Preliminary peak finding results with derivative method for beam test data

<u>Shuaiyi Liu</u>, Yaxin Shen, Guang Zhao, Siman Liu, Linghui Wu, Mingyi Dong

Data sets

- The using data sets are from the result of the beam test at CERN SPS, July 2022.
- Data of run 10, 11, 41, 44, 45, 46, 47, 49 are used in the slides
 - Data of run 10, 11, 47, 49 with gas mixture 90/10, 4 runs in same HV and momentum, each run is in different angle
 - Data of run 41, 44, 45, 46 with gas mixture 80/20, 4 runs in same HV and momentum, each run is in different angle

	Run	ch	angle
Cas	41	4	45
Gas 80/20	44	4	0
00/20	45	4	30
	46	4	60

	Run	ch	angle
Caa	10	changle44540460430	
Gas 90/10	11	4	0
	47	4	60
	49	4	30

2023/2/9

All 8 runs' sampling rate are 2G

Peak finding algorithm

- Low pass filter
 - Filter out high frequency noises in the waveforms to improve the S/N ratio
 - Moving average(MA) filter: $y[i] = \frac{1}{MA} \sum_{j=0}^{MA-1} x[i+j]$.
 - When MA=1, y[i] = x[i], which means no filter.
- Derivative
 - First derivative(D1): D1[i] = y[i] y[i-G]
 - Second derivative (D2): D2[i] = D1[i] D1[i-G]
- Parameter
 - Derivative: D2 threshold for hit detection(Th)
 - Filter: Moving average steps(MA)

Peak finding algorithm

- Use second derivative instead of first derivative
- For first derivative, pile-up on the falling edge is easier to recover, but it is not easy on the rising edge.







Peak finding algorithm: amplitude cut

• The aera where amplitude lower than 0.004 will not be used in peak finding



The example waveform in peak finding with and without the amplitude cut

Scan Threshold (keep MA=1, means no MA)

• When threshold is larger than 0.003, there are too many peaks not found, so we only use threshold smaller than 0.003 later.



Scan MA: MA effect in a waveform example Th=0.001, MA = $1 \sim 3$



MA=1 means without filter



2023/2/9

Scan MA: MA effect in a waveform example Th=0.002, MA =1~3 ™







2023/2/9

Ncount in one channel's data

Too many noises involved

Run44 ch4

• Apply the cut ncount>1 to select out the noise events.



Peak finding with different Th and MA **Run44 ch4** • gas:80/20 δ =18 size = 1cm α =0



12

Expected number of electron peaks

• Get from Brunella's talk at Feb18 2022

Expected number of Electron Peaks

Observable to be checked for understanding if we are going in the right direction with our FindPeak algorithm:

 $\begin{array}{l} \mbox{NPeak (Expected number of electron peaks) = δ} \\ \mbox{cluster/cm (M.I.P.) *drift tube size [cm] *1.3 (relativistic rise)*1.6 electrons/cluster*1/cos(α)} \end{array}$

Where α corresponds to the angle of our muon track w.r.t. drift tube direction

Brunella D'Anzi

Finding electron Peaks algorithm 18 February 2022

Run44 ch4 ncount mean value								
Th\MA	1	2	3					
0.001	19.77	10.78	8.50					
0.002	12.44	6.59	5.76					
0.003	8.71	5.10	4.79					

gas:80/20 δ=18 size = 1cm α=0 Npeak(Expected) = 18*0.8*1.3*1.6*1=29.952

The group with Th=0.001 and MA =1 is closest to the expected number

Compare count numbers in different gas mixture and angle

- For gas 80/20:
 - Run 41,44,45,46
 - same HV and momentum
 - different angles(0, 30, 45, 60).

- For gas 90/10:
 - Run10,11,47,49
 - same HV and momentum
 - different angles(0, 30, 45, 60).

