaon, hard due to dirty PID