



Pion production in MARS & tracking in ICOOL from 5-15 GeV beam for NF Front-End study

This is an update on:

Comparison of MARS BNL and MARS CERN codes.

Comparison between ST2 and ST2a for particle production @5-8-14 GeV (MARS @CERN).

Pions yield (ST2a - MARS @CERN) and tracking (ST2a ICOOL deck) @5-8-14 GeV.

Still need to be done:

- re-run with updated CERN MARS code**
- run all energy bins**
- compare to HARP LA/FA yields**
- tracking with an ICOOL ST2 deck**

MARS BNL and CERN codes (1/)

Two different versions of the MARS code:

- CERN (last update: 16th March 2009)**
- BNL (last update: 1st May 2009).**

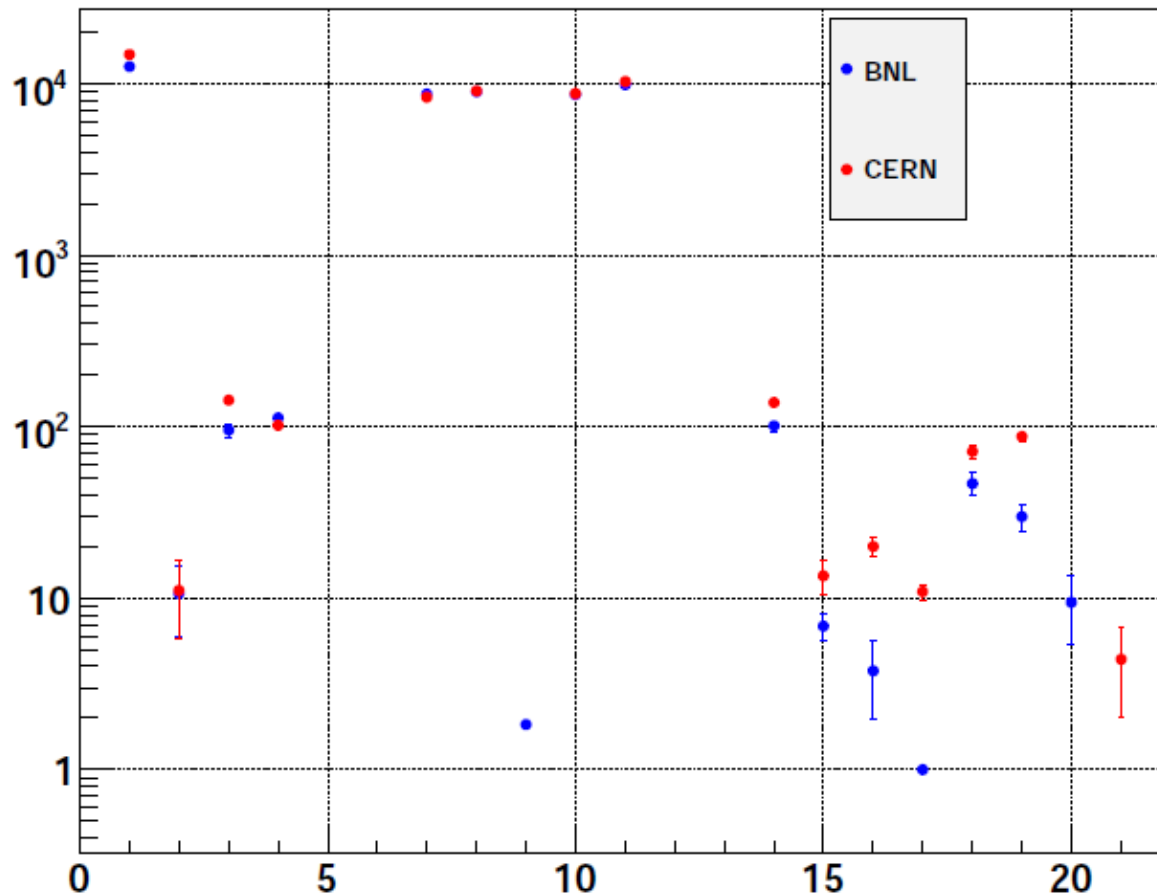
Comparison of the codes using 100000 MARS particles for 5-8-14 GeV beams with ST2 field map.

Look at particle yield at $z = 50$ m and $40 < E_{kin} < 180$ MeV.

MARS BNL and CERN codes (2/)

@5 GeV +8% π^+ , -10% π^- , -4.5% μ^+ , +1.5% μ^- .

Particle ID at $z = 50$ and $40 < E_{\text{kin}} < 180$ MeV – ST2 – 5 GeV beam

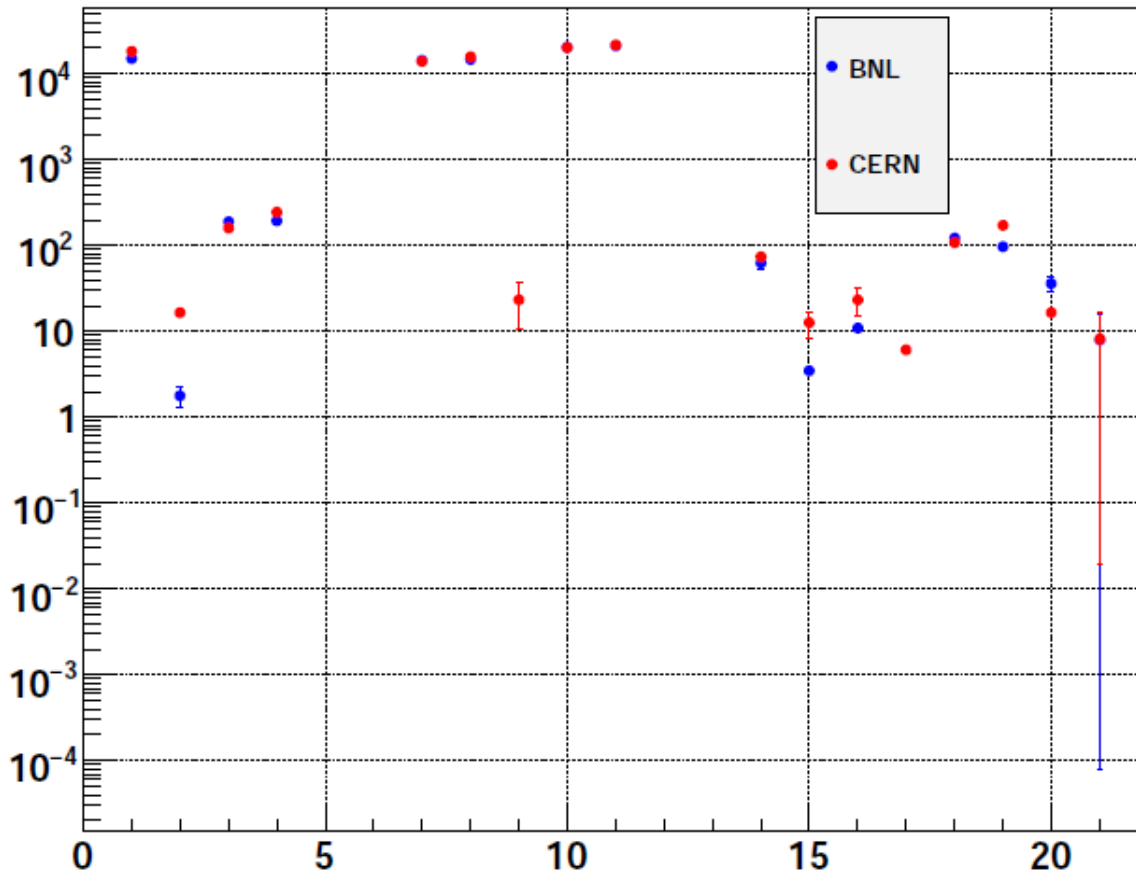


PID	Type	$N_{\text{CERN}} - N_{\text{BNL}}$	Errors
1	ρ	2246	212
2	n	0	7
3	π^+	47	12
4	π^-	-10	9
7	μ^+	-376	154
8	μ^-	117	157
9	γ	-2	0
10	e^-	107	198
11	e^+	413	238
14	D	37	12
15	T	7	3
16	^3He	16	3
17	^4He	10	1
18	ν_μ	25	9
19	$\bar{\nu}_\mu$	58	8
20	ν_e	-9	4
21	$\bar{\nu}_e$	4	2

MARS BNL and CERN codes (3/)

@8 GeV -18% π^+ , +23% π^- , -2.5% μ^+ , +7% μ^- .