	Run	ch	angle
Caa	41	4	45
Gas 80/20	44	4	0
	45	4	30
	46	4	60

	Run	ch	angle
Cas	10	4	45
Gas 90/10	11	4	0
	47	4	60
	49	4	30

Comparison between different angles

• Run 41,44,45,46 ch4 (gas 80/20, 1cm, same HV & momentum, different angle) MA=1

Dataset	Run	ch	angle	Expected number
Gas	44	4	0	29.95
80/20	45	4	30	34.59
	41	4	45	42.36
	46	4	60	59.90



2023/2/9

MA=1										
[h\Angles	0	30	45	60						
0.001	19.77	34.64	47.67	55.90						
0.002	12.44	20.47	28.27	35.60						
0.003	8.71	13.27	18.46	25.03						
		MA=2								
[h\Angles	0	30	45	60						
0.001	10.78	18.72	25.24	29.80						
0.002	6.59	10.46	14.12	18.21						
0.003	5.10	7.09	9.59	13.17						
		MA=3								
Th\Angles	0	30	45	60						
0.001	8.50	13.95	18.61	22.90						
0.002	5.76	8.50	11.32	15.10						
0.003	4.79	6.14	8.20	11.44						

15

Comparison between different angle

Run 10,11,47,49 ch4 (gas 90/10, 1cm, same HV & momentum, different angle)

	Run	ch	angle	Expected number
Dataset	11	4	0	19.97
90/10	49	4	30	23.06
	10	4	45	28.24
	47	4	60	39.94

Count number in gas 90/10 group is larger than gas 80/20 group But not the case in the expected number

		MA=1		
Th\Angles	0	30	45	60
0.001	36.71	48.74	60.04	63.25
0.002	15.33	20.60	26.48	30.64
0.003	8.27	10.95	13.12	17.29
		MA=2		
Th\Angles	0	30	45	60
0.001	14.64	20.03	24.98	27.78
0.002	5.37	7.44	8.54	11.56
0.003	3.56	4.64	4.80	6.93
		MA=3		
Th\Angles	0	30	45	60
0.001	8.93	12.49	15.10	19.00
0.002	4.69	6.29	6.74	9.79
0.003	3.38	4.39	4.38	6.46

Summary and outlook

- Apply peak finding algorithm with derivative method to beam test data analysis
- Scaning threshold and MA shows:
 - For gas 80/20 group, Th=0.001 & MA=1 has closest number with expected
 - For gas 90/10 group, Th=0.002 & MA=1 has closest number with expected
 - Number of found peaks increase with larger angle
- To optimize the derivative algorithm
- To apply the ML algorithm (currently tuning MC simulation based on data)

Backup

R	un number	Date	Start run	Stop run	N. of events	Gas mix	Gas flow (sccm)	Gas pressure (Torr)	HV tag	Trigger delay ns	Sampling rate
	tbdata_0	2022/7/7	19:04	20:18	5000	90/10	800	727	0	700	1.2
	tbdata_1	2022/7/7	22:30	01:00 next day	482	90/10	800	728.7	1	800	1.0
	tbdata_2	2022/7/8	9:06	11:46	1119	90/10	800	728.7	1	800	1.0
	tbdata_3	2022/7/8	13:17	16:22	5000	90/10	800	729.8	2	800	1.0
	tbdata_4	2022/7/9	3:09	3:24	5000	90/10	800	729.2	2	800	1.0
	tbdata_5	2022/7/9	3:26	4:10	10000	90/10	800	729.2	2	800	1.0
	tbdata_6	2022/7/9	4:31	5:00	10000	90/10	800	729.2	2	800	1.0
	tbdata_7	2022/7/9	5:14	5:40	10000	90/10	800	729.2	2	800	1.0
	tbdata_8	2022/7/9	5:45	6:45	10000	90/10	800	729.2	2	800	1.0
ange o	f DRS channels(90/.	10)									
	tbdata_9	2022/7/9	7:53	8:15	10000	90/10	800	729.2	3	526	1.5
	tbdata_10	2022/7/9	8:30	9:49	10000	90/10	800	729.2	3	394	2
	tbdata_11	2022/7/9	9:51	12:06	10000	90/10	800	729.3	3	394	2
			10.05	10.55	10000	00/40		700.0	^	505	
51	tbdata_41	2022/7/	/11 5:00	5:35	10000	80/20	600	725.2	10 corrected	394	2
52	tbdata_42	2022/7/	/11 5:38	7:40	10000	80/20	600	725.2	10 corrected+10	394	2
53	tbdata_43	2022/7/	/11 7:41	12:10	10000	80/20	600	725.2	10 corrected+20	394	2
54	tbdata_44	2022/7/	/11 12:2	2 13:18	10000	80/20	600	725.3	10 corrected	394	2
55	tbdata_45	2022/7/	/11 13:2	4 14:23	10000	80/20	600	725.3	10 corrected	394	2
56	tbdata_46	2022/7/	/11 14:3	0 15:30	10000	80/20	600	725.3	10 corrected	394	2

59	ge of gas the mixture to 90/10										
60	tbdata_47	2022/7/11	16:18	17:30	10000	90/10	800	724.4	3	394	2
61	tbdata_48	2022/7/11	17:35	18:34	interrupted	90/10	800	724.3	3	394	2
62	tbdata_49	2022/7/11	18:35	19:02	5000	90/10	800	724.3	3	394	2

The DAQ system: an oscilloscope interface



WDB interface is similar to the interface of an oscilloscope with 16 channels

Threshold test (Run44 ch4 80/20gas 1cm)









Threshold test (Run44 ch4 80/20gas 1cm)



Run41 ch4 waveform Th0.001~0.003&MA1~3







hs

2023/2/9

25



2023/2/9

26





2023/2/9

28



hs

2023/2/9

29





³¹

4 Runs counting numbers compare

 Run 41,44,45,46 ch4 (gas 80/20, 1cm, same HV & momentum, different angle) The showed number is the mean value of number of found peaks

Count Number of Th 0.001 and MA = 1 is: 15.4878Count Number of Th 0.001 and MA = 2 is: 8.1158Count Number of Th 0.001 and MA = 3 is: 5.9631Count Number of Th 0.002 and MA = 1 is: 9.0614Count Number of Th 0.002 and MA = 2 is: 4.5213Count Number of Th 0.002 and MA = 3 is: 3.6192Count Number of Th 0.003 and MA = 1 is: 5.8757Count Number of Th 0.003 and MA = 2 is: 3.0685Count Number of Th 0.003 and MA = 2 is: 3.0685Count Number of Th 0.003 and MA = 3 is: 2.6147root [2] 18*0.8*1.3*1.6/cos(45./180.*3.1415926)(double) 42.358524Run 41 ch4 45°

```
Count Number of Th 0.001 and MA = 1 is: 11.3535
Count Number of Th 0.001 and MA = 2 is: 6.1126
Count Number of Th 0.001 and MA = 3 is: 4.5507
Count Number of Th 0.002 and MA = 1 is: 6.6605
Count Number of Th 0.002 and MA = 2 is: 3.4158
Count Number of Th 0.002 and MA = 3 is: 2.7803
Count Number of Th 0.003 and MA = 3 is: 2.7803
Count Number of Th 0.003 and MA = 1 is: 4.3054
Count Number of Th 0.003 and MA = 2 is: 2.3152
Count Number of Th 0.003 and MA = 3 is: 1.9875
root [6] 18*0.8*1.3*1.6/cos(30./180.*3.1415926)
(double) 34.585590 Run 45 ch4 30^{\circ}
2023/2/9
```

```
Count Number of Th 0.001 and MA = 1 is: 6.3766
Count Number of Th 0.001 and MA = 2 is: 3.4648
Count Number of Th 0.001 and MA = 3 is: 2.7261
Count Number of Th 0.002 and MA = 1 is: 3.9693
Count Number of Th 0.002 and MA = 2 is: 2.0956
Count Number of Th 0.002 and MA = 3 is: 1.7832
Count Number of Th 0.003 and MA = 1 is: 2.7696
Count Number of Th 0.003 and MA = 1 is: 2.7696
Count Number of Th 0.003 and MA = 2 is: 1.5455
Count Number of Th 0.003 and MA = 3 is: 1.3564
root [4] 18*0.8*1.3*1.6/cos(0./180.*3.1415926)
(double) 29.952000
Run 44 ch4 0°
```

```
Count Number of Th 0.001 and MA = 1 is: 20.5687
Count Number of Th 0.001 and MA = 2 is: 10.8347
Count Number of Th 0.001 and MA = 3 is: 8.2632
Count Number of Th 0.002 and MA = 1 is: 12.8268
Count Number of Th 0.002 and MA = 2 is: 6.523
Count Number of Th 0.002 and MA = 3 is: 5.3469
Count Number of Th 0.003 and MA = 1 is: 8.8806
Count Number of Th 0.003 and MA = 1 is: 8.8806
Count Number of Th 0.003 and MA = 2 is: 4.6487
Count Number of Th 0.003 and MA = 3 is: 4.0057
root [8] 18*0.8*1.3*1.6/cos(60./180.*3.1415926)
(double) 59.903998 Run 46 ch4 60°
```