Particle ID at $z = 50$ and $40 < E_{\text{kin}} < 180$ MeV - ST2 - 8 GeV beam

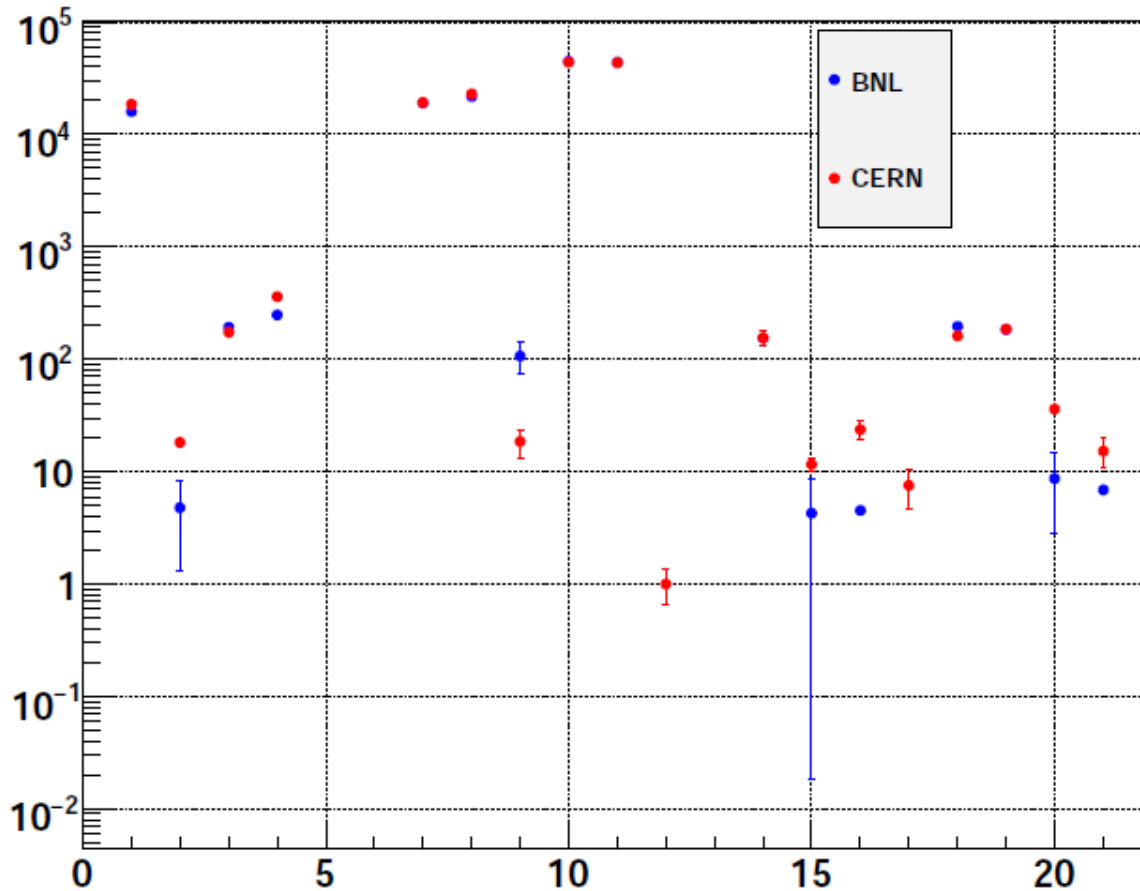


PID	Type	$N_{\text{CERN}} - N_{\text{BNL}}$	Errors
1	ρ	3221	206
2	n	15	2
3	π^+	-31	18
4	π^-	51	21
7	μ^+	-351	240
8	μ^-	1022	354
9	γ	23	13
10	e^-	-300	443
11	e^+	744	445
14	D	11	12
15	T	9	4
16	${}^3\text{He}$	12	8
17	${}^4\text{He}$	6	1
18	$\bar{\nu}_\mu$	-14	17
19	ν_μ	76	19
20	$\bar{\nu}_e$	-20	7
21	ν_e	0	11

MARS BNL and CERN codes (4/)

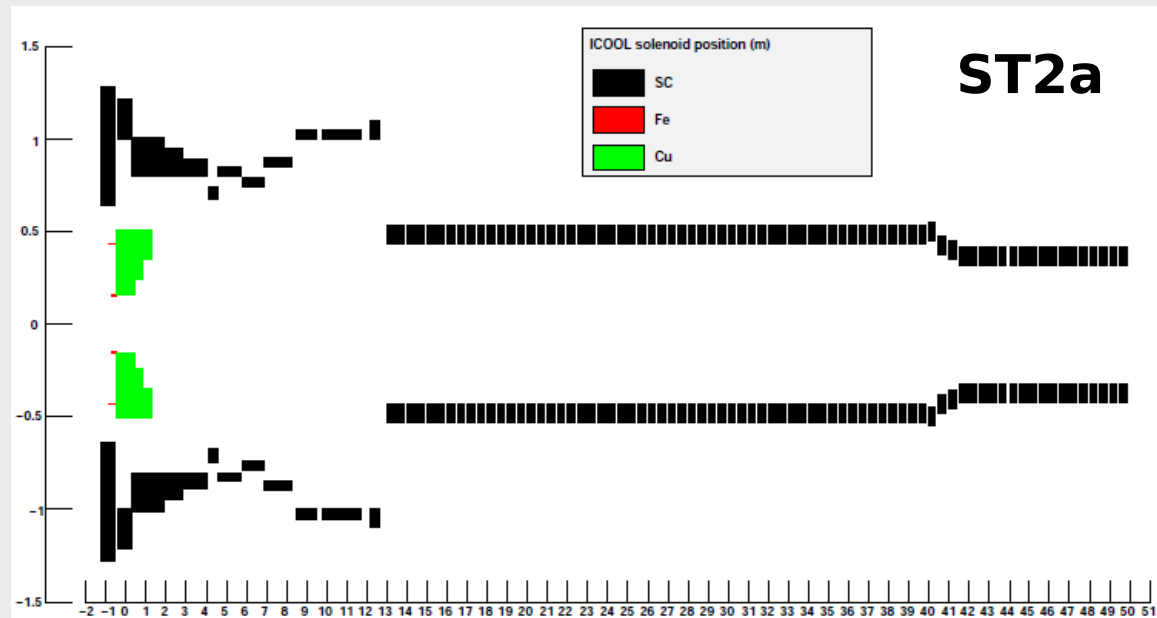
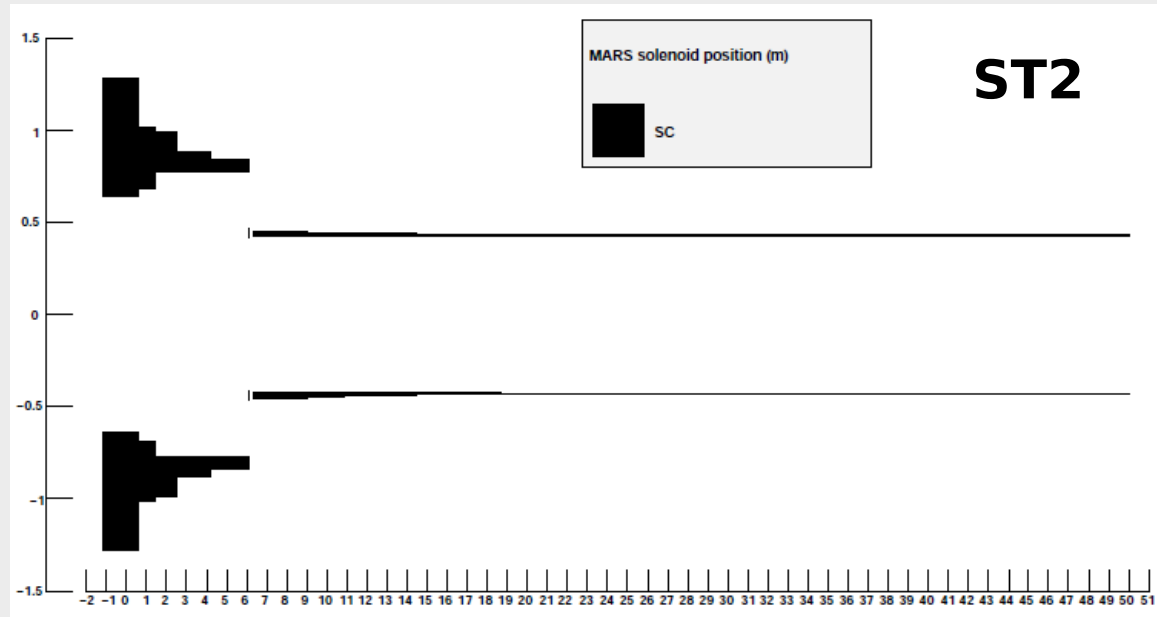
@14 GeV -10% π^+ , +37.5% π^- , +1% μ^+ , +6% μ^- .

Particle ID at $z = 50$ and $40 < E_{\text{kin}} < 180$ MeV - ST2 - 14 GeV beam



PID	Type	$N_{\text{CERN}} - N_{\text{BNL}}$	Errors
1	ρ	2489	285
2	n	14	4
3	π^+	-19	22
4	π^-	114	28
7	μ^+	206	312
8	μ^-	1311	327
9	γ	-89	34
10	e^-	-1010	966
11	e^+	-542	947
14	D	1	28
15	T	7	5
16	^3He	19	5
17	^4He	8	3
18	$\bar{\nu}_\mu$	-34	18
19	ν_μ	3	26
20	ν_e	27	6
21	$\bar{\nu}_e$	8	5

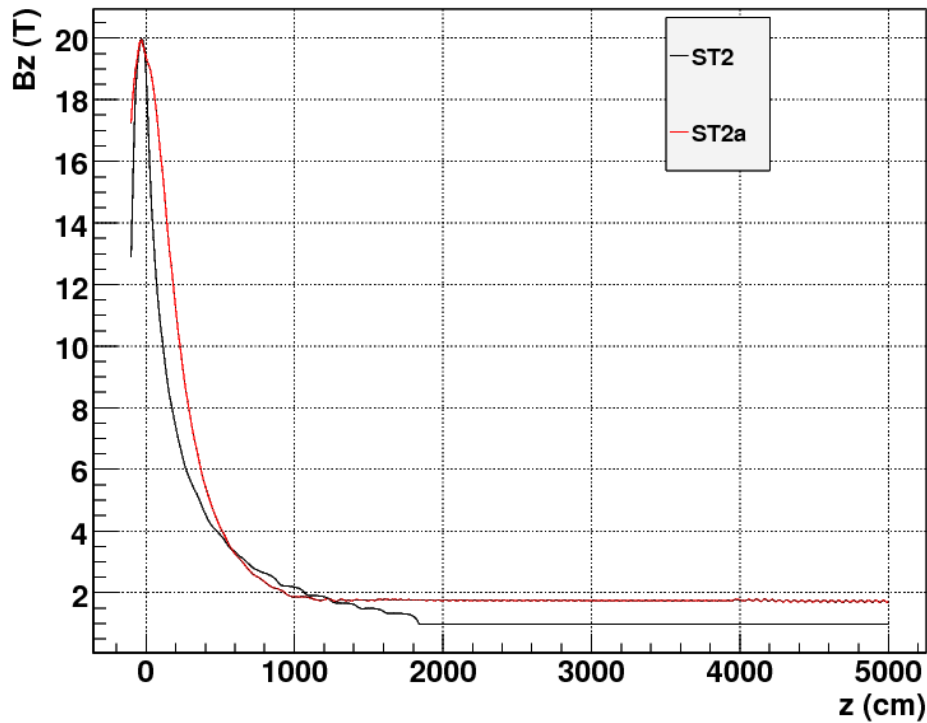
ST2 & ST2a magnets geometry



July 22th 2009

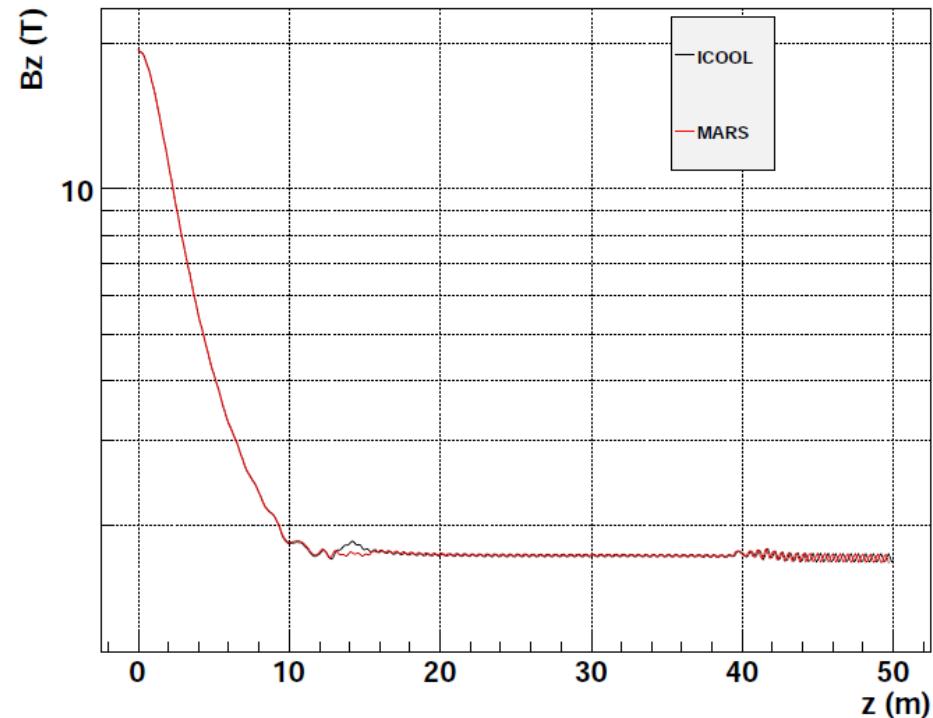
ST2 & ST2a field map

B field on axis from MARS



**Field on axis in ICOOL:
small difference at 12 m**

B field on axis (ST2a)



Field on axis:

1.25 T/1.75 T for the taper

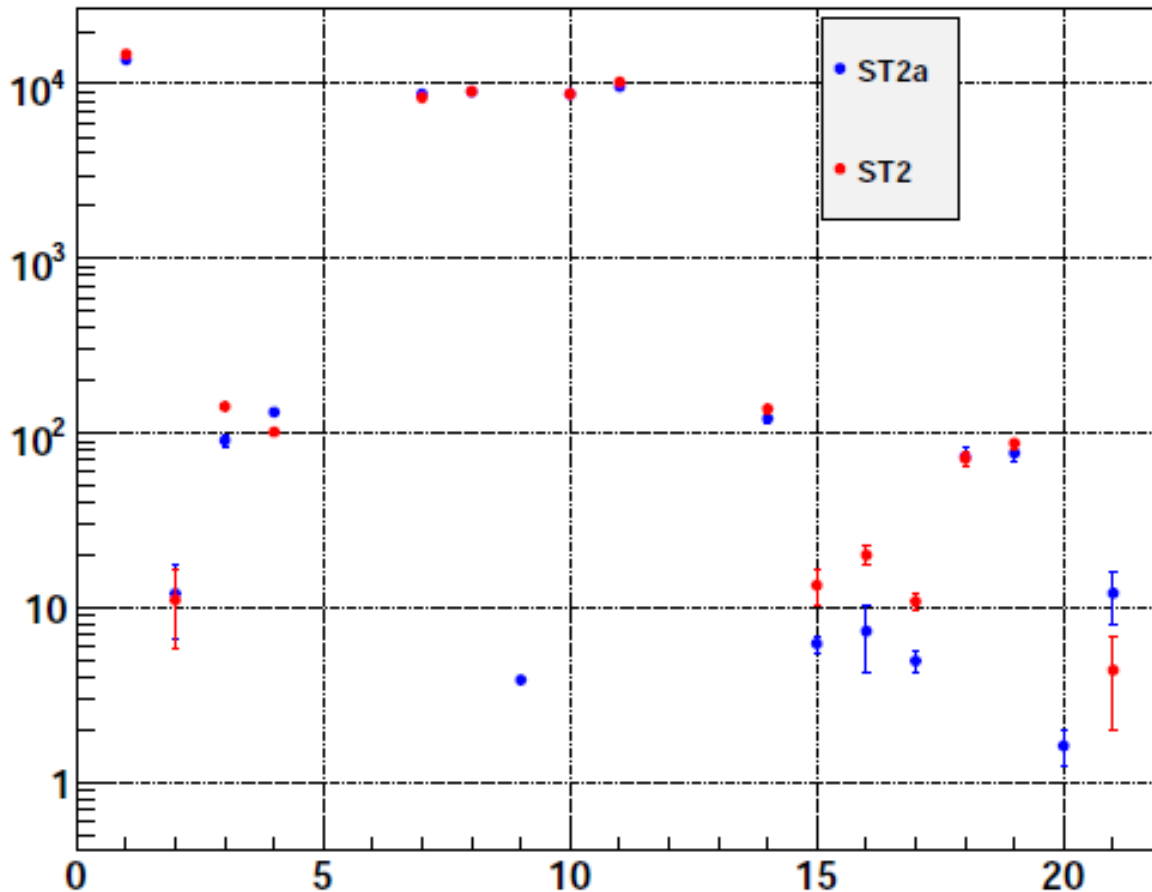
Higher B field for ST2a

July 22th 2009

Particle production using ST2/ST2a

@5 GeV ~5% increase in μ^+ and ~1% loss in μ^- .

Particle ID at $z = 50$ and $40 < E_{\text{kin}} < 180$ MeV - 5 GeV beam

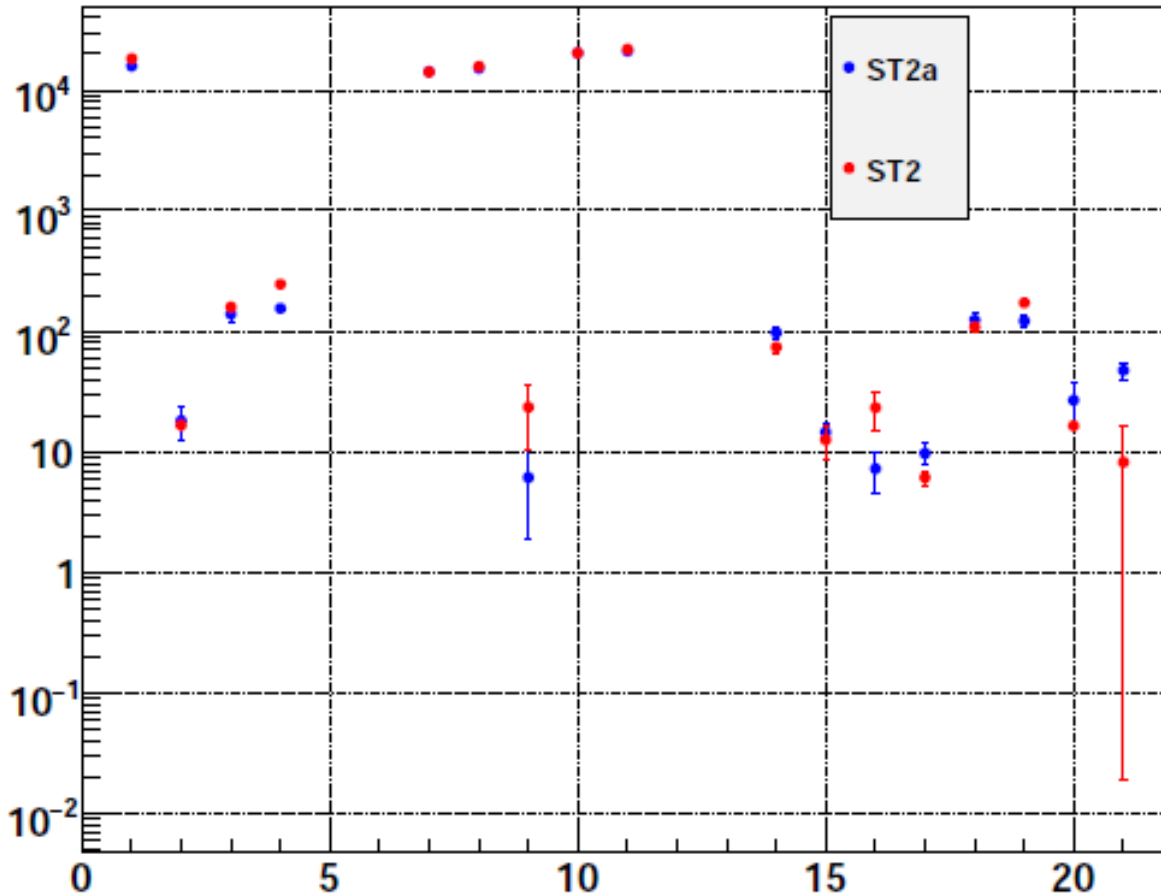


PID	Type	$N_{\text{ST2a}} - N_{\text{ST2}}$	Errors
1	ρ	-986	215
2	n	1	8
3	π^+	-51	12
4	π^-	31	10
7	μ^+	436	155
8	μ^-	-64	156
9	γ	4	0
10	e^-	-17	201
11	e^+	-600	220
14	D	-16	13
15	T	-7	3
16	^3He	-13	4
17	^4He	-6	1
18	ν_μ	2	11
19	$\bar{\nu}_\mu$	-11	10
20	ν_e	2	0
21	$\bar{\nu}_e$	8	5

Particle production using ST2/ST2a

@8 GeV ~2% increase in μ^+ and ~3.5% increase in μ^- .