4 Runs counting numbers compare

• Run 10,11,47,49 ch4 (gas 90/10, 1cm, same HV & momentum, different angle)

```
Count Number of Th 0.001 and MA = 1 is: 20.2631
Count Number of Th 0.001 and MA = 2 is: 7.9133
Count Number of Th 0.001 and MA = 3 is: 4.7006
Count Number of Th 0.002 and MA = 1 is: 8.2799
Count Number of Th 0.002 and MA = 2 is: 2.7035
Count Number of Th 0.002 and MA = 3 is: 2.1583
Count Number of Th 0.003 and MA = 3 is: 2.1583
Count Number of Th 0.003 and MA = 1 is: 4.0513
Count Number of Th 0.003 and MA = 2 is: 1.5874
Count Number of Th 0.003 and MA = 3 is: 1.4231
root [2] 12*0.8*1.3*1.6/cos(45./180.*3.1415926)
(double) 28.239016
Run 10 ch4 45°
```

```
Count Number of Th 0.001 and MA = 1 is: 25.4818
Count Number of Th 0.001 and MA = 2 is: 10.4912
Count Number of Th 0.001 and MA = 3 is: 6.9589
Count Number of Th 0.002 and MA = 1 is: 11.2107
Count Number of Th 0.002 and MA = 2 is: 4.2071
Count Number of Th 0.002 and MA = 3 is: 3.5694
Count Number of Th 0.003 and MA = 1 is: 6.1491
Count Number of Th 0.003 and MA = 1 is: 6.1491
Count Number of Th 0.003 and MA = 2 is: 2.5915
Count Number of Th 0.003 and MA = 3 is: 2.3968
root [2] 12*0.8*1.3*1.6/cos(60./180.*3.1415926)
(double) 39.935999 Run 47 ch4 60°
```

Count Number of Th 0.001 and MA = 1 is: 11.9703 Count Number of Th 0.001 and MA = 2 is: 4.5637 Count Number of Th 0.001 and MA = 3 is: 2.7821 Count Number of Th 0.002 and MA = 1 is: 4.718 Count Number of Th 0.002 and MA = 2 is: 1.7409 Count Number of Th 0.002 and MA = 3 is: 1.5355 Count Number of Th 0.003 and MA = 3 is: 1.5355 Count Number of Th 0.003 and MA = 1 is: 2.5676 Count Number of Th 0.003 and MA = 2 is: 1.2145 Count Number of Th 0.003 and MA = 3 is: 1.1142 root [4] 12*0.8*1.3*1.6/cos(0./180.*3.1415926)(double) 19.968000

Run 11 ch4 0°

```
Count Number of Th 0.001 and MA = 1 is: 18.7056
Count Number of Th 0.001 and MA = 2 is: 7.3
Count Number of Th 0.001 and MA = 3 is: 4.4998
Count Number of Th 0.002 and MA = 1 is: 7.3316
Count Number of Th 0.002 and MA = 2 is: 2.7512
Count Number of Th 0.002 and MA = 3 is: 2.3472
Count Number of Th 0.003 and MA = 1 is: 3.9262
Count Number of Th 0.003 and MA = 1 is: 3.9262
Count Number of Th 0.003 and MA = 2 is: 1.7914
Count Number of Th 0.003 and MA = 3 is: 1.6566
root [4] 12*0.8*1.3*1.6/cos(30./180.*3.1415926)
(double) 23.057060 Run 49 ch4 30°
```

4 Runs counting numbers compare

Run 47,49,52,53 ch4 (gas 90/10, 1cm, same HV & momentum, different angle) 0° & 45° have sampling rate 1.0, while 30° & 60° have sampling rate 2.0

```
Count Number of Th 0.001 and MA = 1 is: 25.4818
Count Number of Th 0.001 and MA = 2 is: 10.4912
Count Number of Th 0.001 and MA = 3 is: 6.9589
Count Number of Th 0.002 and MA = 1 is: 11.2107
Count Number of Th 0.002 and MA = 2 is: 4.2071
Count Number of Th 0.002 and MA = 3 is: 3.5694
Count Number of Th 0.003 and MA = 1 is: 6.1491
Count Number of Th 0.003 and MA = 2 is: 2.5915
Count Number of Th 0.003 and MA = 3 is: 2.3968
root [2] 12*0.8*1.3*1.6/cos(60./180.*3.1415926)
(double) 39.935999 Run 47 ch4 60°
```

```
Count Number of Th 0.001 and MA = 1 is: 8.1767
Count Number of Th 0.001 and MA = 2 is: 3.926
Count Number of Th 0.001 and MA = 3 is: 2.8064
Count Number of Th 0.002 and MA = 1 is: 4.1217
Count Number of Th 0.002 and MA = 2 is: 2.2605
Count Number of Th 0.002 and MA = 3 is: 1.9086
Count Number of Th 0.003 and MA = 3 is: 1.9086
Count Number of Th 0.003 and MA = 1 is: 2.6408
Count Number of Th 0.003 and MA = 2 is: 1.7646
Count Number of Th 0.003 and MA = 3 is: 1.4426
root [6] 12*0.8*1.3*1.6/cos(0./180.*3.1415926)
(double) 319.968000 Run 52 ch4 0°
```

Count Number of Th 0.001 and MA = 1 is: 18.7056 Count Number of Th 0.001 and MA = 2 is: 7.3 Count Number of Th 0.001 and MA = 3 is: 4.4998 Count Number of Th 0.002 and MA = 1 is: 7.3316 Count Number of Th 0.002 and MA = 1 is: 2.7512 Count Number of Th 0.002 and MA = 3 is: 2.3472 Count Number of Th 0.003 and MA = 1 is: 3.9262 Count Number of Th 0.003 and MA = 1 is: 3.9262 Count Number of Th 0.003 and MA = 2 is: 1.7914 Count Number of Th 0.003 and MA = 3 is: 1.6566 root [4] 12*0.8*1.3*1.6/cos(30./180.*3.1415926)(double) 23.057060 Run 49 ch4 30°

```
Count Number of Th 0.001 and MA = 1 is: 13.6295
Count Number of Th 0.001 and MA = 2 is: 6.35904
Count Number of Th 0.001 and MA = 3 is: 4.50886
Count Number of Th 0.002 and MA = 1 is: 7.20652
Count Number of Th 0.002 and MA = 2 is: 3.65436
Count Number of Th 0.002 and MA = 3 is: 3.03326
Count Number of Th 0.003 and MA = 1 is: 4.4371
Count Number of Th 0.003 and MA = 1 is: 4.4371
Count Number of Th 0.003 and MA = 2 is: 2.74942
Count Number of Th 0.003 and MA = 3 is: 2.25812
root [8] 12*0.8*1.3*1.6/cos(45./180.*3.1415926)
(double) 28.239016 Run 53 ch4 45°
```