Particle ID at $z = 50$ and $40 < E_{\text{kin}} < 180$ MeV – 8 GeV beam

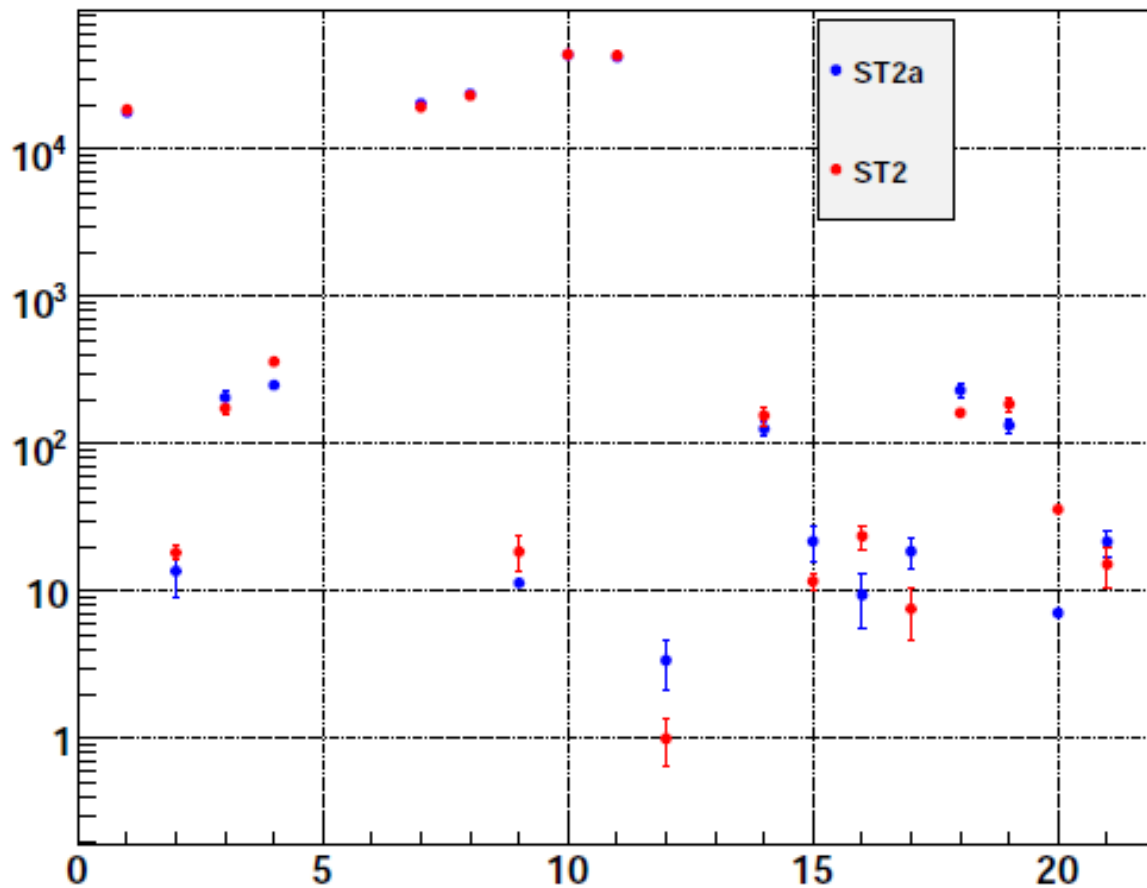


PID	Type	$N_{\text{ST2a}} - N_{\text{ST2}}$	Errors
1	p	-2459	206
2	n	2	6
3	π^+	-19	24
4	π^-	-91	20
7	μ^+	246	245
8	μ^-	548	257
9	γ	-17	14
10	e^-	109	443
11	e^+	-729	457
14	D	24	14
15	T	2	5
16	^3He	-16	9
17	^4He	4	2
18	$\bar{\nu}_\mu$	16	18
19	ν_μ	-50	20
20	$\bar{\nu}_e$	10	11
21	ν_e	39	11

Particle production using ST2/ST2a

@14 GeV ~5.5% increase in μ^+ and ~3% increase in μ^- .

Particle ID at $z = 50$ and $40 < E_{\text{kin}} < 180$ MeV - 14 GeV beam

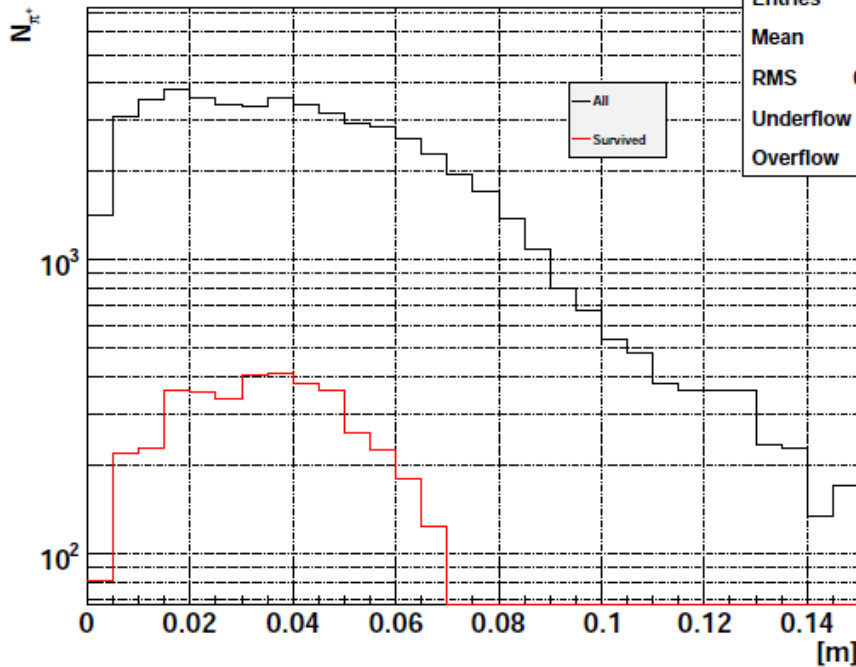


PID	Type	$N_{\text{ST2a}} - N_{\text{ST2}}$	Errors
1	p	-812	290
2	n	-5	5
3	π^+	33	25
4	π^-	-112	30
7	μ^+	1087	320
8	μ^-	651	333
9	γ	-7	5
10	e^-	-115	964
11	e^+	-1084	937
14	D	-30	27
15	T	10	6
16	^3He	-14	6
17	^4He	11	5
18	ν_μ	69	31
19	$\bar{\nu}_\mu$	-52	24
20	ν_e	-29	2
21	$\bar{\nu}_e$	6	6

Pions production & survival (1/)

Pions lost for $R > 7$ cm or $p_T > 400$ MeV/c.

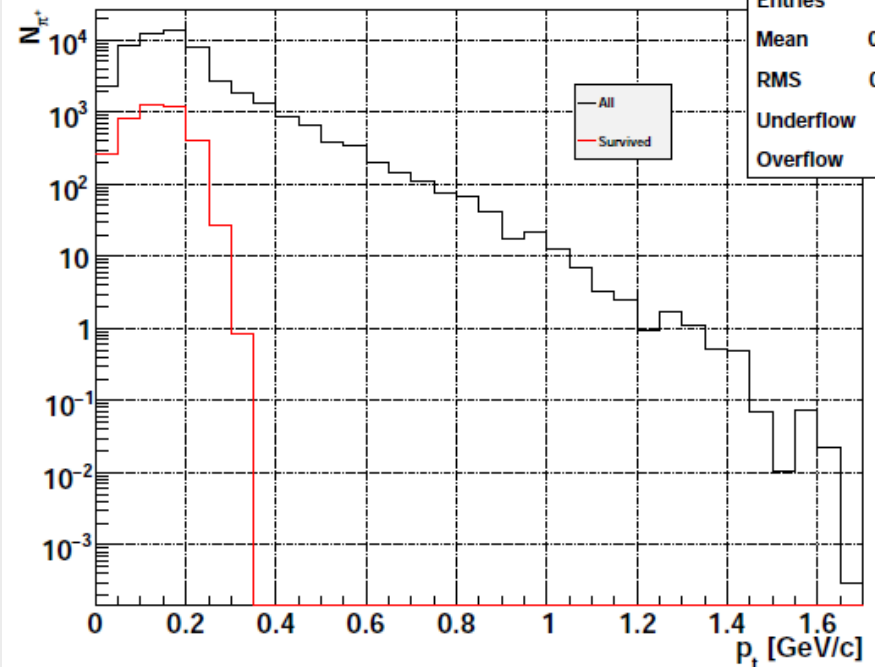
Distance to beam axis at $z = 0$ for π^+



H1DDPI

Entries	16976
Mean	0.0464
RMS	0.03023
Underflow	0
Overflow	0

Transverse momentum at $z = 0$ for π^+



H1DPTPI

Entries	16976
Mean	0.1844
RMS	0.1175
Underflow	0
Overflow	0

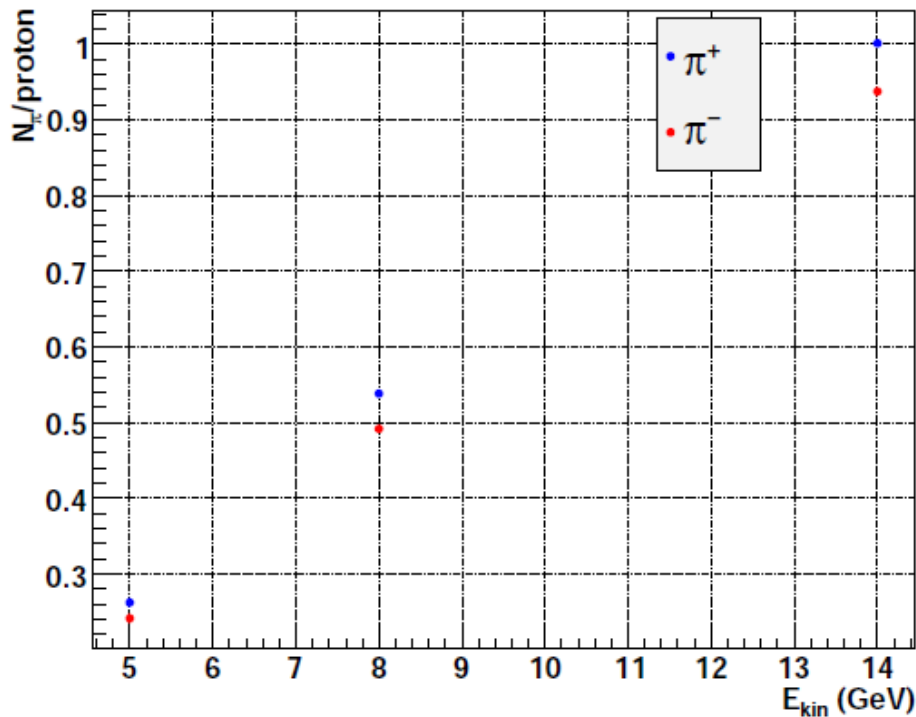
Fraction of pions accepted:

π^+ : **6% (5 GeV) - 7% (8 GeV) - 9% (14 GeV)**

π^- : **5% (5 GeV) - 6% (8 GeV) - 7% (14 GeV)**

Pions production & survival (2/)

Pion yield per proton – ST2a

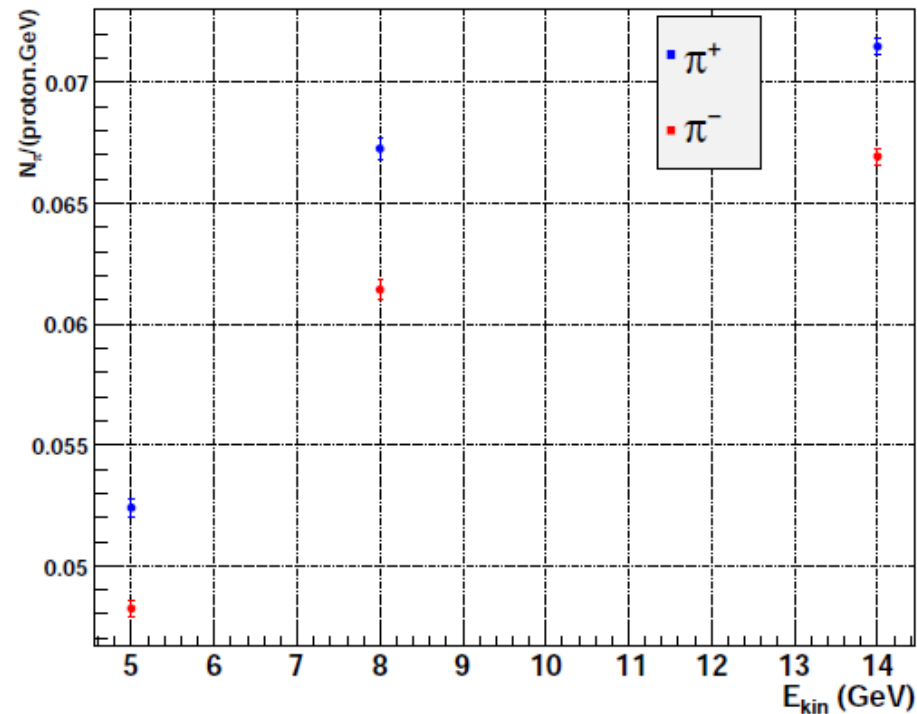


Between 5 - 8 GeV:

π^+ : up to 28% gain

π^- : up to 27% gain

Pion yield per proton and per GeV – ST2a



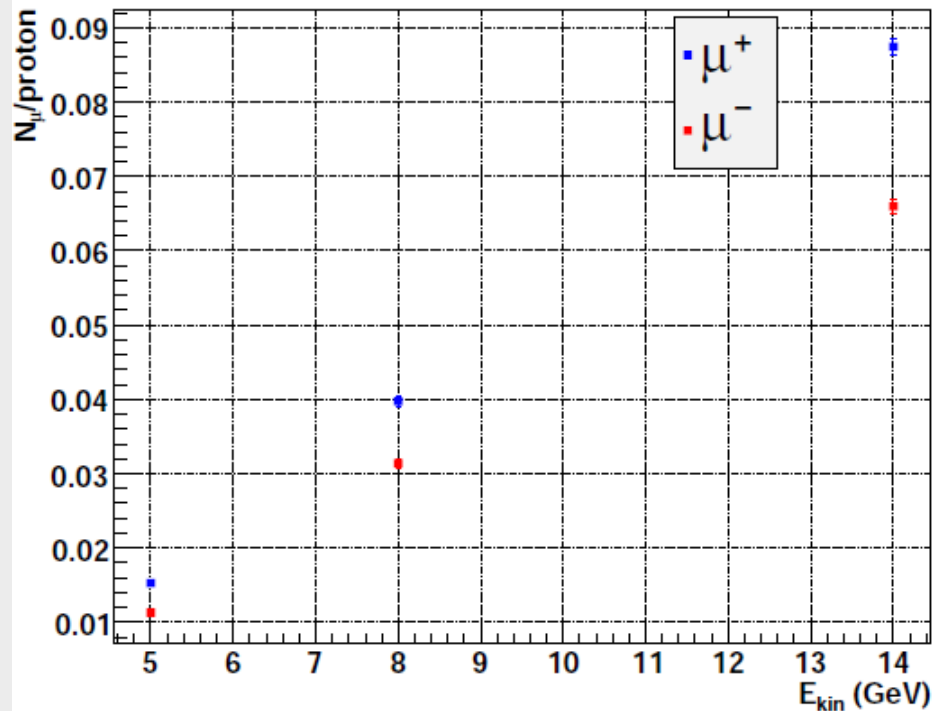
Between 8 - 14 GeV:

π^+ : up to 6% gain

π^- : up to 9% gain

Pions production & survival (3/)

Muon yield per proton - ST2a



Between 5 - 8 GeV:

μ^+ : up to 62% gain

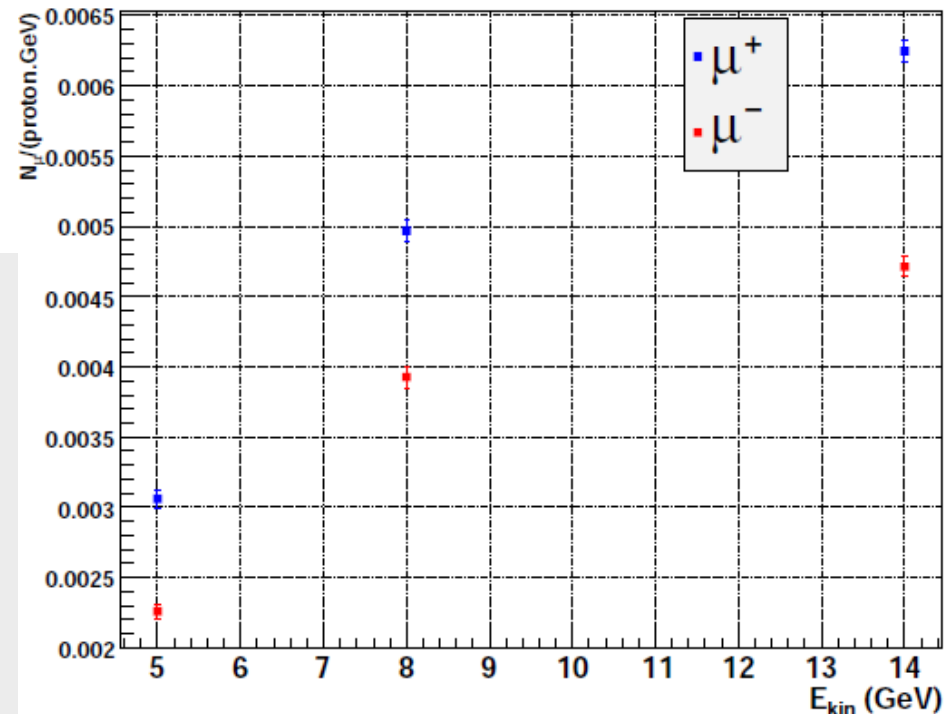
μ^- : up to 74% gain

Between 8 - 14 GeV:

μ^+ : up to 26% gain

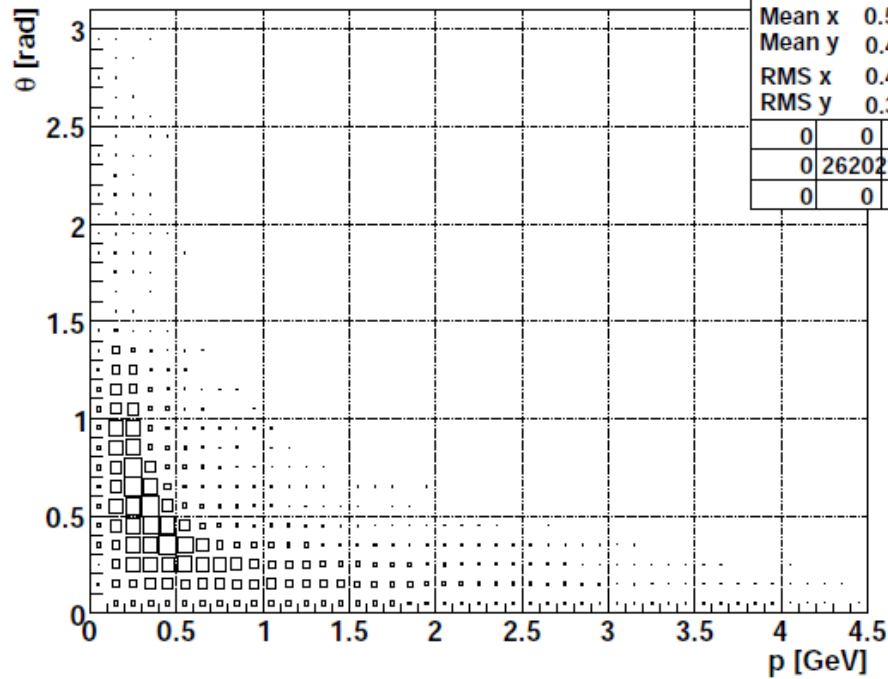
μ^- : up to 20% gain

Muon yield per proton and per GeV - ST2a



Pions production and survival (4/)

Angle versus momentum at $z = 0$ for π^+



H2DP0		
Entries	11895	
Mean x	0.5086	
Mean y	0.4877	
RMS x	0.4469	
RMS y	0.3199	
0	0	0
0	26202	0
0	0	0