34

4 Runs counting numbers compare(ncount>1)

Run 47,49,52,53 ch4 (gas 90/10, 1cm, same HV & momentum, different angle) 0° & 45° have sampling rate 1.0, while 30° & 60° have sampling rate 2.0

```
Count Number of Th 0.001 and MA = 1 is: 63.2458
Count Number of Th 0.001 and MA = 2 is: 27.7829
Count Number of Th 0.001 and MA = 3 is: 19.0023
Count Number of Th 0.002 and MA = 1 is: 30.6413
Count Number of Th 0.002 and MA = 2 is: 11.5628
Count Number of Th 0.002 and MA = 3 is: 9.79108
Count Number of Th 0.003 and MA = 1 is: 17.2887
Count Number of Th 0.003 and MA = 1 is: 17.2887
Count Number of Th 0.003 and MA = 2 is: 6.93065
Count Number of Th 0.003 and MA = 3 is: 6.45867
root [2] 12*0.8*1.3*1.6/cos(60./180.*3.1415926)
(double) 39.935999 Run 47 ch4 60^{\circ}
```

```
Count Number of Th 0.001 and MA = 1 is: 23.5479
Count Number of Th 0.001 and MA = 2 is: 11.654
Count Number of Th 0.001 and MA = 3 is: 8.40497
Count Number of Th 0.002 and MA = 1 is: 12.275
Count Number of Th 0.002 and MA = 2 is: 6.82526
Count Number of Th 0.002 and MA = 3 is: 5.8497
Count Number of Th 0.003 and MA = 3 is: 5.8497
Count Number of Th 0.003 and MA = 1 is: 7.95022
Count Number of Th 0.003 and MA = 2 is: 5.43275
Count Number of Th 0.003 and MA = 3 is: 4.87123
root [6] 12*0.8*1.3*1.6/cos(0./180.*3.1415926)
(double) 219.968000 Run 52 ch4 0°
```

Count Number of Th 0.001 and MA = 1 is: 48.7428Count Number of Th 0.001 and MA = 2 is: 20.026Count Number of Th 0.001 and MA = 3 is: 12.4947Count Number of Th 0.002 and MA = 1 is: 20.6021Count Number of Th 0.002 and MA = 2 is: 7.44215Count Number of Th 0.002 and MA = 3 is: 6.2903Count Number of Th 0.003 and MA = 1 is: 10.9458Count Number of Th 0.003 and MA = 2 is: 4.64362Count Number of Th 0.003 and MA = 3 is: 4.38963root [4] 12*0.8*1.3*1.6/cos(30./180.*3.1415926)(double) 23.057060 Run 49 ch4 30°

```
Count Number of Th 0.001 and MA = 1 is: 36.6063
Count Number of Th 0.001 and MA = 2 is: 17.7834
Count Number of Th 0.001 and MA = 3 is: 12.8379
Count Number of Th 0.002 and MA = 1 is: 20.4038
Count Number of Th 0.002 and MA = 2 is: 10.3846
Count Number of Th 0.002 and MA = 3 is: 8.60863
Count Number of Th 0.003 and MA = 1 is: 12.7172
Count Number of Th 0.003 and MA = 1 is: 12.7172
Count Number of Th 0.003 and MA = 2 is: 7.75204
Count Number of Th 0.003 and MA = 3 is: 6.71546
root [8] 12*0.8*1.3*1.6/cos(45./180.*3.1415926)
(double) 28.239016
Run 53 ch4 45°
```