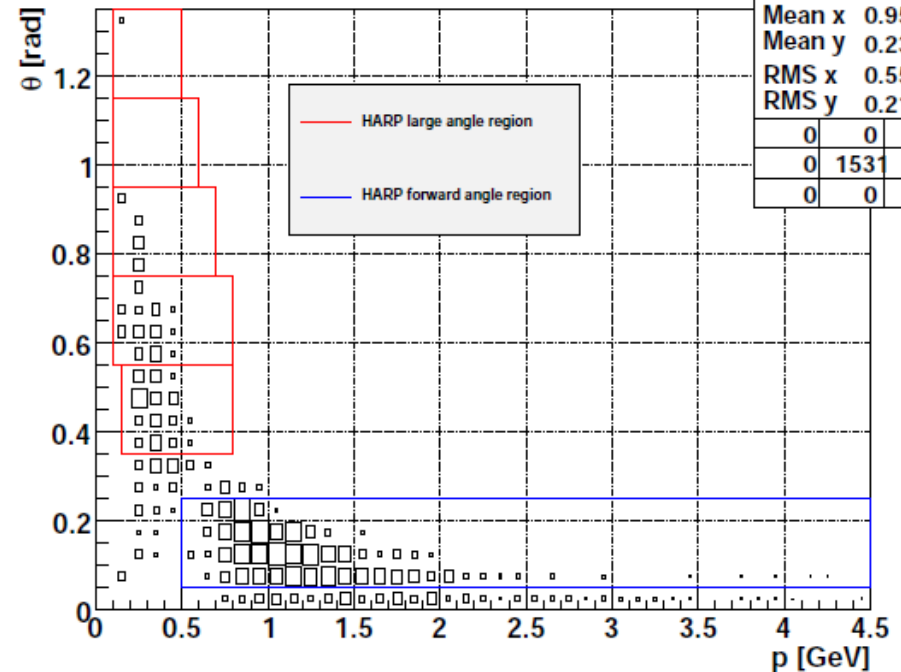
π^+ @ 5 GeV:

916 (60%) in HARP FA region

349 (23%) in HARP LA region

266 (17%) out of HARP regions

Angle versus momentum (survived) for π^+



H2DP		
Entries	845	
Mean x	0.9514	
Mean y	0.2335	
RMS x	0.5566	
RMS y	0.2126	
0	0	0
0	1531	0
0	0	0

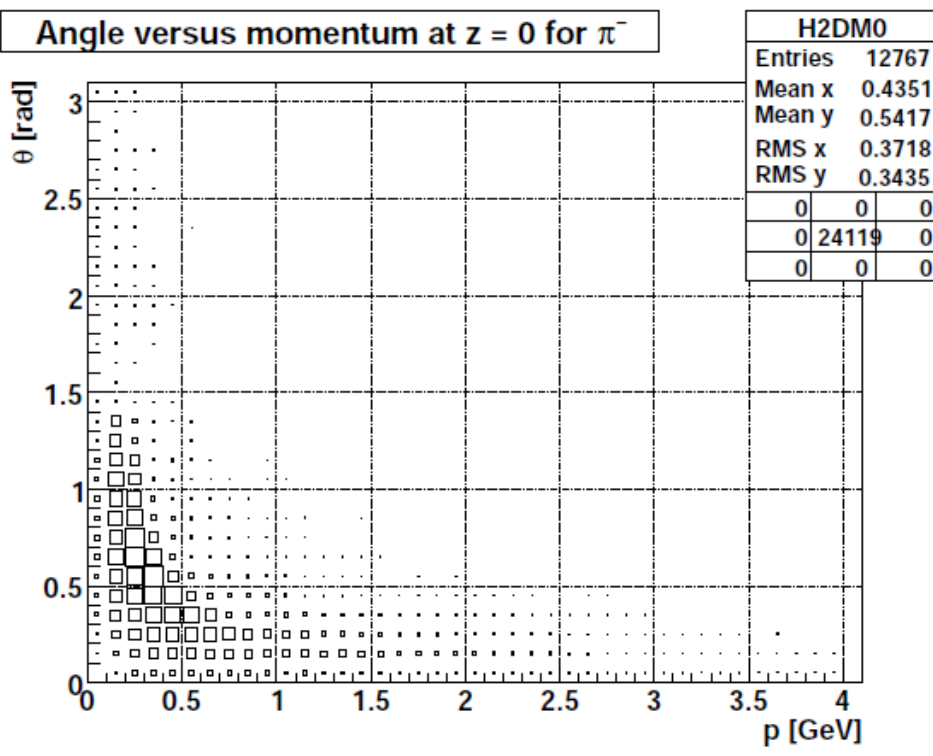
Fraction compared to number of pions in the region:

19% in HARP FA region

2.5% in HARP LA region

4% out of HARP regions

Pions production and survival (5/)

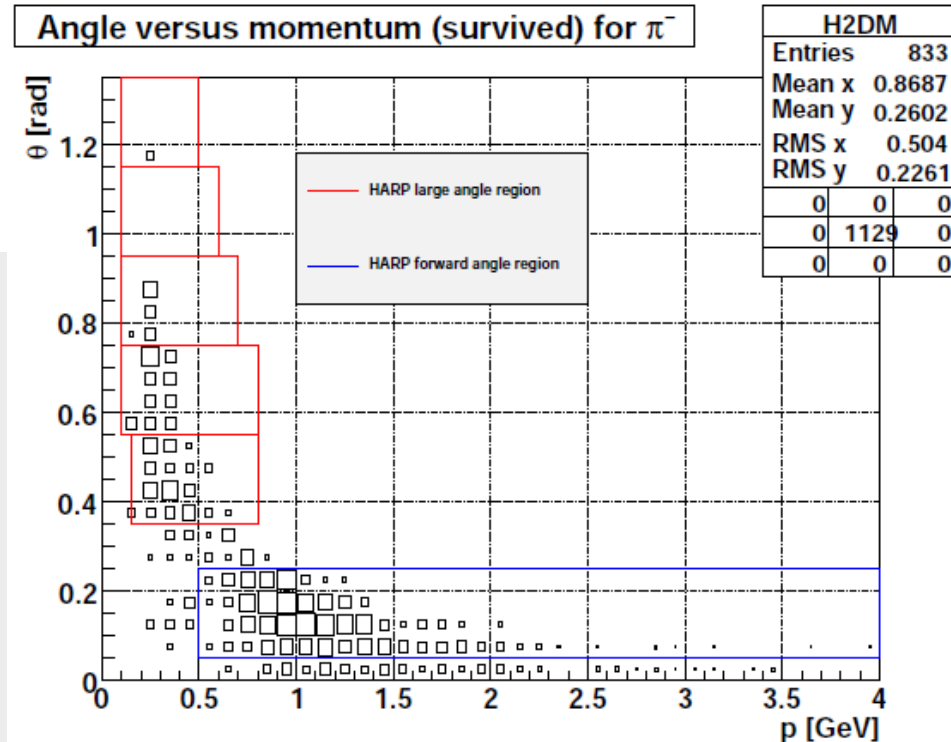


π^- @ 5 GeV:

645 (57%) in HARP FA region

312 (28%) in HARP LA region

172 (15%) out of HARP regions



Fraction compared to number of pions in the region:

19% in HARP FA region

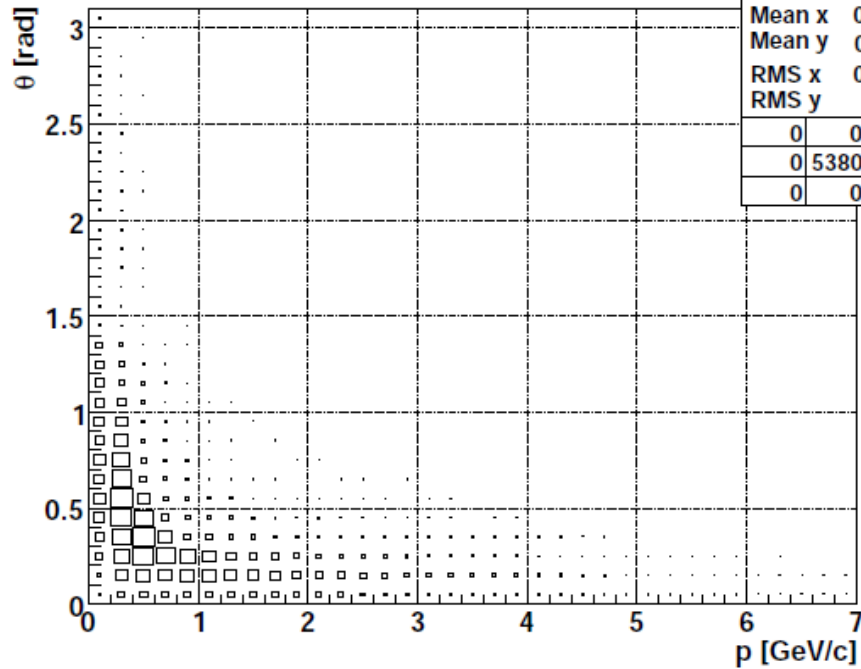
2% in HARP LA region

3% out of HARP regions

July 22th 2009

Pions production and survival (6/)

Angle versus momentum at $z = 0$ for π^+



H2DP0		
Entries	16976	
Mean x	0.7016	
Mean y	0.4282	
RMS x	0.6995	
RMS y	0.311	
0	0	0
0	53807	0
0	0	0

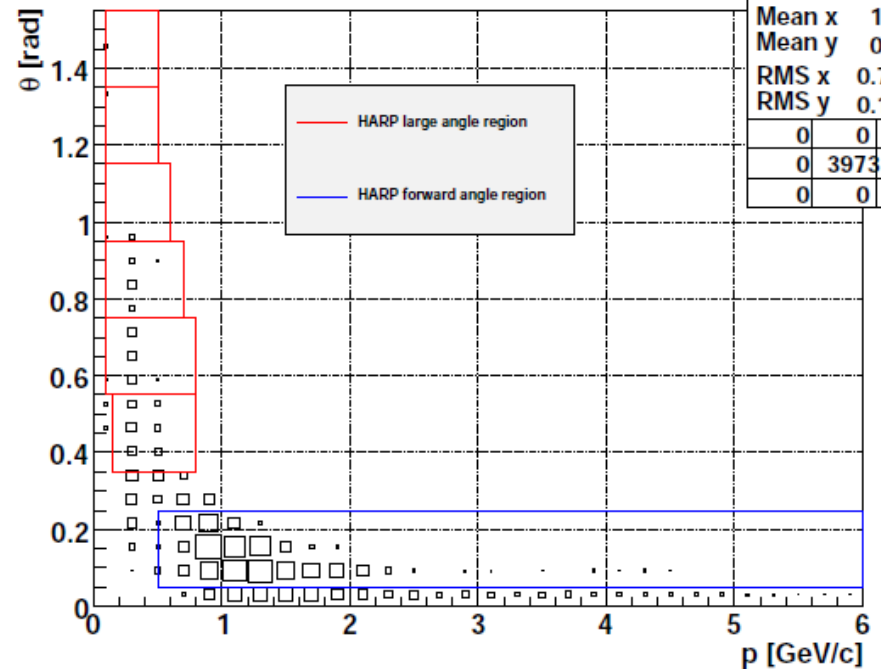
π^+ @ 8 GeV:

2656 (67%) in HARP FA region

445 (11%) in HARP LA region

872 (22%) out of HARP regions

Angle versus momentum (survived) for π^+



H2DP		
Entries	1275	
Mean x	1.182	
Mean y	0.179	
RMS x	0.7233	
RMS y	0.1755	
0	0	0
0	3973	0
0	0	0

Fraction compared to number of pions in the region:

19% in HARP FA region

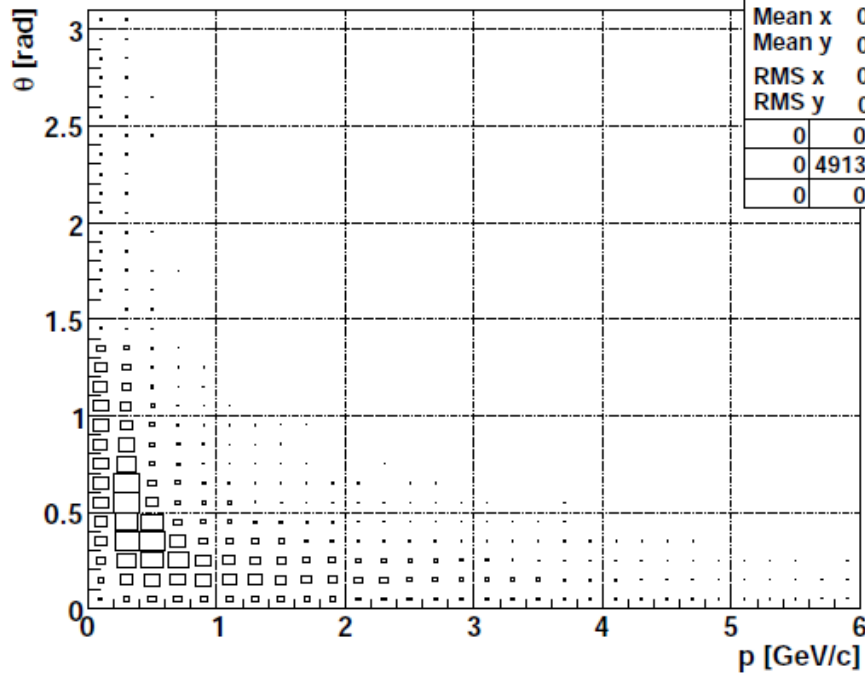
2% in HARP LA region

6% out of HARP regions

July 22th 2009

Pions production and survival (7/)

Angle versus momentum at $z = 0$ for π^-



H2DM0		
Entries	18427	
Mean x	0.6014	
Mean y	0.4773	
RMS x	0.6025	
RMS y	0.3402	
0	0	0
0	49139	0
0	0	0

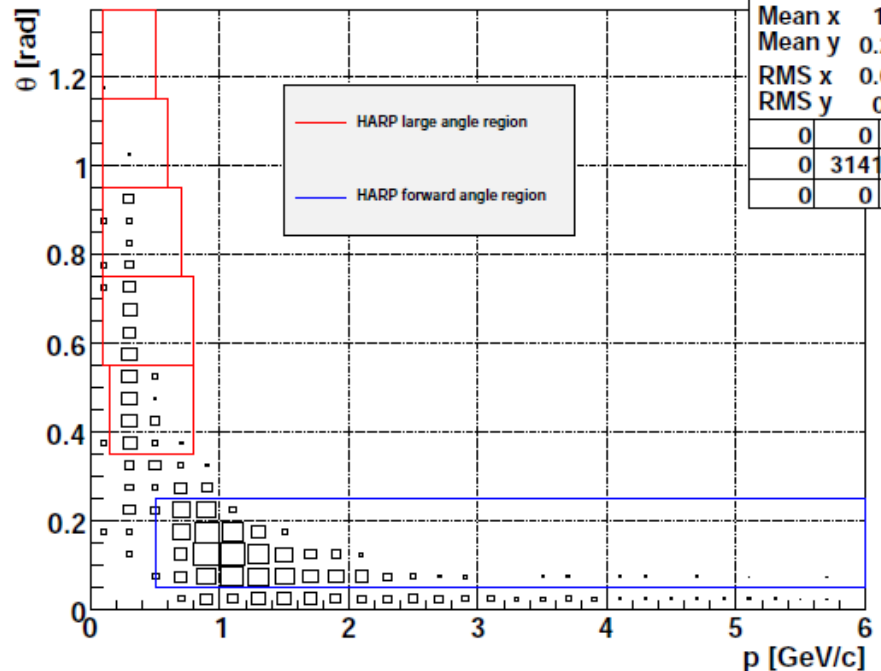
π^- @ 8 GeV:

1955 (62%) in HARP FA region

564 (18%) in HARP LA region

622 (20%) out of HARP regions

Angle versus momentum (survived) for π^-



H2DM		
Entries	1387	
Mean x	1.057	
Mean y	0.2066	
RMS x	0.6412	
RMS y	0.196	
0	0	0
0	3141	0
0	0	0

Fraction compared to number of pions in the region:

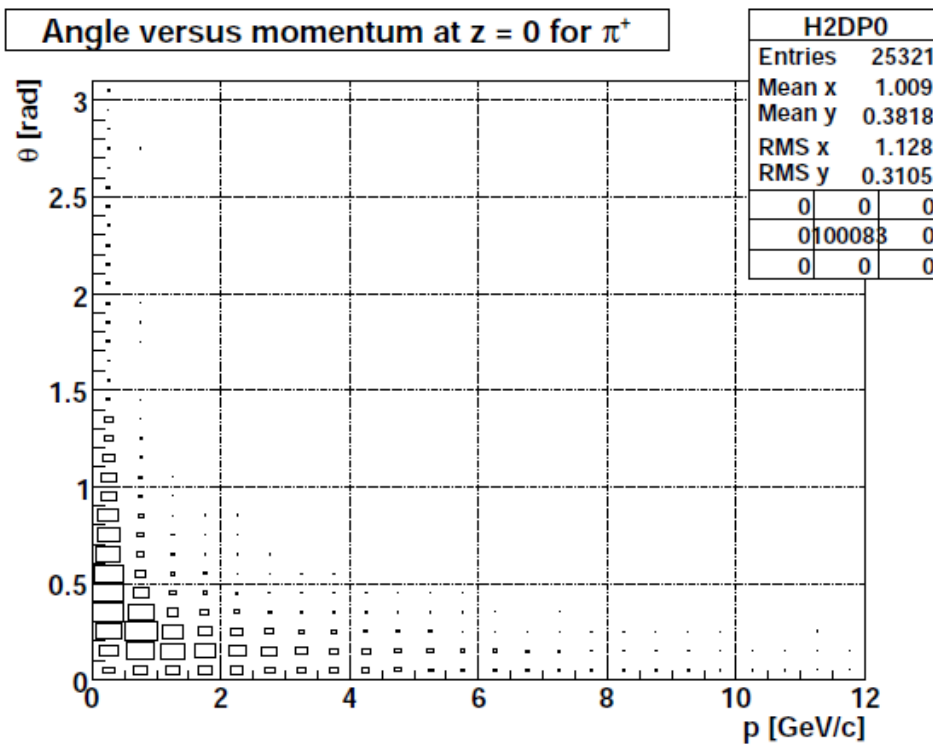
18% in HARP FA region

2% in HARP LA region

5% out of HARP regions

July 22th 2009

Pions production and survival (8/)

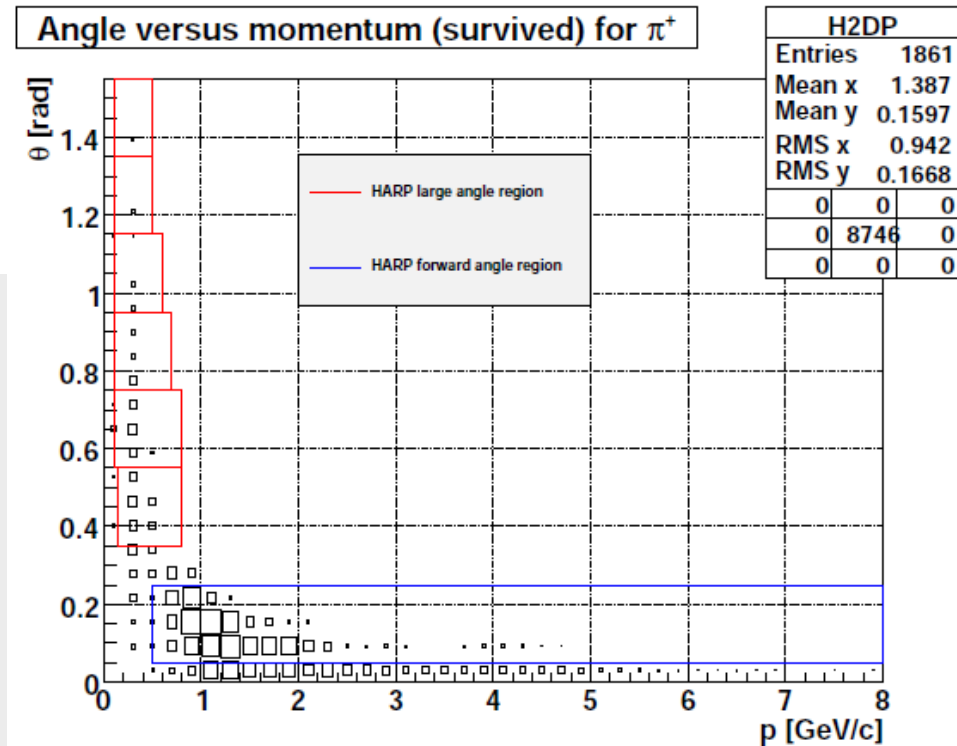


π^+ @ 14 GeV:

5843 (67%) in HARP FA region

858 (10%) in HARP LA region

2245 (26%) out of HARP regions



Fraction compared to number of pions in the region:

16% in HARP FA region

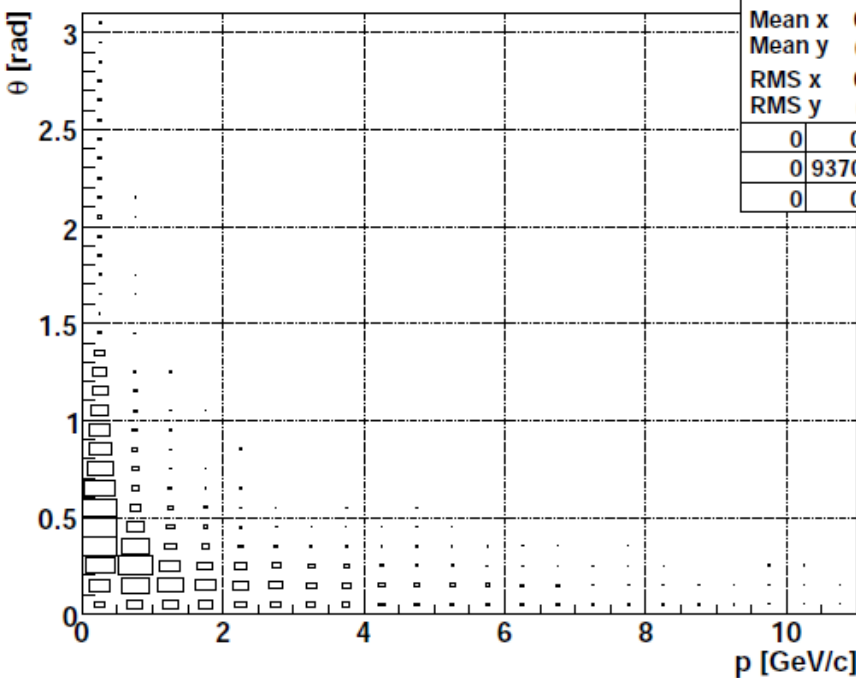
2% in HARP LA region

6% out of HARP regions

July 22th 2009

Pions production and survival (9/)

Angle versus momentum at $z = 0$ for π^-



H2DM0		
Entries	27139	
Mean x	0.8305	
Mean y	0.4278	
RMS x	0.9603	
RMS y	0.3401	
0	0	0
0	93700	0
0	0	0

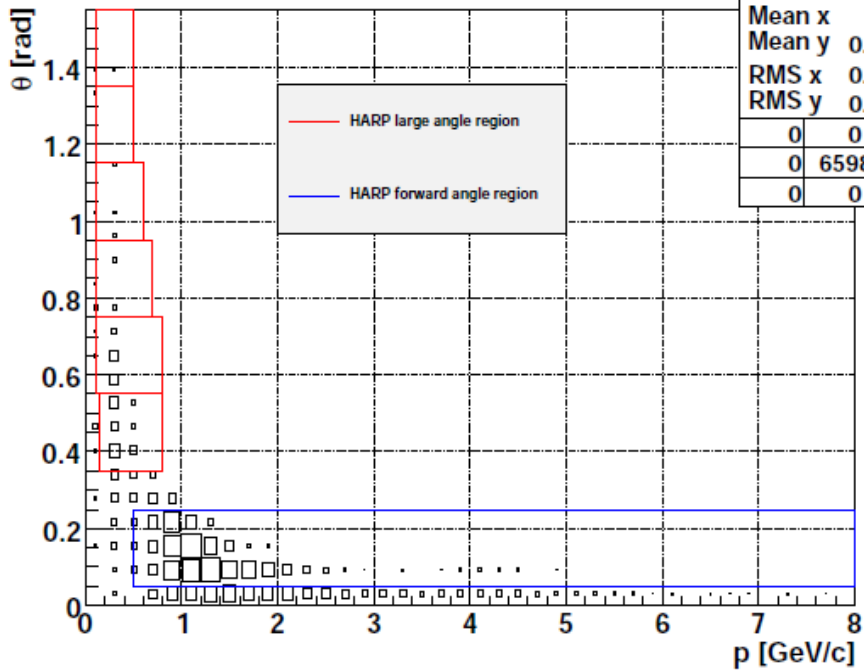
π^- @ 14 GeV:

5198 (64%) in HARP FA region

734 (11%) in HARP LA region

1666 (25%) out of HARP regions

Angle versus momentum (survived) for π^-



H2DM		
Entries	1837	
Mean x	1.301	
Mean y	0.1652	
RMS x	0.8988	
RMS y	0.1728	
0	0	0
0	6598	0
0	0	0

Fraction compared to number of pions in the region:

16% in HARP FA region

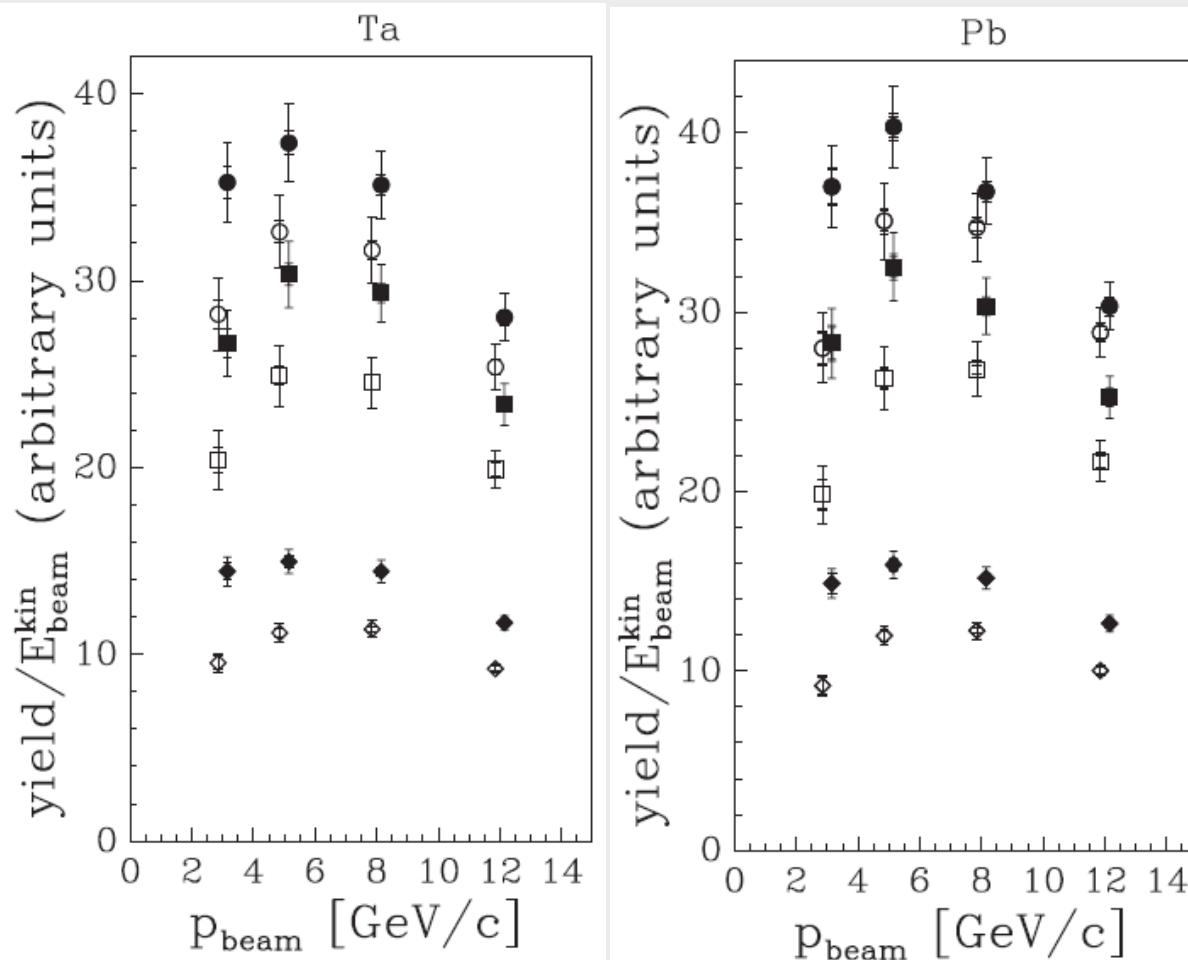
2% in HARP LA region

6% out of HARP regions

July 22th 2009

HARP data (1/)

Large Angle: circles are $d^2\sigma/dpd\Omega$ [mb/(GeV/c . sr)] for π^+ (close) and π^- (open) integrated over $100 < p < 700$ MeV/c and $0.35 < \theta < 1.55$ rad.



**Ta: Z = 73, A-Z = 108
(5.6 mm)**

**Pb: Z = 82, A-Z = 125
(8.5 mm)**

**Hg: Z = 80, A-Z = 121
(~15 cm)**

HARP best yield:

π^+ : 3-8 GeV/c

($2.2 < E_{kin} < 7.12$ GeV)

π^- : 5-8 GeV/c

($4.15 < E_{kin} < 7.12$ GeV)

HARP data (2/)

How to use HARP LA results:

1- Compare to yield from MARS in 100-700 GeV/c and 0.35-1.55 rad range for beam between 5-11 GeV (approx. thick target = thin target).

if big difference in pion yield, use HARP data to re-weight the MC.

2- HARP LA paper on 100% interaction (11.14 cm Ta & 17.05 cm Pb) targets in preparation.

HARP FA data:

Paper in preparation (cf. Talk R. Schroeter)

waiting for cross-section to compare with MARS yields

Conclusions

MC code: different versions can give ~10-20% difference in π/μ yields.

Field map: no clear evidence for using ST2a instead ST2. (ST2 deck to be prepared)

Pion production & tracking:

- **fraction of pions surviving is small (7-9%) (can be improved ?)**
- **yield/p/GeV increase with beam energy**
- **fractions of pions surviving from the different p- θ regions not dependent of the beam energy.**
- **HARP LA data can be used to re-weight the MC.**
- **HARP FA data awaited.**